2014 International Conference on Communication and Network Technologies (ICCNT)

Determination of Stress using Blood Pressure and Galvanic Skin Response

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Abstract - **Stress is a response to mental/emotional or physical aspects that is encountered in daily life. In order to manage stress, it is required to monitor the stress levels on continuous basis. Individual physiological parameters such as Galvanic Skin Response (GSR), Heart Rate (HR), Blood Pressure (BP), ECG (Electrocardiography) and respiration activity can be used as a measure to determine stress. But, the accuracy of determination is limited by using individual parameters. Usage of multiple parameters aids in better determination of stress. A combination of parameters such as GSR and Blood Pressure further increases the accuracy. The paper signifies better detection of stress by using GSR and BP.**

Keywords - Galvanic Skin Response (GSR), Blood Pressure (BP), Physiological parameters, Electro Dermal Activity (EDA), Skin conductance, Stress, Body Mass Index(BMI) .

I. INTRODUCTION

Anything that requires a mental, physical adjustment or a response is termed as stress. Stress is encountered in our day-to-day life. Any activity that is done always creates some form of stress.

Different kinds of stress:

1) *Acute stress* which is short term stress and does not cause extensive damage. It is easy to detect and treatable.
2) *Episodic acute stress* which makes people anxious.
3) *Chronic stress* which is long term stress capable of extensive damage and difficult to be detected.

Chronic stress has serious effect on physical and psychological health. It wears oneself and leads to poor health, either physically or emotionally. It cannot be measured in a consistent and timely way, hence not a deterministic and reliable factor in determining stress. Understanding stress level is important. Stress can be positive i.e. it motivates us, helps in learning new things, achieving daily tasks and engage in creative thinking [1]. Negative stress inhibits one's ability of thinking and functioning on a daily basis. Large amount of stress may cause emotional imbalance and lead to cardiovascular diseases in severe cases. Stress affects one's concentration, performance, thinking ability, reasoning, and behaviour. This is instantaneous and is part of daily life. But on a long run, this could eventually cause damage to neural and muscular system.

Section II describes the effects of stress on human body. Section III discusses the various studies of stress analysis using GSR and BP. Section IV describes the design involved. Section V describes the methodology. Section VI contains results and discussion.

II. STRESS AND ITS EFFECT ON HUMAN BODY

Mental ailments like anxiety and depression are mostly caused due to high levels of stress. Acute stress can be easily measured in a consistent and timely way than chronic stress. The palm of the hand has a very high density of sweat glands and hence proves to be a great spot to measure GSR. Skin conductance changes due to sweat glands which are activated by acute stress. But in relaxed subjects, circulatory changes do not influence emotional sweating and hence can be considered as an independent factor. The Autonomic Nervous System (ANS) is responsible for increase and decrease in stress levels of the body. The Sympathetic-ANS is used to increase heart rate under stressful conditions. The Parasympathetic-ANS lowers the heart rate as a means to relax the body from its stressful condition.

III. STRESS ANALYSIS USING GSR AND BP

Autonomous nervous system consist of two branches Parasympathetic nervous system(PNS) which deals with conservation and restoration of body energy and sympathetic nervous system(SNS). Electro Dermal Activity (EDA) is index of sympathetic nervous system [1].EDA is basically a change of skin conductance at surface. The measurement of EDA was done during both physical and emotional stressor.EDA is solely determined by SNS branch of ANS and independent of the PNS branch. Stress causes disruption of ANS which involves state of high sympathetic activation. Attention grabbing and attention demanding task invoke increased EDA response.EDA assessment is usually done over long term.EDA response is one of the measures to determine stress undergone by a person.

GSR can be measured by using the Biofeedback technology [2] that can be used to avoid sudden attacks that affect the heart or brain. This condition is known as seizure. Biofeedback technology stamps from the fact that when a participant is watching a graphical picture, the GSR decreases. The analysis was made by asking a subject to watch a picture moving back and forth, and skin resistance was calculated. When the picture moved forward, the skin resistance was observed to decrease thus resulting in increase in stress. Conversely when the picture moved backward, the GSR increased thereby reducing the

978-1-4799-6266-2/14/$31.00 © 2014 IEEE

stress. The study suggested that GSR biofeedback has the potential to act as a potent adjunctive to detect stress.

Every stimulus produces a deflection in the galvanometer directly proportional to the actual emotion aroused [3]. The deflection was caused due to change in resistance which was reflected by sympathetic response of the nervous system to emotional stress through the secretion of sweat glands. There are two ways of measuring EDA which are Paper-based and Paperless system. Paper-based system provides a continuous record of the entire session and does not require expensive software or components, and is a much less sophisticated system as marking important events like movement or sudden distractions. But the cost of the paper, ink and pen along with time required for analysing the paper record and mechanical malfunction made the paper-based technique obsolete. Hence a paperless technique, which required an ADC to convert the analog signals to digital and a special program for analysis, was preferred. Irrespective of the technique, the contact area and not the size of the electrodes affect the EDA values. EDA measured from the palm is same for both hands. Also, the skin should be unprepared i.e. no special treatment using abrading agents or soap and water should be carried out.

Reducing stress decreases high blood pressure [4].Too much stress can cause high blood pressure, chest pain, irregular heartbeats etc. When the body is under stress, it responds by producing a surge of stress hormone causing an increase in blood pressure and heart to beat faster. Being exposed to stress for long can be harmful to the body. The body's response to external and abnormal states that tends to affect its homeostasis has an influence on increase in blood pressure [5]. This response is generally called as stress. It consists of even the daily events that increase physiological wear and tear. The study found that, individuals who underwent a stressful task had a late recovery of blood pressure making it a good indicator of stress even after some time.

A new calibration method that includes Pulse Arrival Time (PAT) was used for estimating the blood pressure [6]. The estimation was done during an exercise stress test which increased its quality. PAT and Heart Rate are related to blood pressure. The quality of estimation can be improved by using differential inputs of PAT and HR. The test was conducted on 55 healthy subjects between 19 to 20 years old; who did not have any unhealthy medical records in the last 3 months. The subjects were asked to undergo the exercise test which included 6 stages namely; rest, stage1, stage2, 1-minute recovery and 5-minute recovery. During the test, ECG (Electrocardiogram) and PPG (Photoplethysmogram) signals were recorded at the end of each stage.PPG signal consists of pulses that reflect the change in vascular blood volume with each cardiac beat. Then after a short time, the BP was measured. The R-peak of ECG and foot point of PPG was determined from the signals. The time interval between the R-peak of ECG and foot point of PPG is the PAT. It was seen that the method which included calibration and delta algorithm (i.e. taking differential PAT and HR) had lower errors than other methods. Thus delta-PAT and delta-HR had higher correlation with BP than PAT and HR which thus improved the quality of blood pressure monitoring during the stress test.

The effects on the heart rate and blood pressure due to ageing process, before and after exercise in male subjects were studied in [7]. A total of 80 normal healthy persons who were all males were taken as test subjects. All of them were grouped into 3 age categories namely; 20-29years, 30-39years and 40-49years. Each of the subjects was asked to perform exercise by running on a motor driven treadmill, held in upright position. The readings were taken before and after performing the exercise. The blood pressure was measured using the process of auscultation (listening to sound) by using a stethoscope and sphygmomanometer, which includes a mercury column pressure gauge and a pressure cuff. The systolic and diastolic pressure was recorded before and after the exercise. Also ECG was used to determine the heart rate using the standard R-R method which is the time interval between two successive R waves. It was found that mean heart rate decreases significantly with increasing age after exercise. The systolic blood pressure was found to increase significantly in older group subjects post-exercise and shows a positive linear correlation with increasing age. The diastolic blood pressure was found to decrease non-significantly with increasing age in all groups. A negative linear correlation between Heart Rate and increasing age was observed. Also, there was a positive linear correlation between age and the mean blood pressure after exercise.

Ageing has an effect on blood pressure and heart rate [8]. After excluding patients with diabetes or secondary hypertension, 16 elderly patients (above 60) and 16 young patients (below 60) were taken having systolic and diastolic values greater than 140/90mmHg. The body mass index of the patients was closely matched and had no medical condition with respect to altered blood pressure variability. The heart rate and blood pressure were measured using the Remier M 2000 ambulatory system during the awaking hours of the day. The Remier M 2000 is an accurate and reliable, portable patient activated blood pressure recorder. Four statistics from which the blood pressure variability can be described are namely, the standard deviation of ambulatory mean, coefficient of variation, range and mean hourly change in measurement were compared between the young and elderly. It was observed that only the systolic and diastolic blood pressure range were found to differ with age, whereas other tests of variability, coefficient of variation and standard deviation had no effects on age. Mean systolic blood pressure was seen to be greater in the elderly and mean diastolic pressure was greater in the young. The young had significantly greater range for systolic and diastolic blood pressure measurement.

When stimulated, there always occurs a temporary elevation in blood pressure in both children and adults [9]. But this response reduces once the stimulation or stress causing agent is removed. This response of blood pressure correlates with the BMI, body fat distribution and waist-to-hip ratio of the person. But hierarchical regression does not contribute towards influencing contribution of perceived stress to blood pressure. Reference [10] analysis examined the association between blood pressure reaction to acute psychological stress and the subsequent hypertension due to it. Blood pressure was recorded during different acute stress tasks i.e. strop colour word, mirror tracing, speech etc. It was observed that systolic blood pressure was related to future hypertension and diastolic

pressure was not as much related making it a parameter which is less frequently used to determine the hypertension.

GSR (Galvanic Skin Resistance) technology avails measurement of stress levels reflected from physical symptoms of the person [11]. This technique proves to have 83% success results. The test consists of using electrodes placed on skin through which signals are obtained and analysed. But caution should be taken during testing i.e. the electrodes should be firmly placed on the skin and the person should be still (with no major movements).Relation between GSR and four Blood pressure indexes (BPI) namely systolic, diastolic, pulse pressure, mean arterial pressure was studied before and after treadmill exercise in [12]. Blood pressure is used to study cardiovascular system. GSR is simple sensitive reproducible method of capturing functions of sweat glands as sympathetic nervous system. Test subjects included adults and their GSR and BPI were recorded before and after doing treadmill exercise. It was observed that GSR and BPI occur during physical activity and that there was a positive correlation between GSR value and BPI both before and after exercise.

IV. DESIGN

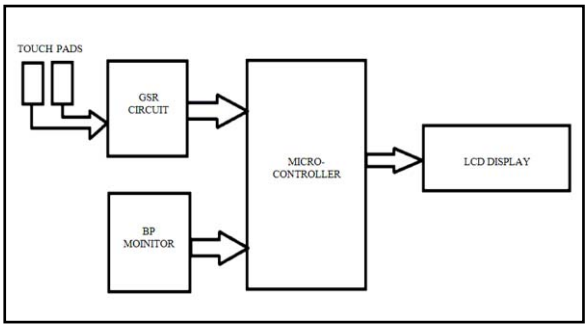

Fig.1. Schematic diagram incorporating galvanic skin response circuit and blood pressure module

The design consists of a Galvanic Skin Response (GSR) circuit and a combined blood pressure and heart rate module which are fed as inputs to a microcontroller. The results after computations are displayed on an LCD module. A user's stress levels are calculated by the GSR circuit using the touchpad's as input. Copper plate touch pads are preferred over aluminium foil for more reliability and accuracy. The blood pressure and heart rate of the user is also calculated using the BP/HR module. The results i.e. the outputs obtained from the stress meter circuit and BP/HR module are given as inputs to the microcontroller through LCD tapping. ATMEGA 2560 development board from Atmel is chosen for this analysis. The microcontroller processes the data obtained and computes the result. The results obtained are then displayed on an LCD module.

V. METHODOLOGY

A total of 25 volunteers, aged between 18-24yrs, consisting of 17 males and 8 females, were observed. Initially, each volunteer was tested for their stress (GSR) and BP levels under normal / calm conditions, and the values were noted. Each one had to place their fingers on the touch pads of the GSR circuit. The GSR circuit showed three levels depending on the resistance of the skin of the particular person and categorized as either low, medium or high. The volunteer was concluded to be low stressed; medium stressed or highly stressed corresponding to body resistance of 2MegaOhms or greater, 1MegaOhms and 500KiloOhms respectively. The output from the GSR circuit (i.e. low, medium, high) was fed into the microcontroller. The BP level of volunteer was examined by inflating a cuff in line with the heart, around the fore-arm which is again fed to the microcontroller. The BP was concluded to be normal if it was less than the value of (135/85) and high otherwise. The result of this computation was then displayed onto LCD display. Next, each volunteer was told to perform certain physical activities like running up a flight of stairs. Each volunteer was told to run up and down two floors because going through such a situation consisting of two or more floors induces stress on any person irrespective of BMI, lifestyle, or sex. After the session of physical activities, each volunteer was told to sit and breathe slowly to get rid of panting or hyper-ventilation. The GSR and BP of the volunteer were recorded once again using the same procedure as followed above. These parameters were then compared per volunteer to analyze change in stress levels

VI. RESULTS AND DISCUSSION

Fig 2 and Fig 3 describe the noted stress and blood pressure levels of volunteers, before and after performing the mentioned activities respectively. These graphs are then computed together to conclude if the volunteer is either mentally or physically stressed or has normal condition. If the volunteer has a low BP along with low stress, it was concluded to be normal condition. But if the stress level is high, and BP remains the same, the volunteer is analyzed to have mental stress whose severity depends on the level of stress. But if the BP is noted to be high, then it was concluded as physical stress.

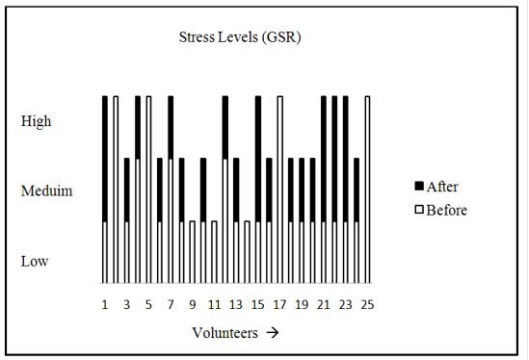

Fig. 2. Graph of stress levels before and after physical activities

Volunteers 2, 5, 9, 11, 14, 17 and 25 have not shown any change in their stress levels (GSR) after physical activities as seen in Fig 2 and hence there is no change in graphical parameters. A similar case is observed while measuring BP of volunteers 8, 13, 14, 21, 22 and 25 as shown in Fig. 3.

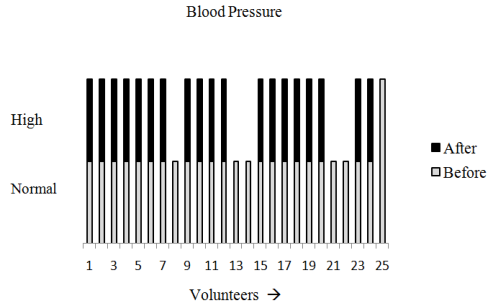

Fig.3. Graph of blood pressure before and after physical activities

A volunteer whose GSR value was high before performing any physical activity were categorized as mentally stressed. Similarly volunteer who had low levels of stress before doing the physical activity and low BP (i.e. less than 135/85) but after performing the physical activity GSR increases and if BP value crosses these level of (135/85) are categorized to be physically stressed. In similar manner if BP value does not increase after the physical activity are termed to be in normal condition. It was observed that, among the volunteers considered, 80% of the volunteers had elevated levels of stress and BP after performing the activities which proves these parameters are correlated and together contain relevant information to actual stress suffered. Also, it was observed that the changes in stress and BP levels were not significant to the sex of the volunteer. The final comparison of the stress and BP levels computes the state of that volunteer, i.e. normal condition, mental stress or physical stress. Fig4 shows the results of the computation. This shows that among all volunteers who performed physical activities, 80% of them got physically stressed but the remaining were not physically stressed and remaining were categorized as mentally stressed.

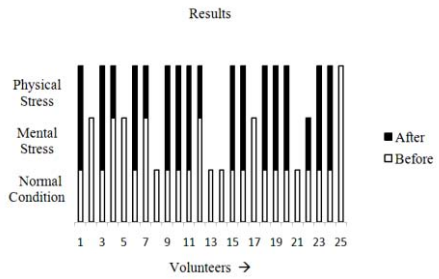

Fig.4. Results of computation (BP & GSR) before and after activities

VII. CONCLUSION

It can hence be verified that although doing exercises results in higher GSR level, it is not related to emotional or mental stress.

VIII. ACKNOWLEDGEMENT

We would like to thank Mr. Gajanan Nagarsekar, MD of Kallows Engineering Pvt. Ltd., Ponda - Goa for his support and guidance.

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