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Original Article

# Heart Rate Variability as a Marker of Changes in Mood State in Daily Life by Photoplethysmography Technique

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## ABSTRACT

**Introduction:** The different mood states in our daily life can affect our mental and emotional health. The aim of our study was to explore photoplethysmography to record heart rate variability as a marker of changes in mood states in our daily life.

**Materials and Methods:** Two groups of affective pictures categorized into positive and negative sets were shown to thirty subjects on two different consecutive days with simultaneously recording of heart rate variability for 5 minutes by photoplethysmography technique. Immediately after recording on each day, 0-9 self-assessment scale was used to assess the mood state of the subject after viewing the set of pictures.

**Results:** Sympathetic domains of heart rate variability like low frequency (200.3 ±4.1 vs. 166.7 ±2.8, $p<0.05$), low- and high frequency ratio (1.45 ± 0.21 vs. 0.55 ± 0.07, $p<0.05$) and low frequency (55.8 ± 2.9 vs. 38.6 ± 2.8, $p<0.05$) significantly increased in negative mood state condition as compared to positive mood state condition. High frequency (157.9 ± 3.9 vs. 264.3 ± 5.3, $p<0.05$) and high frequency (44 ± 2.9 vs. 61.2 ±4.2, $p< 0.05$) significantly increased in positive mood state condition as compared to negative mood state condition. There was significant increase in heart rate (78 ± 2.99 vs. 73 ± 3.11, $p<0.05$) in negative mood state as compared to positive mood state.

**Conclusions:** Increase in sympathetic activity during negative mood state and increase in parasympathetic activity during positive mood state measured by photoplethysmography technique validates this easy and noninvasive mental assessment tool to determine different mood states.

**Keywords**: Heart Rate Variability; Mood States; Photoplethysmography



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## INTRODUCTION

The different mood states in our daily life like depression, anxiety, stress, worry can affect our mental and emotional health. Sadness and anxiety can be considered normal which help us to be alert to protect us from unfavorable conditions and act against it. But, it becomes abnormal when these unpleasant feelings become excessive, illogical, continuing, distressing and interfering in our day to day life.[1] If one is aware that the person is not able to function well as one normally does, this is the time to seek help and diagnose about their mood state of our daily life as it can be managed using different interventions like relaxation, cognitive behavioral therapy and mindfulness.[2] Therefore, it is important to bring into use an easy and reliable mental health assessment tool that assesses the mood states of a person in their daily life.

There are different tools for mental health assessment like recording physiological parameters for detecting the state of autonomic nervous system[3], detecting biochemical stress markers in body fluids[4] and assessment through questionnaire.[5] Out of these,

**Table 1: Anthropometric and cardiac variables of subjects**

| Variables | Mean ± SD |
|---|---|
| **Age, yrs.** | 21.6 ± 3.2 |
| **Height, cm.** | 167.4 ± 2.1 |
| **Weight, kg** | 65.8 ± 4.1 |
| **Body mass index, kg/m²** | 23.5 ± 2.3 |
| **Resting heart rate, beats/min** | 73.4 ± 6.1 |
| **Systolic blood pressure, mmHg** | 116.2 ± 3.4 |
| **Diastolic blood pressure, mmHg** | 74.3 ± 3.2 |

recording of Heart Rate Variability (HRV) as an indicator for the changes in sympathetic and parasympathetic activity of autonomic nervous system is a noninvasive and reliable tool for the changes in mood states.[6] There are different methods of recording of Heart Rate Variability (HRV) like electrocardiography (ECG), a heart-rate chest strap and photoplethysmography (PPG). By traditional method, HRV is recorded through ECG electrode attached on body surfaces and operated by specifically trained individuals. But, the new smartphone-based photoplethysmography technology requires just putting a finger on a camera lens of a smartphone. Photoplethysmography is a new optical technique used to sense volumetric changes of blood in peripheral circulation. It is cost effective and easy to use technique to measure HRV in our daily life without hampering our daily activities. There are ample of literatures that suggest that smartphone use of HRV measurement based on PPG principle is equally accurate and reliable as compared to results derived from a standard ECG method.[7-9] Therefore, the objective of our study was to explore HRV as a marker of emotional changes in our daily life using smartphone based photoplethysmography technique. To our best knowledge till date, this is the first study to establish HRV as a marker of changes in mood state in daily life by using PPG technique.

## MATERIALS AND METHODS

Thirty healthy subjects of age ranging from 18-26 years with informed consents were studied in the Department of Physiology, Birat Medical College and Teaching Hospital, Biratnagar, Nepal. This study was conducted during a period of July, 2018 to August, 2018. Ethical clearance was taken from Institutional Review committee of this study.

**Study Protocol:**

**Experimentally induced changes in mood:**

The study involved showing a series of IAPS (International Affective Picture System) pictures displayed on a laptop screen in front of the subjects. IAPS is a large set of emotionally evocative color photographs that is currently used in experimental investigations of emotion and attention worldwide in psychological and neuroscience research laboratories.[10] These pictures represent a lot of different events that occur in life, some good, some bad and others neutral. Participants were asked to pay close attention to these pictures and think about how they made them feel.

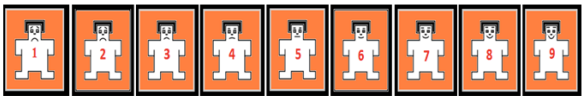


**Figure 1: 0-9 self-assessment scale of different mood states**

IAPS comprises about 1200 pictures each with a quantitative rating of its effect on the mood and categorized into positive, negative or neutral. We selected 36 pictures each for positive, neutral and negative mood condition. In each set of mood state consisting of 36 pictures, each pictures displayed for 5 seconds before the appearance of next picture. Thus, it took 3 minute for displaying 36 pictures of each mood category during which heart rate variability was measured.

**Assessment of Mood**

In this session, the subjects were asked to rate about how the pictures made them feel- unhappy, neutral or happy. A 0-9 self-assessment scale which ranges from a frown to a smile was used for the assessment of mood states. One extreme of the scale represented unhappy, annoyed, unsatisfied, melancholic, bored. If viewing the picture makes subject feel completely unhappy, subject was asked to indicate this by selecting the figure on the left i.e. 1. The other end of this scale represented happy, pleased, satisfied, contented, and hopeful. If viewing the pictures makes subject feel completely happy, subject was asked to indicate this by selecting the figure on the right i.e. 9. The other figures in between allowed the subjects to indicate intermediate feelings of pleasure. If subject felt completely neutral i.e. neither happy nor unhappy, subject was asked to select the figure in the middle i.e. 5. (Fig. 1)

**Heart Rate Variability (HRV) Measurement:**

Short-term analysis of HRV was undertaken for 3 minutes while viewing three different series of pictures i.e. neutral, positive and negative on three different days. Continuous instantaneous heart rates were measured for 3 minutes while viewing three different series of affective pictures i.e. neutral, positive and negative set of pictures by using aneroid app "Heart Rate Variability by Camera" developed by ECG for Everyone which working principle is based on photoplethysmography(PPG). Photoplethysmography is a noninvasive, reliable and easy to use tool for measuring Heart rate variability which is a quantitative marker of autonomic nervous system that is used to assess cardiac health and other physiological conditions.

**Experimental Protocol:**

As a pre-recording procedure, the subjects were screened for selection based on the inclusion and exclusion criteria. For this, a standard questionnaire of the American Heart Association/ American College of Sports Medicine Health/Fitness Facility Pre-participation Screening Questionnaire was taken into consideration.[11] Informed written consents were taken from the subjects. They were screened for any history of disorders that are likely to affect respiratory function and heart rate variability parameters on the basis of physical examinations. Also, different anthropometric and cardiac parameters like age, weight, BMI, resting heart rate and blood pressure of subjects were recorded.

**Table 2: Comparison of ratings of self-assessment scale for positive, neutral and negative mood states**

| Variable | Neutral pictures (Mean ± SD) | Negative pictures (Mean ± SD) | Positive pictures (Mean ± SD) | p1 (Neutral vs Negative pictures) | p2 (Negative vs Positive pictures) | p3 (Neutral vs Positive pictures) |
|---|---|---|---|---|---|---|
| Mood (Happy vs. Unhappy) | 5.0 ± 0.0 | 2.8 ± 1.6 | 8.2 ± 1.4 | <0.01 | <0.01 | <0.01 |

**Table 3: Heart Rate Variability (HRV) parameters between different mood states**

| Variable | Neutral mood (Mean ± SD) | Negative mood (Mean ± SD) | Positive mood (Mean ± SD) | p1 (Neutral vs Negative mood) | p2 (Negative vs Positive mood) | p3 (Neutral vs Positive mood |
|---|---|---|---|---|---|---|
| Heart Rate | 72 ± 4.43 | 78 ± 2.99 | 73 ± 3.11 | <0.05 | <0.05 | NS |
| SDNN | 29 ± 3.7 | 27 ± 4.6 | 28 ± 5.2 | NS | NS | NS |
| RMSSD | 30 ± 3.45 | 29 ± 2.9 | 29 ± 1.8 | NS | NS | NS |
| LF | 188.9 ±3.5 | 200.3 ±4.1 | 166.7 ±2.8 | <0.05 | <0.05 | <0.05 |
| HF | 185.6 ± 4.8 | 157.9 ± 3.9 | 264.3 ± 5.3 | <0.05 | <0.05 | <0.05 |
| LF/HF | 1.0 ±0.2 | 1.45 ± 0.21 | 0.55 ± 0.07 | <0.05 | <0.05 | <0.05 |
| LF (nu) | 50.2 ± 3.6 | 55.8 ± 2.9 | 38.6 ± 2.8 | <0.05 | <0.05 | <0.05 |
| HF (nu) | 49.7 ± 3.1 | 44 ± 2.9 | 61.2 ±4.2 | <0.05 | <0.05 | <0.05 |

The three sets of pictures categorized into positive, negative and neutral groups were shown to subjects on 3 different consecutive days (i.e. set of neutral pictures on first day, set of positive pictures on second day and set of negative pictures on third day) with simultaneously recording of heart rate variability (HRV) for three minutes. Immediately after recording on each day, 0-9 self-assessment scale was used to assess the mood state of the subject after viewing the set of pictures.

**Statistical Methods**

The data obtained were parametric in distribution so, paired t-test was applied for test of significance. P value less than 0.05 was considered significant.

## RESULTS

All the subjects had normal blood pressure and body mass index. Mean age of the study population was 21.6 years. Anthropometric and cardiac findings of the study population is shown in table 1.

**Assessment of Mood**

As shown in Table 2, the ratings of 0-9 Self-Assessment scale for positive, neutral and negative mood state shows significant increase in positive picture series as compared to neutral picture series and significant decrease in negative picture series as compared to neutral picture series. This states that the subject was in happy mood while viewing positive picture series, unhappy mood while viewing negative picture series and neutral mood while viewing neutral picture series.

**Heart Rate Variability (HRV) parameters between different mood states**

As shown in table 3, sympathetic domains of HRV like LF, LF/HF ratio and LF (nu) significantly increased in negative mood state condition as compared to neutral and positive mood state condition. Likewise, parasympathetic domains of HRV like HF and HF (nu) significantly increased in positive mood state condition as compared to negative and neutral mood state condition. Similarly, there was significant increase in heart rate in negative mood state as compared to positive mood state.

## DISCUSSION

In response to the affective pictures, the mood state of the subject was successfully modulated by parallel viewing of affective picture series i.e. neutral, positive and negative. There was significantly greater experience of pleasantness with parallel positive picture viewing compared to with that of parallel, neutral and negative picture viewing; significantly least experience of pleasantness with parallel negative picture viewing compared to neutral and positive picture viewing and significantly neutral pleasantness with parallel neutral picture viewing compared to positive and negative picture viewing. These findings resembles with results reported in many previous studies using Affective International Affective Picture System (IAPS) picture series in various experimental contexts.[12,13]

Likewise, increase in heart rate in negative mood state was seen as compared to neutral and positive mood state. A similar study by Schwerdtfeger et al.[14] revealed that depression lead to higher heart rate all over the day. Similarly, a study by Dobkin and Pihl et al.[15] showed that the heart rate of healthy subjects is higher during stressed then when subject is not stressed during daily life. According to them, anxiety was the reason behind heart rate elevation. Also, a study by Langewitz et al.[16] demonstrated that that stress in subject is significantly associated with increase heart rate in normal subjects.

Likewise, in our present study, sympathetic domains of HRV like LF, LF/HF ratio and LF (nu) significantly increased during stressed state while parasympathetic domain of HRV like HF and HF (nu) significantly increased during relaxed or peaceful emotional state. Similar to our present study, Sloan et al.[17] revealed that the LF/HF ratio is significantly correlated with negative mood state (irritable, anxious, stressed, and unhappy) during daily life in normal individuals. Also, a study by Yoshino and Matsuoka[18] demonstrated that during misery and anxiety in daily life, there is shift of autonomic function toward sympathetic dominance.

This study is not devoid of limitations. We have excluded the effect of circadian rhythm on mood states and heart rate variability on different three consecutive days. Also, besides using photoplethysmography technique, standardized ECG method of HRV recording would have been run simultaneously to increase the reliability and accuracy of HRV measurement than just relying on the results of the previous studies.

## CONCLUSIONS

The result suggests that there is increase in sympathetic domains of HRV in positive mood states while increase in parasympathetic domains of HRV in negative mood state using photoplethysmography technique. Thus, an easy to use, reliable and noninvasive smartphone based photoplethysmography technique can be used for HRV measurement to keep record of potential changes in mood states in our daily life as a low-cost healthcare application.

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