PPG Signal Morphology-Based Stress Assessment

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Aim. Stress is a healthy natural response to a perceived or actual threat. However, when stress is persistent, it decreases work productivity, increases the risk of diseases, and affects the quality of life. Stress is reflected in physiological variables such as blood pressure, velocity of forward and reflected pulse waves related to vessel stiffness, and heart rate, among others. This study analyses parameters derived from PPG signal morphology for mental stress assessment.

Methods. A low-complexity algorithm is designed using the filtered second derivative of the PPG signal for estimation of three wave amplitudes $A_1$, $A_2$, and $A_3$ (located at $T_1$, $T_2$, and $T_3$, respectively), related to the forward pulse $P_1$ and the reflections $P_2$ and $P_3$ from the renal and iliac sites in the central arteries, respectively. The time delay $T_{12}$ between $P_1$ and $P_2$, and $T_{13}$ between $P_1$ and $P_3$ are analyzed as surrogates of instantaneous vessel stiffness. Additional parameters are studied including the amplitude $A_1$ and delay $T_1$ related to systole, the diastolic interval $T_d$ estimated from dicrotic notch until the end of the pulse, and the pulse duration $T_p$. The data (11 subjects) contain a baseline (BL) and five different stages with induced stress: storytelling (ST), memory task (MT), stress anticipation (SA), a video display (VD), and arithmetic task (AT).

Results. The most significant differences between BL and the stress stages are found for $A_1$ and $T_1$, where lower values are related to sympathetic activation, while $T_d$ shows better performance than $T_{12}$, $T_{13}$, and $T_p$.

Conclusion. The analyzed PPG signal morphological parameters are related to stress-induced sympathetic activation, thus offering the potential to be used in wearable devices for unobtrusive monitoring and management of occupational stress, and prevention of cardiovascular diseases.

Boxplots of the parameters: (a) amplitude $A_1$ of $P_1$, (b) time delay between $P_1$ and $P_2$, (c) time delay between $P_1$ and $P_3$, (d) time delay $T_1$ of $P_1$, (e) duration of diastole $T_d$, (f) pulse-to-pulse interval $T_p$. Significant differences relative to BL are marked with * ($p < 0.05$) and ** ($p < 0.001$).