Novel Wrist-worn Device for Sleep Analysis

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Aiming at improving the comfort of subjects undergoing sleep analysis studies, a novel optical sensor worn at the wrist is presented. In collaboration with CHUV – University Hospital of Lausanne, a polysomnographic survey involving 26 patients was performed. Accordingly, the novel sensor provided estimates of heart beat-to-beat intervals in agreement of those measured by an electrocardiogram.

Sleep is a critical determinant of health and well-being. While the incidence of sleep disorders is continuously increasing in modern societies, there is a clear demand for technologies to assess sleep-related parameters under ambulatory conditions. The gold-standard for sleep analysis is polysomnography [1]. Unfortunately, a complete polysomnographic measurement setup is nowadays too obtrusive and, therefore, not suitable for long-term analysis of night-sleep (Figure 1).

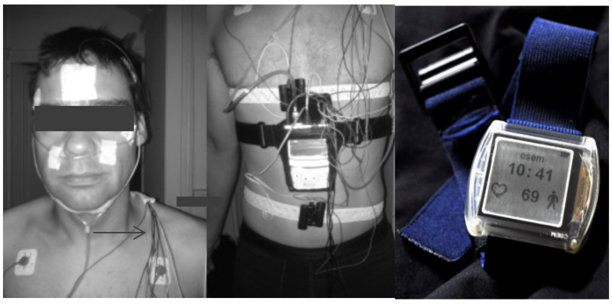

Figure 1: A complete setup for polysomnographic studies (left) and in comparison a CSEM wrist worn sleep analysis device (right)

The analysis of the variability of heart beat-to-beat intervals (RR) in time and frequency domains (HRV) provides non-invasive information about the control of the autonomic nervous system (ANS) [2]. This control is directly related to different events occurring during night-sleep such as sleep stages, arousals and sleep fragmentation [3]. The current research at CSEM aims at assessing whether a CSEM patented wrist pulse monitor (Figure 2) is capable of providing RR interval estimates that are accurate enough to be further used in the estimation of HRV during night. Achieving this goal would represent a first step in the development of a revolutionary unobtrusive system for night monitoring. Note that the optical monitoring technology was originally developed by CSEM for the strapless estimation of heart-rate at the wrist during physical activities. The technology is based on the so-called Photo-Plethysmographic (PPG) technique.

In 2012, CSEM included its novel wrist monitoring device in a study conducted in La Paz (Bolivia) by the University Hospital of Lausanne (CHUV). In total 26 subjects participated in the study (age: 48.1±14.4, BMI: 28.3±5.2, Indian). Data was recorded during the entire night without interfering with subjects. A total of 13'991 minutes of data was recorded, containing a total number of 932'948 heart beats. The RR intervals extracted from a reference electrocardiogram (ECG) signal and from the optical signals of the wrist device (PPG) where aligned and their differences were analyzed. Figure 2 illustrates 100 consecutive heart-beats, as extracted from the reference ECG device and the novel PPG wrist monitor.

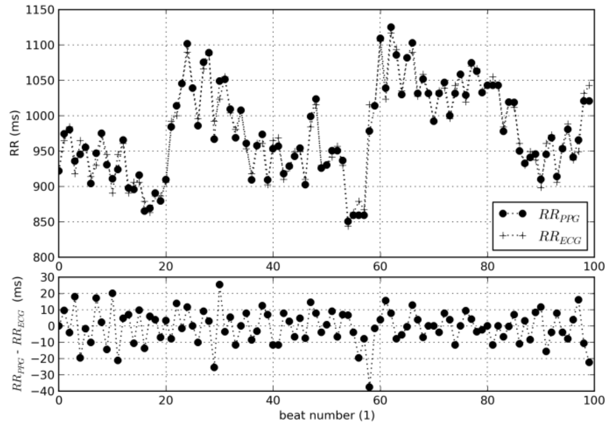

Figure 2: Illustrative example showing 100 heart beats of reference RR intervals (RR_{ECG}), and the associated RR intervals as estimated by the wrist device (RR_{PPG}). Lower plot depicts the instantaneous difference between synchronous RR intervals

The overall average error when comparing RR_{ECG} and RR_{PPG} was of 0.05 ± 17.96 ms. While a standard deviation of ± 10 ms is justified by the different PPG and ECG sampling frequencies, the remaining ± 8 ms is due to intrinsic PPG-ECG methodological differences. An early analysis has shown that the reported small differences do not significantly degrade HRV indicators: an additional on-going study is validating this finding.

The resulting RR intervals validate the usability of a wrist worn device to perform heart rate variability analysis during the night. Even more, the fact that good agreement is obtained even under cardiovascular stress conditions, induced by chronic exposure to high altitude, indicates that the novel wrist device approach is robust against non-stationary cardiovascular states. The use of a comfortable, non-obtrusive monitoring device might in the future provide novel insights into cardiovascular regulation mechanisms occurring during sleep.

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