Non-contact Measurement of Respiration Rate With Camera-based Photoplethysmography During Rest and Mental Stress

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Introduction: Respiration rate is an important parameter to comprehend the human state, e.g. in heart rate variability analysis. Camera-based photoplethysmography, a non-contact monitoring technique, allows the parallel assessment of heart rate, heart rate variability, and respiration rate. This work addresses non-contact respiration rate measurement during rest and mental stress and, for the first time, systematically investigates the influence of the combination of color channels provided by RGB videos.

Methods: Data from 55 healthy participants of a stress study (Mannheim Multicomponent Stress Test) provided synchronized chest expansion signals (reference), earlobe photoplethysmograms, and RGB video recordings with a total duration of more than 40 hours. From the video recordings, we extracted photoplethysmograms for the red, green, and blue channel to perform a hemispherical surface grid search on their linear combinations. All signals were split into 10 s segments, band-pass filtered in the range of 0.167 Hz to 0.5 Hz to gain respiratory signals and transformed to the frequency domain to extract respiration rates from the highest peak in the respective amplitude spectrum. We evaluated the photoplethysmographic measurements with the mean absolute error (MAE_{RR}) and the median signal-to-noise ratio (SNR_{resp}).

Results: The earlobe photoplethysmogram yielded MAE_{RR} = 4.46/min and SNR_{resp} = -1.33 dB. The systematic grid search for the camera-based measurements showed monotonic progression with the minimum MAE_{RR} of 3.16/min (SNR_{resp} = -0.70 dB) close to the green channel. Thus, the optimal color channel combinations for measuring heart rate and respiration rate differed. Lower SNR_{resp} indicated larger errors, which mainly resulted from dominant low-frequent influences. Respiration rates from the reference and both photoplethysmograms differed highly significantly between rest and stress states ($p < 0.001$, Mann-Whitney U-test).

Conclusion: The optimized color channel combination increases the measurement quality. Camera-based photoplethysmography appears suitable for respiration rate measurement to comprehend human states or pathophysiological processes.