Stress Quantification Using a Wearable Device for Daily Feedback to Improve Stress Management

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Abstract. Stress is becoming a major problem in our society and most people do not know how to cope with it. We propose a novel approach to quantify the stress level using psychophysiological measures. Using an automatic stress detector that can be implemented in a mobile application, we managed to create an alternative to automatically detect stress using sensors from a wearable device, and once it is detected, a score is calculated for each one of the records. By identifying the stress during the day and giving a numeric value from biological signals to it, a visualization could be produced to facilitate the analysis information by users.

Keywords: Stress · Stress management · Wearables · Heart rate · Skin temperature · Galvanic skin response

1 Introduction

Stress can be defined as the state of psychological response to stimulus (either external or internal) that generates changes in several systems of the body. Stress is usually visible by observable behavior like perspiration, mouth dryness, breathing difficulties, or an increase in speech speed [1]. The correct management of stress, on the other hand, could help to reduce reported health problems like flu, sore throat, headaches, or backaches that occur when stress is present several times a day [2]; and to attenuate more challenging problems like immune system impairment, sleep difficulties, and the rise of the glucose level [3, 4].

Given the great variety of stress reactions, predicting behavior by only describing a particular situation becomes an impossible task, mainly because someone could tremble, sweat, and experience discomfort, but in the same situation, another person might not show the same level of subjective discomfort [5], or visible changes in behavior like facial expressions [6]. Given this scenario, for long time people have been used psychological measurements, starting with the formal description of a polygraph in 1881 [7], and later on, with the first efforts to measure emotions in 1925 with the use of galvanic skin response [8]. However, it was until the works of Schwartz [9] and Ekman [10] when this information was measured more accurately, and a better understanding was achieved on how emotions produce body responses.

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For this work, based on the work done by [10–12], we are characterizing stress by the rise of heart rate (HR), due to the effect of the cortisol hormone, which also decreases the blood flow to the limbs, causing a decrease in skin temperature (ST) and a rise of GSR; this last change is caused by increase in the limbs perspiration.

2 Formulas to Characterize Stress

Traditional ways to assess stress and anxiety are self-reported; one good example in this area is the Beck Anxiety Inventory [13]. Here we propose a non-subjective characterization of stress and anxiety.

2.1 Development

The sympathetic autonomous nervous system reacts when a stress episode occurs, and based on that, we created the next formula using the product of HR, ST, and GSR. The final value is squared to avoid negative numbers:

$$Stress = \left(\alpha_1 \varphi_{\alpha_1}(HR) \cdot \alpha_1 \varphi_{\alpha_1}(100 - ST) \cdot \alpha_2 \varphi_{\alpha_2}(GSR)\right)^2, \quad (1)$$

where $\phi\,\alpha_{\mathrm{i}}$ (x) is defined as a sigmoid by:

$$\varphi_{\alpha_i}(x) = \frac{e^{\alpha_i x}}{1 - e^{\alpha_i x}}, \quad (2)$$

and x to the value of HR, ST, and GSR in the same period of time. The equations were created to give a positive value in which a higher value means a higher level of stress. In this particular case, the low raw value of ST is interpreted as a higher level of stress; that is why the inverse value has to be calculated, to match the logic of the equation. To do this, we select the maximum possible value that a wrist in normal condition could rise.

A parameter α was added to the formula to balance and to give more importance to the GSR value. Previous research shows that this metric is strongly related to the activation of the sympathetic autonomous nervous system. This activation increases perspiration in the limbs and is correlated to emotional activity [12, 14–16]. For that reason, the value of α_2 is higher (0.5) than that of α_1 (0.25) and the sum of the three values equals one, giving the 50 % of the weight to calculate the stress to the GSR. Finally, with the purpose of helping in the visualization and making easier understanding of the values, the next formula was used to normalize the values between 1 and 100.

$$StressNorm = \frac{Stress_i - min(Stress)}{max(Stress) - min(Stress)} \cdot 100 \quad (3)$$

3 Testing

To test the stress formula, we used a filtering algorithm[1] that receives the HR, ST, and GSR values and detects when the persons have a stress episode; after the detection, the formula is used to measure the stress intensity. The main reason to have this distinction was for minimum and maximum values of the normalization formula, if it was applied to all the data, these values could not reflect the real parameters.

In the present work, one person used a Basis PeakI® for 28 different days between January and April of 2015. The days were randomly selected and the participant had to keep a diary of stressful events. After data collection, we ran a filtering algorithm to detect stressful events and then, the stress formula to get minimum and maximum values for this particular user to do the normalization in the next step. The values were: $\min(\text{Stress}) = 283.61$ and $\max(\text{Stress}) = 1,397.79$.

We plot a visualization of the normalized stress level to help a user to understand the changes during a day. All graphics presented in this work starts at 7 a.m. and finish at midnight. On Fig. 2 we can see how stress episodes can be visualized; one between 8:48 to 8:56 h. with score of 726.097, other between 17:24 to 17:45 h. with a score of 1540.76 and the third one at 22:38 until midnight with a score of 5,611.59. With a final score for March 18th was 7,878.45 (Fig. 1).

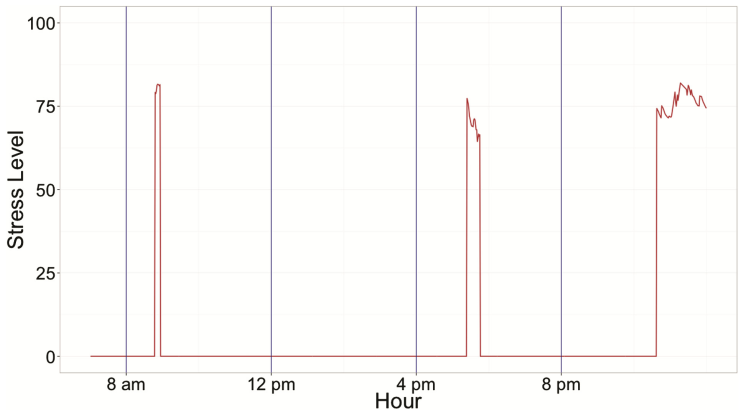

Fig. 1. March 18th.

4 Application

A possible application for this new approach is in a cognitive-behavioral program aimed to help people with a degenerative disease like diabetes or high blood pressure. In both cases stress management is important, because stress can compromise

[1] The algorithm will be publish on a future work by the same authors.

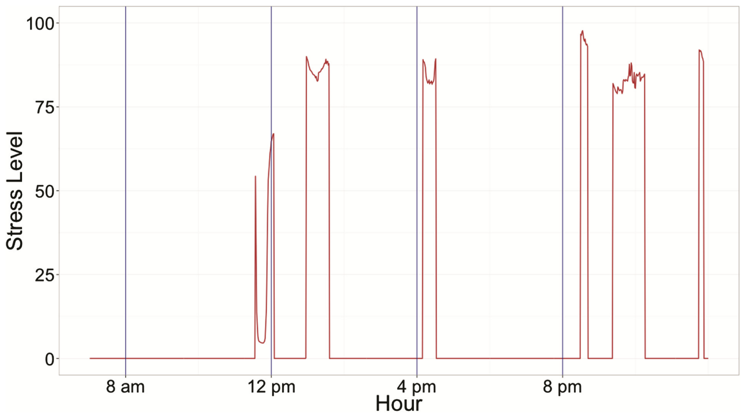

Fig. 2. January 21st.

treatment adherence and metabolic control, increase glucose levels in people with diabetes, and even accelerate the appearance of complications [17, 18].

Evidence-based decision making, as part of this approach, can use this information to help a patient to take better decisions to improve his/her health [19, 20]. This information could help to take healthier choices, facilitating change in patient's life style. This will improve quality of life and avoid health complications [21].

As can be seen in Fig. 2, it has the highest values from all the figures, the total score of that day was 12,283.46. This could be one day before a stress management program starts, the patient could wear a device for a week and the information collected could be the baseline. At the end of the program, a post-evaluation can be done to see how the patient improved, and as seen as in Fig. 3, a visual difference can be seen on stress intensity. Even though the stress episode lasted longer on April 1st, now the patient can handle it in a healthier way and the day's score is 4,462.759 (64 % lower than January 21st). An ongoing evaluation could be helpful if the patient can have the wearable device

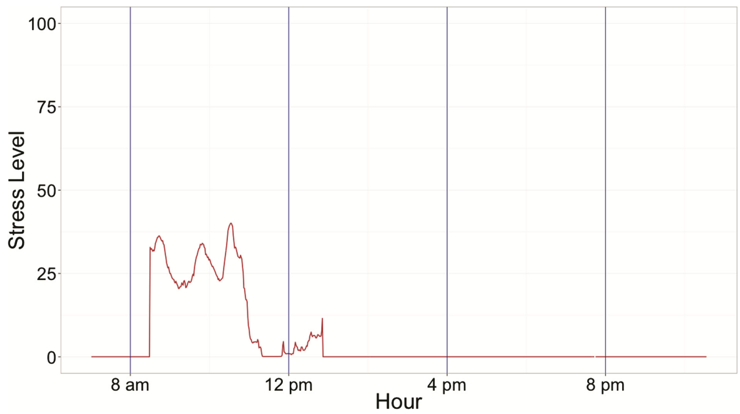

Fig. 3. January 21st.

every day of the program. The patient could take better decisions with this additional evidence of his performance.

5 Conclusion

With new technologies available and new wearable devices with several sensors that used to be big and uncomfortable to use, the new scenario presents as a great opportunity to create new ways to assess emotional responses like stress 24/7. The formula proposed in this work, could lead to novel approaches, not only in health care, but in other stressful scenarios where an ongoing evaluation could be more helpful that a post-test inventory.

Future work must be to collect data from a bigger sample to normalize the values on people with different demographics, to have a standardized scale based on psychophysiological metrics. This data could be collected in a psychoeducational program and it can help to test if this new approach can improve stress management.

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