International Journal of Engineering & Technology, 7 (3.34) (2018) 890-894

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET

Research paper

Automated Stress Detection Using Non Invasive Parameters and Internet of Things

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Abstract

Stress is an increasing cause of concern in today's world that manifests psychological and physiological complications. The study is focused at developing a low cost non invasive continuous stress monitoring prototype with an integrated infrared therapy application. Infrared light has considerable effect in lowering the cortisol levels and this property makes it a useful application in stress therapy. The Pulse rate and Galvanic Skin Response (GSR) sensors are used to detect the stress threshold of an individual through a wearable device. The sensor values from the body are given as a feedback to the device, to wirelessly activate a compact Infrared light therapy setup to the patient, when a programmable threshold value of the sensors is reached. The monitored sensor values are continuously updated on the Internet and the physician is notified in case of any abnormal stress levels through Internet of Things (IoT). A pilot study was conducted with 40 normal subjects to observe the changes in Pulse rate and GSR during relaxed and stressed states. By taking average, the stress threshold was identified to be different for different individuals. Thus the prototype is customizable for every individual based on their stress threshold that is easily programmable. The prototype is light weight, portable, battery operated and comfortable for use at home or work.

Keywords: *stress; galvanic skin response; pulse rate; infrared*

1. Introduction

Psychological stress is defined as a feeling of strain and pressure. Certain types of stress resulting from our day to day activities are beneficial to the human body and helps in efficient working of the mental and physical self. This stress is called positive stress and it assists in motivation, adaptation and reaction to environment. Stress causes one to experience anxiety, pressure and the negativity surrounding a situation. Physiological stress can be treated with medication and rehabilitation. The 'fight and flight' mechanism experienced by the human body under stress is for emergencies and usually the body gets back to normal after the stressor is removed. On the other hand, mental stress persists for a longer time resulting in continuous response from the body against the stressor putting the body at serious risk. Every time one gets stressed, the pulse rate and blood pressure are elevated.

With time, this can lead to major health issues causing problems in various functions in the body like the digestive system, reproductive systems, central nervous system, immune system and endocrine system. Mental stress can be due to external stressors or internal stressors. The external causes of stress can be due to major sudden life changes, financial problems, family situations, relationship difficulties and career problems. The most common internal causes of stress are negative thinking, pessimism, unrealistic expectations, lack of flexibility and the inability to accept uncertainty. Stress can also occur as a symptom of neurological disorders, other illness and as a side effect of certain medication. The significant effects of mental stress are insomnia, depression, anxiety, muscle fatigue, tiredness, headaches, shortness of breath, stomach aches, erectile dysfunction, irregular menstrual cycle, high risk of heart attack, increased blood glucose levels and blood pressure.

The sympathetic nervous system causes the pulse rate and blood pressure to increase and also activates the sweat glands in the skin during an emotional arousal. Increased sweat secretion in the skin results in a higher skin conductance and thus a lower skin resistance [1]. Pulse rate and Galvanic Skin Response (GSR) are the two most significant parameters used to detect mental stress. These biosignals can be taken non invasively, which is of huge convenience for the people [2]. Pulse rate is defined as the number of heart beats per minute, measured at the wrist of the person. The normal pulse rate is from 60 to 80 bpm. Galvanic Skin Response measures the skin resistance and gives output in terms of voltage (V).

Rehabilitation for stressed subjects can be of different ways such as listening to calming music, taking anti depressants, undergoing counseling, light therapy, altering lifestyles, exercising, meditating and doing yoga. One such method is Infra red light therapy. During mental stress, the cortisol levels of the body gets increased and Infra red light therapy has been proven to lower cortisol levels in human body [3].Whenever the body gets stressed or perceives danger the adrenocorticotropic hormone (ACTH) gets released in the brain. This in turn makes the adrenal gland to release the cortisol and adrenaline hormones. Increase in cortisol levels causes panic, increase in heart rate and dry mouth [4]. Continuous emission of IR light at a certain frequency at the foot or the neck of the patient can significantly decrease the cortisol level in the body [5].

IR light therapy is used for detoxification of body, pain relief, muscle pain, cancer and overall health of the body. This therapy is efficient as it reduces stress and is non invasive. The IR light causes the skin surface temperature to increase when exposed for a long time that results in decrease in mental stress [6]. In the work presented in the paper, pulse rate and GSR are used to detect if a subject is stressed and in turn provide IR therapy based on his / her stress threshold. The therapy unit is automatically and wirelessly operated without any supervision. The monitored stress values are uploaded on the internet and the physician is notified in case of any abnormal stress values.

2. Materials and Methodology

The block diagram of the stress monitoring prototype consists of two main units namely the sensor unit and the therapy unit as shown in Figure 1.

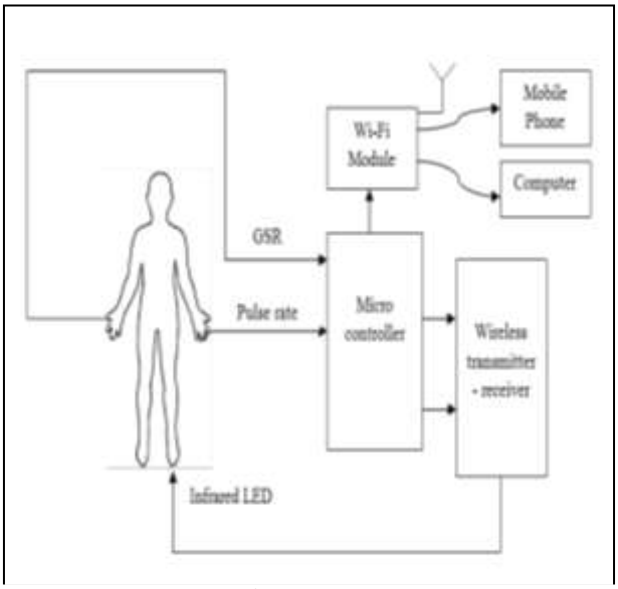

Figure 1: Block diagram of the Stress monitoring and IR therapy prototype

2.1. Pulse Rate Sensor

The pulse rate sensor is used to detect the pulse rate by placing it at the tip of the index finger of the person. The PR sensor uses the concept of a pulse oximeter to determine the pulse rate. The sensor consists of an IR LED of 940nm as a source and a photodiode of range 400nm – 1100nm as a detector. Red LED is not used as the sensor does not need to measure oxygen saturation [7]. The finger is placed in between the LED and the photodiode where the IR light passes through the finger to the detector. As the heart beats, it pumps blood into the capillaries of the body. In between the beats the blood volume in the capillaries decreases and the blood volume increases in the consecutive heart beat. Though this volume fluctuation is very small a pulse rate sensor can detect this change. The blood volume change is used to calculate the pulse rate of the person.

2.2. Galvanic Skin Response Sensor

GSR measures the skin resistance of the person with two copper plates. The copper plates are fashioned inside a Velcro band so as to adjust it around the patient's fingers. The middle finger and the ring finger are used to collect the data. One copper plate is connected to +5V and the other copper plate is connected to ground of the micro controller. The circuit is only closed when two fingers are placed on the copper plate and open otherwise. The copper plates can measure the resistance change in the skin and converts it to voltage. The skin resistance of a person cannot go beyond 1KΩ. The GSR automatically gives the resistance in terms of voltage. During the experiment, the GSR readings of the prototype ranged from 4.00 to 4.99 for the subjects.
The resistance of the skin can be calculated from the output voltage readings. 1KΩ is made equal to 5V in GSR by the resistors in the circuit while the other resistance values can be calculated as given in Equation.

$$Rout = (GSR_{out} * 5) / I \text{ (mA)}$$

Rout = Resistance for the correspondingGSR value (KΩ)
GSR_{out} = GSR value in voltage (V)
I = Current through the circuit (mA)

2.3. Microcontroller and Wi-Fi Module

The microcontroller is used to process the bio signals from the GSR circuit and PR sensor circuit. The ATMEGA 328 microcontroller has a built-in ADC and converts the analog bio signals to digitals signals. A red LED is used to notify when the circuit is switched on. A green LED is used to notify when the prototype starts collecting data from the sensors. The sensors output is given to the analog input pins of the microcontroller. A Wi-Fi module is fixed in the microcontroller to upload data to the internet automatically as the prototype initiates acquiring data. A URL is created beforehand, in which the data is continuously uploaded using the concept of Internet of Things (IoT). The IoT makes it possible to send the information from the sensor to the internet [8]. The Wi-Fi module needs an internet connection and a microcontroller that is sophisticated enough to process it.
The Wi-Fi module present in the circuit uses a Hotspot connection from a mobile phone. The network SSID and the password for the connection is pre programmed in the circuit. The hotspot of the mobile phone must have its security as WPAN PSK and not as open security. The mobile network SSID and password must match the prototype's ID. By this the prototype can access the hotspot of the mobile phone. Once Wi-Fi is enabled the prototype starts uploading data onto to the internet in the designated website. The IoT enables continuous monitoring of the patient without any disturbance and the collected data can be viewed at any time anywhere using internet. It is not necessary that the care taker / doctor must be near to know the state of the subject. The additional feature of IoT is that a message is sent to the doctor whenever the PR or GSR goes abnormal for the immediate attention of the patient. The doctor's number can be registered or even changed as per convenience. The message containing the abnormal value of the heart rate along with the patient ID and name is sent to the doctor. The doctor can immediately view the other values of the patient through the internet remotely [9].
The GSR and PR sensor along with the micro controller and Wi-Fi module comprises the sensor unit of the prototype as shown in Figure 3.

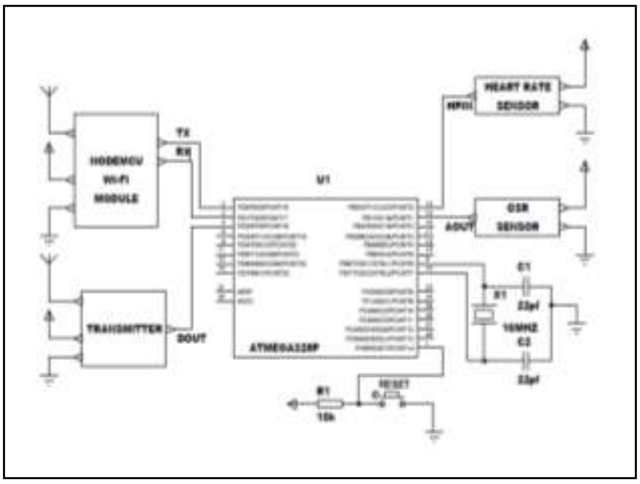

Figure 3: Block Diagram of Sensor circuit

2.4. Infrared Therapy Circuit

The application of the prototype is activation of an IR therapy for the subject under stressed state. The IR LEDs are switched on when the variables obtained reach a certain threshold. The threshold is the specific value of PR and GSR that is programmed when the prototype is calibrated for the subject. The threshold values are not standard for all people since the mental and physical condition of the subject must be taken into consideration. Therefore the threshold values are user defined and can be programmed prior to use [10].

The device must be calibrated to each person so as to determine their threshold values of PR and GSR. The calibration can be done by continuously monitoring the subject for a period of time. The parameters are noted during relaxed state for 10 minutes and during stressed state for 10 minutes. The average of the values can be taken for stressed state and a threshold is fixed. This threshold value is programmed into the prototype and every time when the threshold value is crossed the IR LEDs get switched on for therapy.

The IR therapy circuit consists of 10 IR LEDs, each in the range of 960 nm fixed on a board in a circular arrangement. This IR therapy can be given both in the foot or neck of the person depending upon the patient's comfort level. This prototype is however designed for therapy in foot of the person for duration of about two minutes. The ten LEDs together give more intensity which is required for the therapy. The IR LEDs automatically get switched off after the two minute duration. The duration of the therapy is also programmable since the subject may need extra therapy time depending upon the stress levels. The IR LEDs are controlled by an ATMEGA 328 microcontroller which is powered by a 9V battery or a 12V power supply. The usage of battery makes the prototype portable while using an adapter for power supply gives longer life to the prototype. A voltage regulator is used to convert the 12V power supply to 5V for the microcontroller and another voltage regulator is used to convert 5V to 3V in order to power the transmitter–receiver module.

The transceiver is used to transmit data from the sensor circuit to the IR circuit. When a certain threshold is crossed in the sensor circuit, logic 1 is transmitted to the receiver in the IR circuit which in turn initiates the micro controller. The microcontroller is programmed in such a way that the IR LEDs must switch on whenever logic 1 is received by the microcontroller and remain switched off otherwise. A relay circuit is used to automatically cut off the LEDs after the desired therapy duration is reached. The IR unit is shown in Figure 4.

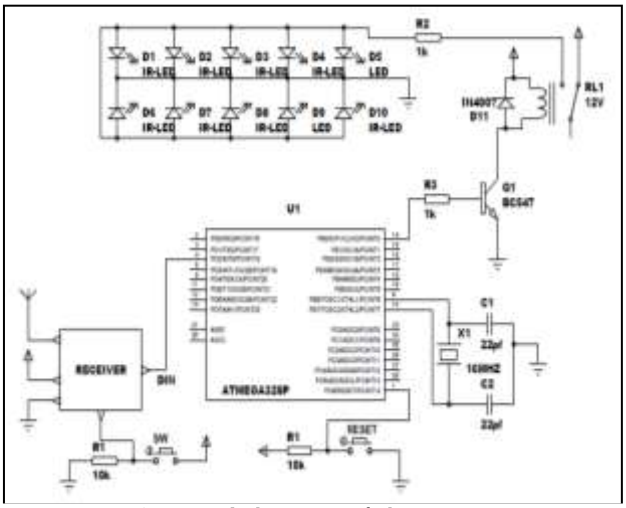

Figure 4: Block Diagram of Therapy unit

The sensor unit and the IR unit are connected only by the transceiver module. Even though the module has a range of 10m, the sensor unit will be placed on the subject's hand while the IR therapy unit is placed on the foot of the subject and so will not have any interruption while transmitting or receiving data.

3. Experimental Setup

The sensor readings were taken for 40 subjects under both relaxed and stressed states. The stress was either induced by making the subjects solve mathematical calculations or the subject was under natural mental stress due to their personal circumstances. Subjects who are about to attend their job interviews were also included in the study. The experimental setup for subjects attending interview is shown in Figure 5.

Figure 5: Experimental setup of subject prior to interview

The subject under study was asked to sit idle for about 30 seconds and then the blood pressure was taken in their right hand using an automatic BP machine. A questionnaire was then given to them to fill, which had questions about their anthropometrical measurements such as height and weight, sleep duration, intake of any medicine for over a period of time, prevalence of diabetes and blood pressure and contact information. The subject is then made to sit in a comfortable position with their fingers inside the GSR and PR sensors for monitoring. The experimental setup of subjects posed with mathematical problems is shown in Figure 6.

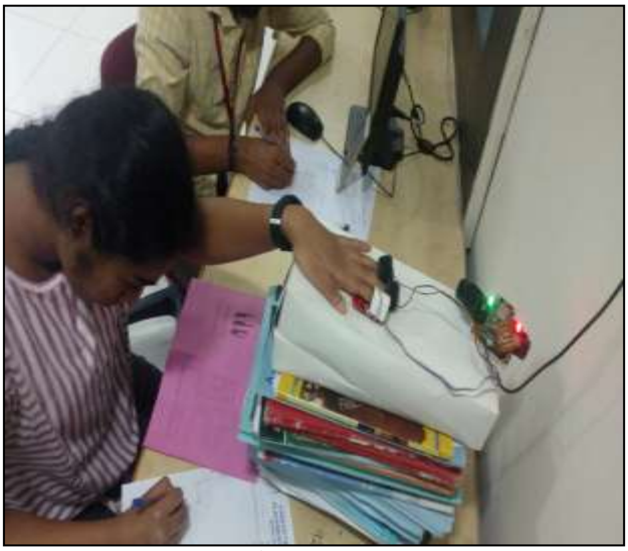

Figure 6: Experimental setup of subject posed with mathematical problems

The subjects were given mathematical aptitude questions and the tests were timed. The subject if right handed was asked to place the left hand on to the sensor circuit and to take the test with right hand. This enables continuous monitoring of the subject throughout the test. The subjects were usually given 5 minutes to complete the test and the corresponding readings were noted. The subjects who were already stressed due to personal situations or prior to job interview were not given any tasks and the readings were taken in their left hand while they were sitting idle.

4. Results

4.1. Interview Attending Subjects

The GSR values of each interviewee were plotted against their pulse rate to obtain a partially non linear trend as shown in Figure 7.

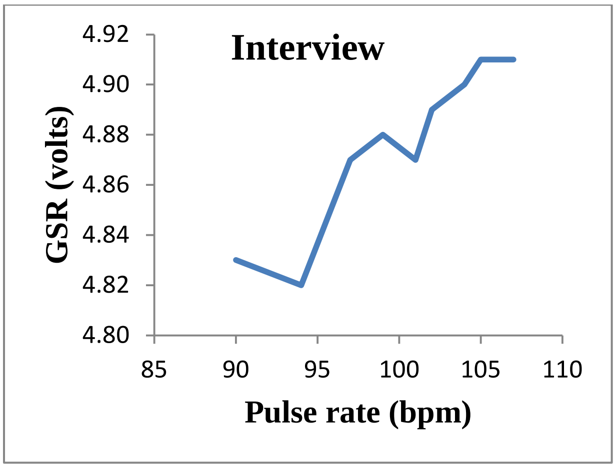

Figure 7: GSR pattern of subjects before an interview

It is seen that there is increase in the GSR voltage with increasing pulse rate of the subject. A subject is usually presumed to be in mental stress before an interview. However, there are certain non linear data points on the trend which exhibits a lower GSR for an increased pulse rate. This depends on the varying psychological state of each subject prior to the interview.

4.2. Subjects Posed with Mathematical Problems

The GSR values of each subject who was given a set of mathematical problems to solve, were plotted against their pulse rate to obtain a fairly linear trend as shown in Figure 8.

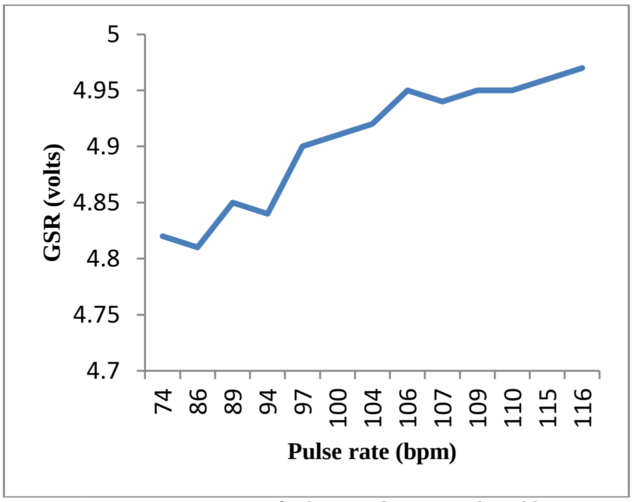

Figure 8: GSR pattern of subjects solving a math problem

The above graph shows a constantly increasing GSR with increasing pulse rate. This is a relatively consistent trend as compared to that of the subjects attending interview. This also indicates increase in the induced stress level of the subjects when posed with a mathematical problem.

4.3. Subjects with Personal Issues

The GSR plot of subjects who claimed to be mentally stressed due to personal problems was studied as shown in Figure 9.

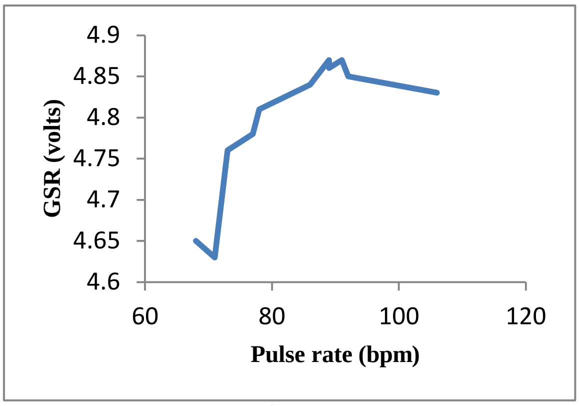

Figure 9: GSR pattern of subjects with personal issues

The GSR trend of subjects who claimed that they were stressed due to personal issues shows a fluctuating relation with pulse rate. The first possible reason for this trend might be varying levels of stress causes for different subjects. The other reason might be that prolonged stress levels are not immediately reflected when the experiment was conducted. This facilitates the need for longer duration of study to understand the GSR pattern for such subjects.

4.4. Overall GSR Trends

The Pulse rate and GSR average was taken for each subject category and the consolidated average values are shown in Table 1.

Table 1: Pulse rate and GSR average for various experiments

Category	Pulse rate average (bpm)	GSR average (volts)
Relaxed	74	4.35
Interview	99	4.88
Math problem	100	4.90
Persona issues	86	4.80

It is observed from the averaged data that there is a linear increase in the GSR value with Pulse rate in all the experiments. The obtained average values shall be considered as the stress thresholds for the respective subject category. The stress thresholds are the highest for subjects who were given mathematical problems and lowest for subjects who claimed to be stress due to personal issues. The subjects posed with mathematical problems were in a state of increasingly induced stress within a short duration and this is reflected in the GSR trends as well as in the averaged data.

The GSR plot of three different subject categories were combined and studied as shown in Figure 10.The consolidated plot shows the concentration of GSR data points for different experiments over a range of pulse rate values. It is seen that the GSR points for relaxed subjects, ranging from 4.25 volts to 4.45 volts, are much lower than that of other categories. The interviewee subjects and those who attempted mathematical problems showed largely coinciding GSR values ranging from 4.80 volts to 4.95 volts, which reflects efficient stress induced over a short period. These values were also shown to be acquired at high pulse rate values optimally ranging from 85 bpm to 115 bpm. On the other side, the GSR trend of subjects with personal issues had a wide range from 4.65 volts to 4.9 volts over a largely varying pulse rate from 68 bpm to 112 bpm. This shows that there is no immediate effect on the GSR for subjects with prolonged stress levels.

5. Future Work and Conclusion

The prototype was successfully tested and studied for subjects under various situations for a fixed duration of 10 minutes. The average values of Pulse rate and GSR for each category was considered as the stress threshold for activating the Infrared LED setup. As the study was conducted over a large number of subjects to test the effectiveness of the prototype, the obtained stress thresholds are not standardized for practical applications. In practice, the prototype has to be customized for each subject, by calibrating the stress threshold for the desired amount of time before usage. This is because, the response of each individual is different to different situations and thus the resulting stress threshold will vary.
The prototype is comfortable for use in home or work environment. The light weight of the device makes it easy to carry and wear. Future work may include conducting clinical trials for evaluating the GSR response of each subject, after Infrared Light therapy is given.

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