Submission No.:C000012
Artificial Intelligence

Estimation of Office Worker's Emotions Using Wearable Bio...
Emotion, Wearable sensor, Pulse wave, Job stress, Workplace

ISASE 2020

Estimation of Office Worker's Emotions Using Wearable Biometric Sensor

Junichiro HAYANO*, Tetsuya TANABIKI**, Shinichiro IWATA**, Katsumi ABE** and Emi YUDA***

Nagoya City University Graduate School of Medical Sciences, 1 Kawasumi Mizuho-cho, Mizuho-ku, Nagoya 467-8602, Japan
hayano@acm.org
** Monodukuri Solutions Center*, Services and Technologies, NEC Co., Tokyo, Japan*
t-tanabiki@bp.jp.nec.com   s-iwata@bp.jp.nec.com   k-abe@bp.jp.nec.com
*** Tohoku University Graduate School of Engineering, 6-6-05 Aoba Aramaki, Aoba-ku, Sendai, 980-8759, Japan*
yuda@ieee.org

Abstract: We developed a model that estimates the emotions of office workers using information obtained by wearable biometric sensors. In 11 healthy office workers, pulse rate, pulse rate variability (PRV), skin temperature, body motion, and conversation time were continuously monitored between 08:30 and 21:30 on every workday using a bracelet-shape wearable sensor. During the monitoring, subjects recorded four strongly conscious emotions (happy, relaxed, sad, and angry) every 30 min. Based on the Russel's Circumplex emotion model, four emotion types were developed into coordinates consisting of arousal and valence axes. The linear models were developed for estimating the value of each axis using the biometric information. From a total of 911 days of records in the 11 subjects, a total of 9,737 hours of data were obtained. By stepwise regression analyses, the coefficient of variation of high-frequency PRV amplitude and skin temperature were extracted as the best variable combination explaining the valence axis, and the frequency variability of PRV respiratory peak and conversation time were extracted for the arousal axis. The models discriminated between high valence (happy and relaxed) and low valence (angry and sad) states with an AUC of receiver-operating characteristic curve of 0.64 ($P = 0.0001$) and discriminated between high arousal (happy and angry) and low arousal (relaxed and sad) states with an AUC of 0.61 ($P = 0.001$). Our findings suggest that information related to two coordinates comprising the Russel's Circumplex model could be obtained by wearable biometric sensors, helping the estimation of emotion type of office workers.
Keywords: *Emotion, Wearable sensor, Pulse wave, Job stress, Workplace*

1. INTRODUCTION

The development of technology for estimating the emotions of workers using objective biometric indicators is expected to provide useful information for improving work efficiency and safety, preventing job separation due to work stress, and managing occupational health. We have been working on a project to estimate the emotions of office workers from by wearable biometric sensors [1, 2]. In a previous study in five subjects [1], we found that the type of emotion can be developed into two coordinates consisting of the biometric information and that the coordinates reflect the levels of arousal and valence of the Russel's Circumplex model of emotion [3]. However, the sample size was small (n = 5), total monitoring period was 173 days, and only 161 out of 388 records of emotion were able to be analyzed.

The present study was performed to confirm the previous findings. We increased subjects and monitoring period. Furthermore, we added new indices reflecting the stability of respiratory frequency which may change with emotional states. We also adopted a new method that directly estimates arousal and valence axis values based on the Russel's Circumplex model.

2. METHODS

2.1 Subjects

Subjects were 11 healthy office workers (one female) in a company. The protocol of this study has been approved by the Ethics Review Committee of Nagoya City University Graduate School of Medical Sciences and Nagoya City University Hospital (No. 60-18-0211).

2.2 Protocols

Subjects wore a bracelet-type pulse wave sensor (Silmee W20, TDK Co., Japan) between 08:30 and 21:30 every day except holidays. The device also equipped with built-in sensors for reflection plethysmograph, acceleration, temperature, ultraviolet light, and sound. It

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detected continuously beat-to-beat pulse intervals (PI), physical activity (level and kind), skin temperature, environmental ultraviolet, and the periods of conversation and sleep. During the measurement, subjects were instructed to record the labels of strongly conscious emotions (happy, angry, relaxed, and sad) every 30 min when feeling strong emotions.

2.3 Data Analysis

From beat-to-beat PI data, the frequencies and amplitudes of very-low frequency (VLF, 0.0033-0.04 Hz), low-frequency (LF, 0.04-0.15 Hz), and high-frequency (HF, 0.04-0.45 Hz) components of pulse rate variability (PRV) were measured by the method of complex demodulation [4, 5]. The PRV measures were averaged over every 30 min synchronized with the time frame of emotion label and the coefficient of variance (CV) of VLF, LF, and HF amplitudes (VLFcv, LFcv, and HFcv) were calculated for the same time frame. To estimate the respiratory frequency instability, PRV power spectra were calculated for 5-min windows shifting with a step of 1 min. The frequency of the highest spectral peak between 0.15 and 0.45 Hz was determined in each spectrum and were moving-averaged with 5-min window width (5 data points). The percent deviations of original respiratory frequency from the moving average were calculated with 1 min interval as fvRSA.

2.3 Statistical Analysis

The emotion types were converted into x and y coordinates putatively reflecting valence and arousal, respectively, i.e., happy, angry, relaxed, sad, and no-label (control) as (1, 1), (−1, 1), (1, −1), (−1, −1), and (0, 0), respectively. Then, biometric variables that explained x and y coordinates were extracted by regression. The performance of regression models to discriminate between high and low valence (happy-relaxed vs angry-sad) and between (high and low arousal (happy-angry vs relaxed-sad) were evaluated by receiver-operation characteristic (ROC) curves.

3. RESULTS

3.1 Associations between emotion type and biometric indices

From a total of 911 days of records in the 11 subjects, a total of 9,737 hours of data were obtained. During the monitoring, a total of 954 self-reported emotion labels were obtained, 470 of which were obtained with simultaneous recording of PI analyzable for PWV.

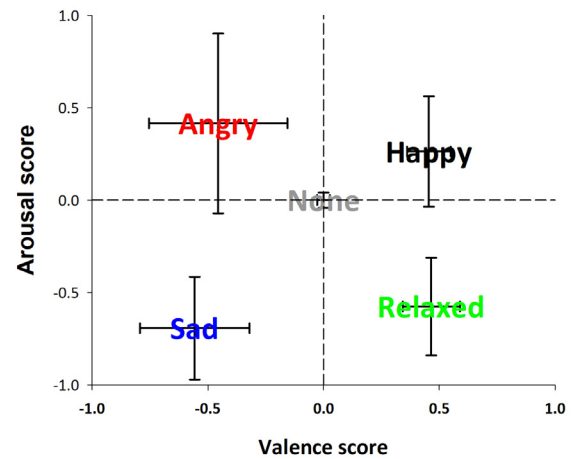Univariate analysis showed that HF amplitude and

Figure 1. Development of emotion labels on four quadrants consisting of the valence and arousal axes composed of these biometric signals.

HFcv increased with angry and sad. LF/HF increased with relaxed. Anger tended to associate with an increase in fvRSA. Skin temperature increased with happy and relaxed and decreased with angry and sad. Conversation time was longer when reported as happy and angry than when reported as relax and sad.

3.2 Biometric indices explaining valence and arousal axes

By stepwise regression analyses, HFcv and skin temperature were extracted as the best variable combination explaining the valence axis values and fvRSA and conversation time were extracted as the best variable combination explaining the arousal axis values. The ROC curve revealed that the models discriminated between high valence (happy and relaxed) and low valence (angry and sad) with an AUC of 0.64 ($P = 0.0001$) and between high arousal (happy and angry) and low arousal (relaxed and sad) with an AUC of 0.61 ($P = 0.001$). Figure 1 shows the distributions (means and standard errors) of valence and arousal axes values calculated from these regression models for each emotion type.

4. DISCUSSIONS

We developed a model that estimates the emotions of office workers using information obtained by wearable biometric sensors. HFcv was associated with the valence axis and of fvRSA with the arousal axis. HFcv may reflect intermittent wrist movements and fvRSA reflect the

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instability of respiratory frequency. Because the respiratory frequency is stabilized during NREM sleep [7], it seems reasonable that fvRSA increased with arousal level.

This study has limitations. As expected, the valence and arousal axis values estimated by biometric signals showed significant discriminant power between happy-relaxed and anger-sad and between happy-ager and relaxed-sad, respectively. However, the discriminant accuracy for the classification of four emotion types was modest. Further refinements of the model are needed in the future studies. Additionally, this study was performed in office workers working mostly indoor. Although skin temperature and conversation time were extracted as explanatory variables of valence and arousal, respectively, these signals could not be used in hot or cold environments or in other workplace where conversation is restricted. On the other hand, the results of this research may have broad utility beyond the originally intended purpose. This research project has been implemented to be used for workers' emotion estimation to improve work efficiency and safety, prevent work separation due to work stress, and manage occupational health. With the rapid penetration of artificial intelligence into everyday life and the workplace, however, the ability to infer human emotions would become an important component of the ability of machines to properly communicate with humans.

5. CONCLUSIONS

Our findings suggest that information related to two coordinates comprising the Russel's Circumplex model could be obtained by wearable biometric sensors, helping the estimation of emotion type of office workers.

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