Abstract

Towards Precision Stress Management: Design and Evaluation of a Practical Wearable Sensing System for Monitoring Everyday Stress

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Abstract

Background: Overstress is becoming an epidemic issue in modern society, contributing to a broad range of health problems ranging from depression to cardiovascular diseases. According to a 2015 national survey by American Psychological Association, 75% of Americans reported experiencing at least one symptom of stress in the past month, such as anxiety and headaches. Despite the growing evidence of the negative impact of stress, there is still a lack of practical tools that can unobtrusively gauge and manage people's day-to-day stress.

Objective: Our study aims to design, develop, and evaluate a practical wearable sensing system that can continuously and reliably infer the wearer's stress level through analyzing passively obtained bio-signals. Such a system can potentially offer individuals timely awareness of stress and personalized interventions for reducing stress.

Methods: We investigated the feasibility of using biomarkers based on heart rate variability (HRV) to infer stress. To this end, we developed algorithms that process signals from photoplethysmography (PPG) sensors (Empatica E4 wristband1) to extract an HRV-based biomarker that is indicative of stress. We then investigated the correlation between each subject's self-reported stress and the biomarker by conducting controlled, in-lab experiments designed to put subjects through structured periods of relaxation and stress. We also conducted in-field experiments to identify and deal with the practical challenges associated with measuring stress in real-life situations, such as unpredictable data quality due to motion artifacts. To evaluate the system's in-field performance, we compared the system's stress output and the self-reported stress associated with a particular daily event.

Results: A total of 17 subjects were recruited for the initial data collection. We collected more than 300 hours of data that contains activities such as working, giving a presentation, driving, doing cognitive challenges, etc. Of the activities tracked, 146 were annotated by the subjects with associated stress information (eg, "8-8:30 am, driving to work, feeling stressed about being late" and "3-4pm, attending a seminar, not stressed"). We found that the subjects are more likely to report stressful activities (114 reported) than non-stressful activities (32 reported). Compared with the reported stress information, results from the system achieve a sensitivity of 92.1% (105/114) and a specificity of 50.0% (16/32).

Conclusions: Our results suggest that the developed system can offer a reliable proxy of stress, and therefore has potential in serving as a convenient tool for gauging and understanding daily stress dynamics. The relatively high false positive rate results in a 50% specificity, which was mainly caused by interferences from subjects' physical activities. The specificity can be further improved by mitigating the impact of such interferences—for example, by taking other biomarkers and contextual information into account. In future studies, we will also explore methods of leveraging the system's continuous stress level output to generate timely notifications and personalized recommendations.

(iproc 2017;3(1):e15) doi:10.2196/iproc.8441

KEYWORDS

mobile health (mHealth); stress; wearables

Multimedia Appendix 1

Full poster.

[PDF File (Adobe PDF File), 3MB - iproc_v3i1e15_app1.pdf]

Edited by T Hale; This is a non-peer-reviewed article.submitted 13.07.17; accepted 25.08.17; published 22. 09.17

Please cite as:
Hao T, Rogers J, Chang HY, Ball M, Walter K, Sun S, Chen CH, Zhu X
Towards Precision Stress Management: Design and Evaluation of a Practical Wearable Sensing System for Monitoring Everyday Stress
iproc 2017;3(1):e15
URL: http://www.iproc.org/2017/1/e15/
doi:10.2196/iproc.8441
PMID: