Developing a monitoring psychological stress Index system via photoplethysmography

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Abstract: The purpose of this paper is to assess the psychological stress index (PSI) by using oxyhemoglobin saturation by SpO2 (i.e., plethysmograph (PPG) signal), which is measured easily and conveniently. We use plethysmograph amplitude (PPGA) and heart beat interval (HBI) extracted from SpO2 waveform to obtain the stress index and quantify it from 0 to 100. Also, the respiration rate can be extracted from heart rate interval according to our previous research. Therefore, the PPG signal can display heart rate, SpO2 waveform, SpO2 concentration, respiration rate and psychological stress index. This methodology has been tested in 9 volunteers under English presentation stress for Taiwanese students. The experiment in 30 min for each student was separated into three stages: preparation, presentation & discussion, and relaxation. The PSI values of these three stages are 49±10, 60±11, and 56±10, respectively. The results have been shown very successful for PSI value changing from low, high, and low during these three stages. In the near future, we try to implement this system into robotic wheelchair in order to monitor this PSI of elderly at nursing home to evaluate their psychological condition based on this method.

Keywords: Photoplethysmograph, pulse oximeter, plethysmograph amplitude (PPGA), heart beat interval (HBI), psychological stress index (PSI).

I. INTRODUCTION

In society, there are more and more factors that affect people's health. Recently, a lot of people have excessive stress, which leads to physical disease [1]. There are many diseases that occur due to excessive stress. Psychological stress leads to physiological changes that help people cope with unexpected situations and critical incidents. But frequent, strong, and sustained stress will create an adverse impact on the body. In the past, there are several famous scholars who research stress. One is Walter Cannon, who proposed "Homeostasis"[2]. He thought stress affects an individual's balance. If the body's system cannot keep balance, the person will "flight or fight". This response from epinephrine is trying to restore a stable body. The other is Hans Selye, who found that stress response is a "General Adaptation Syndrome" [3]. When feeling stress, the body will go through alarm, resistance and exhaustion where Glucocorticoid is playing a vital role in this part. Both stress responses were similar no matter where the stressors come. When people suddenly have a threatening situation or emotional stimuli, there is an increase in heartbeat, blood pressure, adrenaline etc. [4,5]. Hence, a lot of researchers try to measure physiological signals to represent the stress.

In order to monitor physical condition continuously, people usually need to wear a lot of equipment. Based on the patient's condition, they may have many physiological signals that need to be monitored, like electrocardiography (ECG), pulse oximeter (SpO2), respiration, etc. When people have many signals that need to measure, they wear multiple devices. Considering patients only have limited ability, complicated physiological monitoring systems are inconvenient to them. If people only wear one device to capture one signal, with other signals derived by this, it can get comprehensive physiological information easily.

In 2007, Huiku et al. [6] developed a method to assess stress index during surgical operations. The experiment in the paper is to observe the effect of various physiological signals such as plethysmograph amplitude (PPGA), heart beat interval (HBI), pulse transit time (PTT), response entropy (RE) when a patient suffers two opposite stimulus, incision and anesthetic drugs. They point out PPGA and HBI have the most remarkable correlation with stress and establish an equation to calculate surgical stress index (SSI). We analyzed the psychological condition based on this method.

Hence, the purpose of this paper is to assess the psychological stress index (PSI) by using oxyhemoglobin saturation by SpO2, which is measured easily and conveniently. We use PPGA and HBI extracted from SpO2 to obtain the stress index and quantify it from 0 to 100. Also, the respiration rate can be extracted from heart rate interval according to our previous research. Therefore, the PPG signal can display heart rate, SpO2 waveform, SpO2 concentration, respiration rate and psychological stress index.

II. METHODOLOGY

1. Photoplethysmography

A plethysmograph sensor is a medical instrument used mainly to determine variations in oxygen saturation. PPG [7] selects a skin area and measures the optical characteristics of that region. Usually we send red and infrared light through the skin and blood vessels. The components of blood Hb (reduced hemoglobin) and HbO (oxygenated hemoglobin) [8] will have different degrees of absorption. Therefore, the amount of oxygen in the blood can be measured due to the different absorption of red and infrared light through the skin and blood vessels.

2. Calculating heart rate from PPG

We mainly used maximum gradient to detect the peak point of SpO2 signal that is similar to the R-R interval in ECG signals as shown in Fig. 1. The first derivative was calculated at each point of SpO2 in the following equation (1):

$$Y(n)=X(n+1)-X(n) \quad (1)$$

If the gradient was larger than 60, we marked the X (n) point. Then, we found the local initial climbing point. According to this point, we took the front and back 30 points as a domain and found the maximum and minimum points. Then, PPGA is the amplitude between adjacent peak point and foot point (Fig. 2). And, HBI is the time interval between adjacent peak points (Fig. 2) that is similar to the R-R interval in ECG signals so the heart rate is easily obtained from this P-P interval.

3. Calculating respiration rate from PPG

The calculation of HBI from SpO2 signal in previous section can be applied to calculate the respiration rate. More details can be seen in our previous study [9].

4. Psychological stress index

Surgical stress index (SSI) [10, 11] has been used in surgery. It can be used to determine a patient's pain during surgery. SSI values near 100 corresponding to a high stress level, and values near zero corresponding to a low stress level. Firstly, we need to get PPG amplitude and the heartbeat intervals. Secondly, the standard deviations of PPG amplitude and heart rate variability are needed to calculate for normalization as shown in Fig. 3 (a). Finally, we can calculate the PSI value according to the following equation (2) as shown in Fig. 3 (b).

$$PSI= 100-(0.7 \times PPGAnorm - 0.3 \times HBInorm) \quad (2)$$

where PPGAnorm is normalized continuous blood oxygen pulse amplitude and HBInorm is normalized heart beat interval.

We tried to use this algorithm to calculate psychological stress index (PSI), but the volunteer did not lay on an operating table during surgery. We designed a pressure environment and measured the physiological signals during this period. We can measure the signal and used the equation (2) to calculate PSI.

III. RESULTS

This study has been tested in 9 volunteers under English presentation stress for Taiwanese students. They are not use English as their mother language and asked to discuss their research with two professors in English. The experiment in 30 min for each student was separated into three stages: preparation, presentation & discussion, and relaxation as shown in Fig. 4. Therefore, the PPG signal can display heart rate, SpO2 waveform, SpO2 concentration, respiration rate and psychological stress index as shown in Fig. 5. The PSI values from 9 volunteers of these three stages are 49±10, 60±11, and 56±10, respectively as shown in Table 1. The results have been shown very successful for PSI value changing from low, high, and low during these three stages.

IV. CONCLUSION

In conclusion, we confirm a new method to assess the psychological stress index by using SpO2 signals. At the moment, the method is limited to normal people and short-term condition. The method is particularly useful in situation where the SpO2 is the only available information source. Using a pulse oximeter, the user can obtain both psychological and physiological information at the same time.

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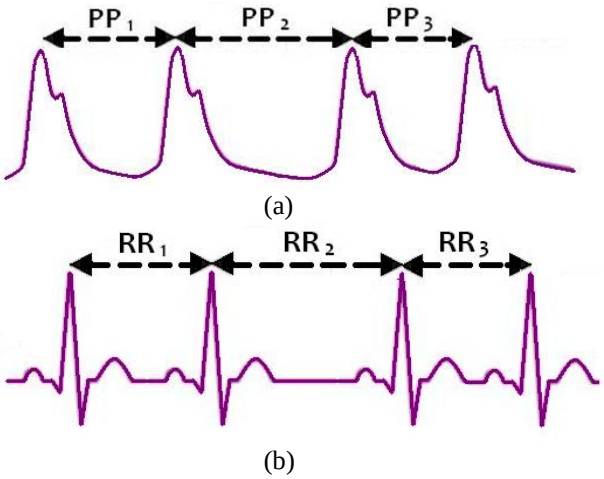


Fig. 1. Definition of peak to peak signals (a) from PPG signal (b) from ECG signal

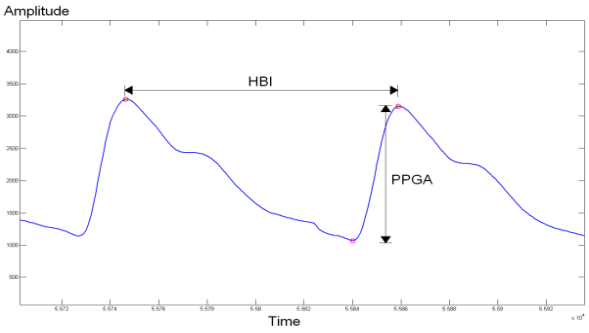
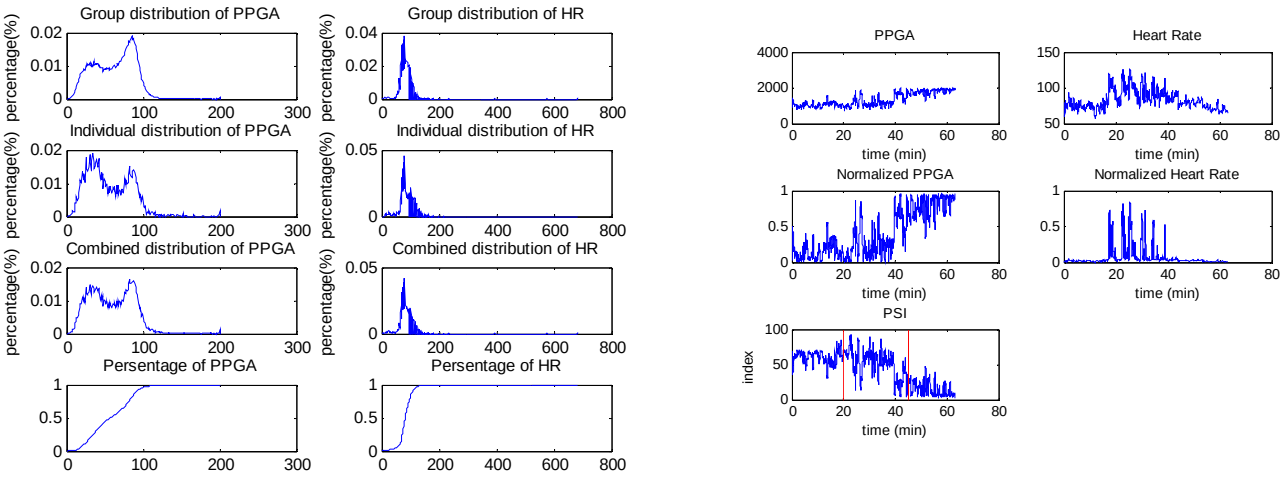


Fig. 2. Definition of PPGA and HBI

Table 1. The PSI in the experiment during skype meeting

Case	Before Presentation	During Presentation	After Presentation
A	46 ±13	57±11	56 ±20
B	33 ±10	52 ±17	62 ±12
C	59 ±10	68 ±10	57 ±9
D	60 ±12	57 ±16	57 ±14
E	45±12	57±11	51±2
F	60±10	60±10	64±10
G	34±10	62±11	53±8
H	N/A	62±12	61±6
I	59±12	65±9	48±10
Average ±SD	49±10	60±11	56±10



(a) (b)

Fig. 3 An example of (a) the process of normalization and (b) the variety of PSI in experiment

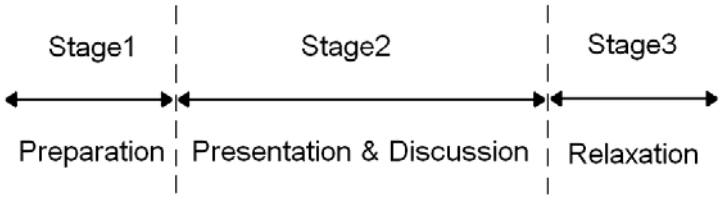


Fig. 4. The procedure of experiment

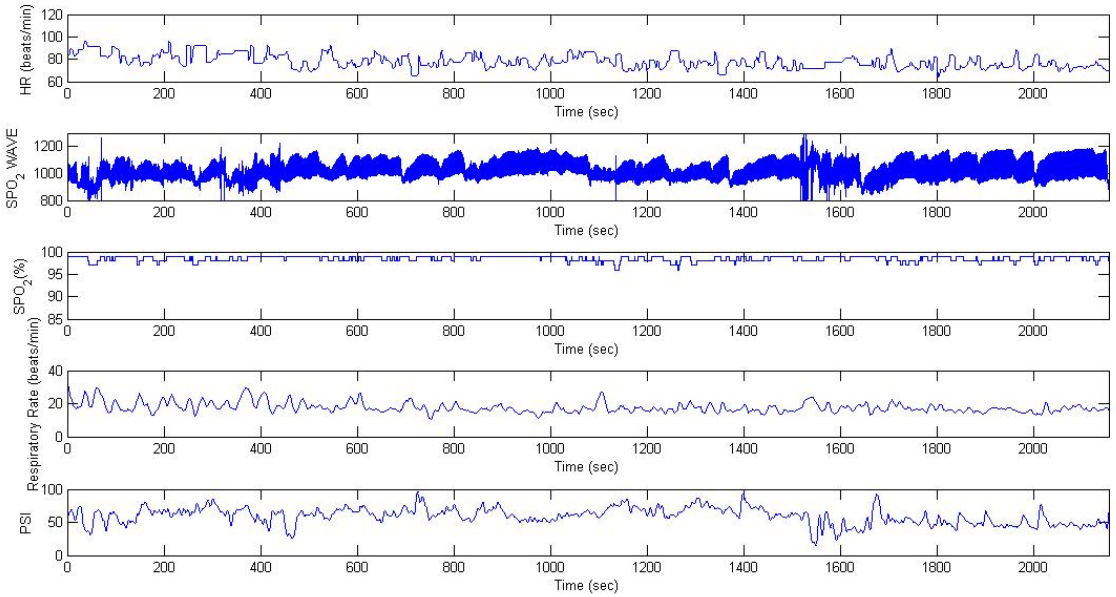


Fig. 5. An example of volunteer's heart rate, SpO2 waveform, SpO2 concentration, respiration rate and psychological stress index during skype meeting