Relationship between Depression Level and Bio-signals by Emotional Stimuli

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Abstract: Recent studies in mental/physical health monitoring have noted to improve health and wellbeing with the help of Information and Communication Technology (ICT) and in particular, application of biosensors has mainly done because signal acquisition by non-invasive sensors is relatively simple as well as bio-signal is less sensitive to social/cultural difference. Prior to developing a depression monitoring system based on non-invasive bio-signals, we examined a relationship of depressive level and changes of biological features during exposure of emotional stimuli. Ninety-six subjects' depressive level was measured by a self-rating depression scale (SDS). Electrocardiogram (ECG) and photoplethysmograph (PPG) were recorded during six baseline and emotional states (interest, joy, neutral, pain, sadness and surprise) and heart rate (HR) and pulse transit time (PTT) were extracted. Pearson's correlation was conducted to examine the relation of depressive level and biological features. The results showed that relation of depressive level and HR is positive in emotional states and there is a negative correlation between depressive level and PTT. We identified that they are meaningful biological features related to depression.

1 INTRODUCTION

In the field of ICT for health and wellbeing, the most current trends have shown that there have been increasingly various studies on correlating mental disorders to non-invasive biological measures such as skin conductance response, heart rate, and temperature. They have several advantages in that signal acquisition by non-invasive sensors is relatively simple as well as bio-signal is less sensitive to social/cultural difference. Also, it is known that several bio-signals are significantly correlated with human emotional state (Drummond and Quah, 2001; Tefas, Kotropoulos and Pitas, 2001). To provide more effective wellbeing service, it is considered to understand and recognize the emotions of humans. They mainly target depression and bipolar disorder and make use of mobile technologies and biosensors (Riva et al., 2011). They rely on biosensor devices for monitoring physiological parameters and on electronic self-assessment of mood so that the early warning signs of relapse into depression or bipolar disorder can be better recognized (Warmerdam et al., 2012; Faurholt -Jepsen, 2013; Valenza, Gentili, Lanat`a and Scilingo, 2013). However, because there are currently no objective biological markers by non-invasive techniques used in the diagnosis of depression, there has been a surge of research activity that has shed light on both the neurobiological, physiological, and behavioural effects of depression (Sung, Marci and Pentland, 2005). In this study, to identify biological measures related to depression as a preliminary study for a depression monitoring system based on bio-signals, we have considered heart rate (HR) and the dynamics of the PTT time series as tools for a better diagnostic of depression. Therefore, we examined a relationship between depressive level and changes of biological features, i.e., heart rate (HR) and pulse transit time (PTT) during exposure of six emotional stimuli (interest, joy, neutral, pain, sadness and surprise).

2 EXPERIMENTAL METHODS

2.1 Participants

Ninety-six male and female college students (mean

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20.0 years ± 1.8) participated in this study. None of them reported any history of medical illness of taking psychotropic medication and any medication that would affect the cardiovascular, respiratory, or central nervous system. A written consent was obtained at the beginning of the study when they were introduced to the experimental procedures, and they were also paid $30 USD to compensate for their participation.

2.2 Emotional Stimuli

To successfully provoke target emotions, we have used audio-visual clips as emotional stimuli. Each emotional clip which was excerpted from a variety of movies and pictures from PC etc. lasted 1- to 3-minute long. They were counter-balanced to minimize the order effect. Table 1 is the example of the emotional stimuli to induce six emotions. The emotional stimuli had 81.8% effectiveness on average by the other experiment for collection of emotional stimuli. The effectiveness means the intensity of the induced emotion by each stimulus.

Table 1: Examples of emotional stimuli.

Emotion	Context of Stimuli
Interest	
Joy	
Neutral	
Pain	
Sadness	
Surprise	

2.3 Experimental Procedures for the Measures of Bio-Signals

Prior to measures of bio-signals, they rated their depressive level on a self-rating depression scale (SDS) by Zung (1965). Then, bio-signals were recorded using MP150 (Biopac, Inc., USA) during baseline and six emotional states (interest, joy, neutral, pain, sadness and surprise). ECG was recorded through Ag/AgCl surface electrodes from the bilateral wrist and the left ankle as a reference. PPG were detected at the volar surface of the distal phalanx of the thumb of non-dominant hand.

For the data analysis, we chose the most emotional 30-sec section from six emotional states. HR and PTT were extracted from the signals. HR in beats per minute was analysed by an AcqKnowledge (version 3.7.1) program that detects R-waves in the ECG and calculates consecutive R–R intervals. PTT in ms was determined as the time between the R-wave in the ECG and the systolic peak in the pulse signal.

To analyse the biological data, we chose the most stable 30-seconds section from the baseline and the most emotional 30-seconds section from each emotional states. The emotional states were determined based on the results of the participant's self-reporting, in which an emotion was most strongly expressed during the presentation of a stimulus. Pearson's correlation examined the relation between depressive level and changes of biological features induced by emotional stimuli.

3 RESULTS

3.1 Validity of Emotion Induction

The results of appropriateness and effectiveness by the participants' ratings mean their psychological responses to emotional stimuli. The emotional stimuli had 92.0% effectiveness on average. The effectiveness of each emotional stimulus is as follows: interest 88.0%, joy 81.6%, neutral 94.8%, pain 95.9%, sadness 94.8% and surprise 97.0%).

3.2 Relationship between Depressive Level and Biological Features

Pearson's correlation coefficient (Pearson's *r*) as a measure of the linear correlation between two variables was used to examine the relation between depressive level and biological features during emotional states (Table 1). The results showed that relation of depressive level and HR is significantly positive in emotional states (Figure 1). This means that depressive level is higher, HR increase.

Table 2: The results of Pearson's *r*: correlation between depressive level and biological features during baseline and emotional states.

	Emotional States					
	INT	JOY	NEU	PAI	SAD	SUR
HR	.136	.237*	.274*	.208*	.339***	.178*
PTT	-.300**	-.167	-.308***	-.090	-.189	-.228**

*. p <.05, ** p < .01, *** p < .001

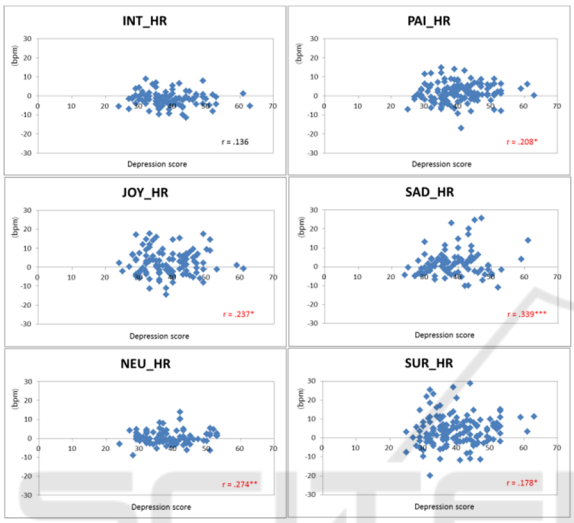

Figure 1: The relation between depressive level and heart rate (HR) during six emotional states.

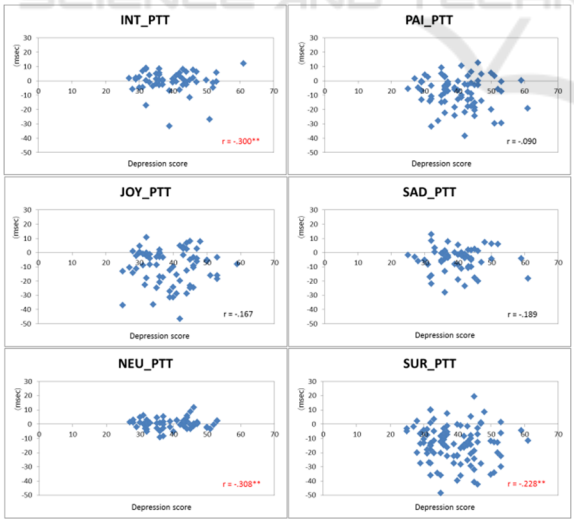

Figure 2: The relation between depressive level and pulse wave transit time (PTT) during six emotional states.

In addition to, there was a negative correlation between depressive level and PTT, i.e., depressive level is higher, PTT is lower (Figure 2). In particular, the correlation results of PPT were significant in three emotional states, interest, neutral, and surprise.

4 CONCLUSIONS

We have attempted to investigate the relationship between depressive level and changes of biological features induced by six emotional stimuli. The results showed that relation of depressive level and HR, SCL are positive in all emotional states except for interest and there was a negative correlation between depressive level and PTT in three emotional states. This means that depressive level is higher, HR increases and depressive level is higher, PTT is lower. In clinical study, increased heart rate was reported in the depressed in spite of unchanged autonomic balance (Moser et al., 1998). Also, they have discussed the possibility that the increased heart rate seen in the absence of vagal tone changes may not be due to altered vagal or sympathetic tone and other factors, including altered autonomous heart rate, may be responsible for the higher heart rate in the depressed group (Figure 3).

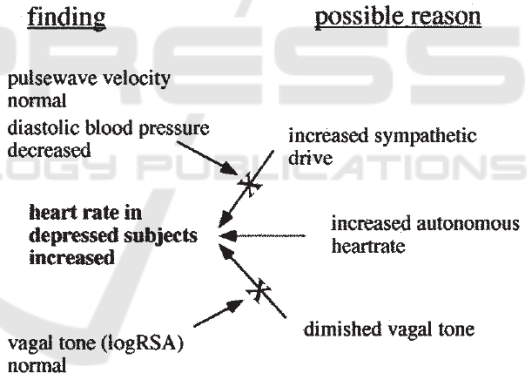

Figure 3: Possible physiological factors determining heart rate (right) and findings of Moser et al. (1998) (left) indicating, that increased autonomous heart rate is most likely the reason for the significantly heart rate in depressed subjects.

Pulse wave transit time (PTT) measures the time it takes for a pulse pressure wave to travel from the aortic valve to the periphery (Khandelwal, Sahni, Kumar and Kumar, 2014). PTT is inversely proportional to blood pressure, and the falls in blood pressure which occur with inspiration correspond to rises in PTT. Therefore, shortened PTT means rises in blood pressure and quantitative measure of inspiratory effort.

Although we haven't clearly examined that the relationship between depressive level and biological

feature (in particular, PTT) is linear under all emotional states (Table 1), we will perform the additional work to improve correlation between them. Spearman or Kendall correlation coefficient, a nonparametric measure of rank correlation, may be more suitable.

Nevertheless, we could identify that HR and PTT are meaningful biological features related to depression using non-invasive biosensors. This result will contribute to the use of integrative approaches capable of assessing multiple biological variables in developing the depression monitoring system.

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