A Survey on Analysis of Stress

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Abstract- Stress can cause hypertension and heart diseases. Continuous monitoring of an individual's stress levels is essential for understanding and managing personal stress. Non-invasive physiological parameters such as Galvanic Skin Response (GSR), Heart Rate (HR), Blood Pressure (BP), respiration activity, and ECG (Electrocardiogram) are used to analyze stress. Heart rate increases when people are mentally stressed. But, using heart rate alone as an indicator to detect mental stress may lead to misclassification. By using heart rate with GSR can assist in the analysis of stress. The survey emphasizes the combination of GSR and HR to provide better analysis and detection of stress.

Keywords – Galvanic skin response, Heart rate, Physiological parameters, Skin conductance, Stress

I. INTRODUCTION

Stress is a physiological response to mental/emotional or physical aspects that we encounter in our day-to-day life. Most people experience acute stress during their respective everyday life. Any activity that is done always creates some form of stress.

Stress comes in three factors:
1) Acute stress which is caused by a short instance or short term stress factor.
2) Episodic acute stress that occurs more frequently.
3) Chronic stress which is caused by long term stress factors and can be very harmful on a long run. Chronic stress plays a role in mental illnesses such as anxiety and depression and also in determining physical stress. But chronic stress is difficult to manage because it cannot be measured in a consistent and timely way, hence it would not be a very deterministic and completely reliable factor to determine stress.

Stress can be positive that tends to motivate and enable to respond well to a particular situation, or it can be negative which may cause emotional imbalance or may even cause cardiovascular diseases in severe cases. GSR can alone determine the quantity of stress in human but there are various different techniques to measuring stress. An example is GSR in combination to heart rate monitor to detect mental stress. It is apparent or proven that when a person is mentally stressed his heart rate increases. Galvanic skin resistance is one reliable method that can be used to detect stress levels. It exploits the phenomenon of skin conductance and sweat production. When a person is stressed, the nervous system generates an electrical signal through the body. Also, the human skin offers some resistance to current and voltage. The signals generated due to stress cause a change in the skin resistance which is thus
proportional to the amount of stress faced by an individual and therefore GSR meter can be effectively used to determine the stress levels of a person.

Section II describes the effects of stress on human body. Section III discusses the various studies of stress analysis using GSR and HR. Section IV contains the results and discussions.

II. STRESS AND ITS EFFECT ON HUMAN BODY

Stress impairs one’s attention and concentration, performance, behaviour, thinking ability, reasoning, time management, responsibility, etc. On a long run, these could eventually cause exhaustion of hormonal, cardiovascular, neural and muscular system due to insufficient recovery and repair. Long term consequences include, for example, an impairment of immune system, delay of healing processes and musculoskeletal overload.

Stress plays a role in mental illness such as generalized anxiety disorder and depression. An important thing to be noted is that, emotional sweating is not influenced by circulatory changes in relaxed subjects. Chronic stress is difficult to manage as it cannot be measured in a consistent and timely way. Hence, mental stress (Acute) which activates sweat glands is analysed, of which skin conductance is an indicator. GSR is measured from hands or feet since sweat gland density is the highest. Autonomic Nervous System (ANS) regulates body’s major activities including heart’s beating, gland secretion, blood pressure, and respiration. It has two branches: Sympathetic (SNS) and Para-sympathetic (PNS). Sympathetic is used for action under stressful conditions. Sympathetic activity leads to increase in heart rate (example: during sports and exercise). Para-sympathetic does the opposite, i.e. relaxes the body into steady state. It induces a lower heart rate (during sleep).

III. STRESS ANALYSIS USING GSR AND HR

A study in which, four saliva samples were collected from ten participants for two consecutive days (on both days samples were collected at 9:00, 12:00, 15:00, and 18:00) was carried out in [1]. Cortisol reactivity to stressful situations can differ according to the time of the day, typically in the morning; it is higher than that in the late afternoon. Measurement of stress in human body is psychological in nature, and hence the different cortisol (skin resistance) conditions tested, gave the variations of cortisol throughout the day.

Stress during activities like sitting, standing and walking and the variation in different parameter values during these activities was studied [2]. A group of 13 men and 7 women of various age groups were monitored while performing the activities individually and performing some thinking and mental calculations.

A test subject underwent the following segments of the test:

- Baseline segment (listened to meditation music in any one position for some time)
- Mental task segment (made to undergo a Stroop test and perform mental arithmetic under time pressure in the same position). (Stroop test is subjecting a person to select the font color of a word which spelt another color)
- Recovery segment (sit in a chair with closed eyes and listen to meditation music)

According to the analysis, heart rate increased by variation of position: supine to sitting (66-77 bpm); sitting to standing (86 bpm); standing to dynamic body movements (92 bpm). It was concluded that heart rate and GSR provided highest overall correlation with the test subject’s stress level in various conditions, reaching an accuracy of 97%.

Reference [3] describes the various factors correlated to stress. A description of various non-invasive physiological features were correlated to high stress situations. Subjects were healthy college going adults and were engaged in a poker tournament. During the course of play, the physiological and behavioural states were recorded which included HR, GSR, heat flux, body temperature, speech features and movement data. It was observed that stress had 79% accuracy using skin conductance peaks and 82% accuracy using two features such as skin conductance and voice pitch variations. It is concluded that among all the factors considered, GSR, HR, and voice pitch variations were highly correlated to stress.

Reference [4] indicates stress measurable through heart rate monitor. To determine stress it was required to decouple Sympathetic Nervous System (SNS) and Para-sympathetic Nervous System (PNS) from heart rate variability. This decoupling can be done by determining spectral analysis (PSD) of heart rate variability, blind fold separation technique, Principal dynamic mode (PDM), of these methods PDM was observed to be better by a narrow margin as it used less expensive heart rate monitors compared to expensive ECG, etc. Test had two conditions: within subject and between subject. In the first case, classifier trained based on data obtained over several days, the subject was trained and tested to measure stress by performing the process five times and tested on data for remaining days and this procedure was repeated five times. In second case, data from two subjects was taken and tested on third subject and the procedure was repeated three times for each subject. Results proved that PSD was
better than PDM in within the subject case but PDM outperformed PSD by only a narrow margin in-between subject case. But it was proved that PDM had lower variance across subjects and hence was more stable than PSD. It provided accuracy of 69%.

The effects of stress due to physical or mental factors were studied in [5]. A study was conducted in which 25 subjects of mean age 20.30 ± 1.53 of both sexes were considered. The subjects were divided into two personalities namely type – A, and type – B; depending upon a personal questionnaire given to each. Type – A group was more exposed to stress (mental>physical) and were more responsive to stress while Type – B group revealed a greater capacity to cope up with stress. During the course of the test, each of them was subjected to reverse calculations (mental stress) and shoulder abduction (physical stress) with a rest period of 15 minutes in between. It was observed that due to mental stress, there was a significant increase in heart rate, left frequency domain and ratio of left frequency to right frequency domain as compared to physical stress. An increase in high frequency domain with an increase in physical stress was observed. The subjects of type-A category were more susceptible to cardiovascular diseases.

The interaction between HR, Heart Rate Variability (HRV) and mental stress on group level and for individual changes was investigated in [6]. By measuring ECG during rest and during a mental task, HRV was analysed to provide an insight into how the heart reacts to a mental task. Average heart beat period in ms (Mean RR) was calculated for each subject for the two conditions derived from the raw RR-interval. HRV analysis is possible in the time or frequency domain. Time domain analysis is the easiest way, calculated directly from the raw RR-interval. The frequency domain shows us the variability of the RR-signal over time by looking at the proportion of the frequencies relative to the original RR-signal. Generally used spectral measures are peak frequency and power of very low frequency bands (VLF: 0 to .04 Hz), low frequency bands (LF: .04 to .15 Hz) and high frequency bands (HF: .15 to .4 Hz) and the ratio of LF/HF, which is often interpreted as a measure of sympathovagal balance. The following time domain measures of HRV were calculated: standard deviation (SD) of HR and proportion of successive NN intervals with a difference greater than 50 ms (pNN50). Mean RR was significantly lower with the mental task than in the rest condition (p=2.29E-06). Comparing rest and mental task conditions, 24 of the 28 subjects had significantly lower mean RR with the mental stressor. From the HR and HRV data reported, it was concluded that short term HRV was reduced with a mental task.

Reference [7] describes the study of stress patterns using GSR sensors. An experiment was performed on 5 workers who were subjected to job stress factors, for a total time series of 72 minutes. From the study, it was concluded that the quality of GSR signal from contact sensors depends primarily on the continuity of contact between the device and skin of the test subject. Also, a steady increase in GSR is caused due to gradual changing environment factors or genuine stress response differentiated by intensity of peaks. One important fact that has been observed is that although doing exercises results in higher GSR level, it is not related to emotional stress.

The study of surgical stress and how GSR can aid anaesthesiologists in administering the exact amount of anaesthetic drugs was studied in [8]. A study was conducted on 11 patients among whom were 8 women and 3 men of age 45 ± 15 years and having a BMI of 24.5 ± 4.5 Kg/m2. From the study, it was concluded that GSR changes are more specially linked to pain responses than blood pressure and heart rate. Pain stimuli induced an immediate increase in emotional sweating and skin conductance fluctuations; and when the stimuli are stopped, the fluctuations decreased immediately. Emotional sweating is not influenced by circulatory changes in relaxed subjects. The important fact observed was that heart rate and blood pressure are influenced by both para-sympathetic and sympathetic nervous system responses i.e. GSR fluctuations. But GSR is not influenced by heart rate and blood pressure.

The number of physiological signals that were necessary in determining stress of an individual was studied in [9]. The physiological parameters considered were GSR, HR, skin temperature and ECG. Different people were taken as test subjects and their HR and GSR were recorded in various conditions, such as resting state, stress invoking or excitement (ex hyperventilation, speech talk preparation) and Post excitement. The data was collected and a genuine data base was formed. The combination of HR and GSR obtained from latter tests were then compared with the standard data base values. Of the various techniques involved, fuzzy logic provided better accuracy. It was tested on a large population (i.e. 80 individuals) and provided an accuracy of 99.5%. Most importantly, it used minimum number of physiological signals to determine stress (GSR and HR).

Reference [10] describes that GSR can be used in combination with BP as a device for lie detection which has advantage over polygraph since data obtained through polygraph in experimental and actual field vary. The subjects chosen were 62 criminal suspects who were interrogated in connection with serious offences. None of them had been informed that part of interrogation was used for scientific purpose. GSR through skin and blood pressure through cuff around arm were measured. A card test was conducted which included attaching a GSR module to the finger on left hand and cuff the upper right arm. The subjects were asked to choose one card and answer ‘no’ to all
subsequent questions. The ‘no’ sequence was randomized such that each ‘no’ appeared twice in questioning. The test was accounted for two conditions: GSR and BP simultaneously and GSR only. In first condition 32 hit and 30 miss were observed and in the second case, 35 hit and 27 miss were observed. These results provided an additional support for efficiency of GSR channel during stress. It can also be concluded that there is not much variation in either case and two factors BP and GSR do not interfere with each other.

### III. RESULTS AND DISCUSSIONS

GSR is chosen for analysis of stress because the skin conductance is a measure of emotional state and arousal and can be used to measure various types of stress such as surgical stress in anaesthesia, mental stress, pain, etc. GSR depends primarily on continuity of contact between device and skin of test person. A steady increase in GSR is caused due to gradual changing environment factors or genuine stress response differentiated by intensity. A transient increase in skin conductance is proportional to sweat secretion. Pain stimuli induce an immediate increase in emotional sweating and skin conductance fluctuations and when pain stimuli are terminated skin conductance fluctuation decreases immediately. Doing physical exercises results in higher GSR level and yet it is not related to emotional stress. It is impractical to exclude the effects of physical activity while developing stress monitoring application for everyday use.

### Table -1: Comparison of stress analysis parameters

<table>
<thead>
<tr>
<th>Parameters used</th>
<th>No. of Subjects tested</th>
<th>Detected Stress Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>HR (PDM and PSD)</td>
<td>5-6</td>
<td>69%</td>
</tr>
<tr>
<td>GSR (Skin conductance)</td>
<td>15</td>
<td>79%</td>
</tr>
<tr>
<td>GSR + Voice variations</td>
<td>15</td>
<td>82%</td>
</tr>
<tr>
<td>GSR + HR</td>
<td>80</td>
<td>99.5%</td>
</tr>
</tbody>
</table>

The various studies conducted show that the combination of GSR and HR provides an accuracy of 99.5% for determining stress.

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