Analysis of U-shape Patterns in RR-interval Time Series during Sleep

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Purpose: In recent years, sleep assessment has gained momentum in clinical practice, with studies showing that sleep deprivation can lead to negative physiological effects such as myocardial hypertrophy, cognitive impairment and hypertension. Although numerous studies have been performed in the context of sleep analysis, ECG-based sleep analyses have relatively received less attention. The proposed study investigates a phenomenon, defined as "U-patterns", that takes place in the RR-interval time series during sleep. These patterns are defined as a U-shaped decrease-increase in the RR-intervals, with a duration of 20 to 40 seconds with a minimum decrease of 15% in the local RR-interval mean value. This paper studies statistical characteristics of U-patterns on subjects undergoing sleep deprivation.

Methods: 15 healthy subjects (7males, 22.1 ± 1.7 yrs.) participated in an experiment over a span of 17 days, in three immediate stages. A baseline phase lasting for seven days, during which the subjects slept normally; A sleep deprivation phase with a duration of three days, during which they could only sleep three hours at night; Finally, in a 7-day recovery phase subject went back to sleeping normally, as they would in the baseline phase. While sleeping, polysomnographic data was recorded from the participants.

U-patterns were extracted using a non-linear filtering technique [1], U-patterns were extracted for and statistical characteristics. Alongside the incidence of these patterns, their depth, duration and area were measured.

Results: U-patterns were present in all participating subjects. Moreover, U-patterns are recurrent within the RR-intervals. There is a significant difference in their frequency, depth and duration from baseline to sleep-deprivation and recovery. Table 1 reports detailed statistical characteristics of U-patterns.

Conclusions: Our preliminary results suggest that the characteristics of U-patterns change when subjects are undergoing sleep deprivation, suggesting these patterns can be used to identify patients suffering from sleep deprivation.

Table 1 - Average quality indexes obtained by the proposed method.

Attribute	Baseline ($mean \pm std$)	Sleep Deprivation ($mean \pm std$)	Recovery ($mean \pm std$)
No. of U-patterns	34.1 ± 10.0 $*,°$	30.6 ± 12.5 †	30.7 ± 12.2
U-pattern Frequency (mHz)	1.4 ± 0.4 $*,°$	1.1 ± 0.5 †	1.3 ± 0.4
U-pattern Duration (s)	29.0 ± 3.2 °	28.4 ± 2.4	28.0 ± 2.4
U-pattern Depth (ms)	292.5 ± 99.7°	268.9 ± 45.1	284.1 ± 60.3
U-pattern Integral (ms.s)	4116 ± 117 $*,°$	3700 ± 478	3911 ± 759

$*$ $\mathbf{p < 0.5}$ **baseline** $\rightarrow$ **slp.dep.** ° $\mathbf{p < 0.5}$ **baseline** $\rightarrow$ **recovery** † $\mathbf{p < 0.5}$ **slp.dep.** $\rightarrow$ **recovery**

[1] S. Yazdani, S. Fallet, and J-M. Vesin. A novel short-term event extraction algorithm for biomedical signals. *IEEE Trans Biomed Eng* 2018;65(4):754:762.