2021 43rd Annual International Conference of the
IEEE Engineering in Medicine & Biology Society (EMBC)
Oct 31 - Nov 4, 2021. Virtual Conference

Evaluation of Robust HRV Analysis against Motion Artifacts for Wrist-worn PPG Device

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Abstract—**Heart rate variability (HRV) analysis in wristband PPG device is gathering interest for emotion related and well-being application; however, motion artifact is critical issue. We verified robust framework against motion artifacts for detecting HRV by motion-tolerant instant heart rate (IHR) detection algorithm [1]. The results suggested high correlation between HRV calculated from PPG by our method and HRV calculated from ECG, and the improvement in stress/resting classification in PPG even when motion artifact occurred.**

I. Introduction

Wearable heart rate monitors such as wrist-worn devices are increasing expectations for stress coping and well-being application in daily life. However, most of the commercially available heart rate monitors can only detect the average heart rate (HR) due to motion artifact issue, and there is a limitation in analyzing HRV. A previous study [2] showed possibility of HRV by PPG as alternative of HRV by ECG but limited to the resting state. Another study [3] proposed a robust HRV index for PPG to motion artifacts, which made progress in terms of evaluating it in cases with sleep and the trier social stress test (TSST) tasks, but only compared the HRV index based on SDNN. Therefore, we introduced a robust IHR detection against motion artifacts for PPG device [1] and verified its effect of HRV detection during TSST task in terms of both traditional HRV analysis and data-driven evaluation by DNN.

II. Methods

Healthy human participants (N = 41) conducted a baseline task in resting for 10 minutes, TSST for 10 minutes, and a recovery task for 10 minutes, respectively. The TSST task was conducted to naturally induce participant's high arousal state with motion behavior. In the TSST task, the participant was prompted to start a 5-minute presentation like job interview in front of two interviewers, and was asked to count from 2023 to zero, subtracting 17, as fast and as accurately as possible. Upon each mistake, the participant was interrupted and prompted to start over with providing no social feedback. PPG measurements were recorded with an Empatica E4 wristband attached to the participant's non-dominant hand. Shimmer3 ECG was attached to the participant's chest for reference IHR measurement. Our proposed method [1], robust IHR detection against motion artifacts with integration of adaptive filtering by IMU signals and bandpass filtering in response to heart rate trend to minimize noise signals and pulse periodicity detection by autocorrelation analysis, was applied to pulse wave (BVP.csv) from E4. As the baseline for heart rate measurement with the E4 device, we used HR.csv (HR in 1Hz) because IBI.csv contained a lot of missing samples. To verify the effect of our framework, we evaluated ultra-short term HRV (Mean Heart Rate, HF, pNN50) with 90-s sliding windows for ECG IHR, E4 HR, and our proposed method. Furthermore, we evaluated classification performance by 1-D CNN in Fig.2 (A) to investigate how much informative information each method included by a data-driven approach.

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III. Results & Conclusion

As shown in Fig.1, there is high correlation in changes of HR and HRV between ECG IHR and our proposed method, while E4 HR did not include HRV information. As shown in Fig. 2 (B), the classification performance of the proposed method was significantly higher than that of E4 HR, especially in TSST-recovery classification ($p < 0.05$), while there is no statistical difference between ECG IHR and our proposed method. These results suggested the robustness of our proposed method against motion artifact in detecting HRV in terms of both traditional method and data-driven evaluation.

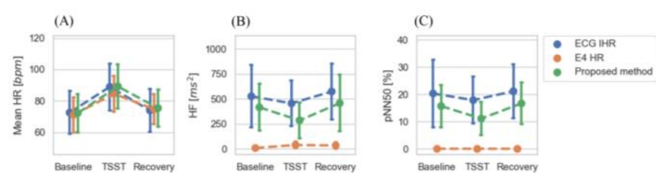

Figure 1. Changes of HR and HRV indices among baseline, TSST, and recovery tasks. (A) Mean Heart Rate, (B) HF, and (C) pNN50

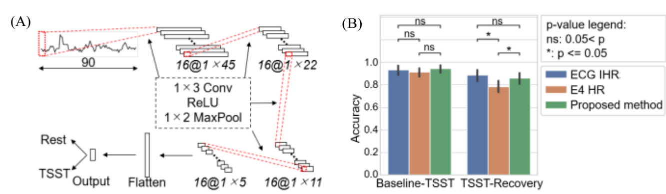

Figure 2. Clasiffication by 1-D CNN. (A) the network architecture (B) accuracy for each method by leave-one-person-out cross validation.

References

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