Connected heart rate sensors to monitor sleep quality

Electrodes, Chestbelt and smartwatch users acceptability

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***Abstract*—12 participants wore 3 different heart rate sensors during sleep. They consult the respective reports and filled a questionnaire to help us to identify which one is the most acceptable connected device to monitor sleep.**

Keywords—sleep, heart rate sensor, acceptability

I. Introduction

The "PREventive Care Infrastructure based On Ubiquitous Sensing" (PRECIOUS)[1] project aims to improve motivation to healthy life by providing the end-users with a lifestyle dashboard. The system collects information about the user from a variety of connected devices that measure food intake, physical activity, stress level and sleep quality.

"Sleep is a basic human need and is essential for good health, good quality of life and performing well during the day." [1]. The National Health and Nutrition Examination Survey (NHANES) has shown that 30% of adults reported an average inferior to 6 hours of sleep per night [2]. Although too short sleep time issue is well-known, few people are aware about the fluctuations of the recovery quality during sleep. However, today this precious information can easily be available and consulted thanks to new connected heart rate (HR) sensors.

In this study we investigated whether the connected HR sensors are suitable to sleep with. More precisely we addressed the following issue: "Which of the electrodes, chestbelt and smartwatch is the most acceptable device to monitor sleep quality?"

II. Connected heart rate sensors

HR data is fundamental to produce a relevant interpretation about sleep recovery [3]. HR variability (HRV) gives an insight about the sympathetic (activation) and parasympathetic (recovery) activities of the autonomic nervous system during sleep. There are three main types of connected HR sensors devices on the market at the moment.

Devices collecting ECG *via* electrodes (e.g. Firstbeat Bodyguard 2) are very accurate [4] and capable of collecting very long measurements regarding both the amount and accuracy of the data and the battery life.

Devices collecting ECG *via* chestbelt (*e.g.* Suunto smart sensor chestbelt) are designed to give information about and during exercise. However it could be wear for extended periods as during the night. The data quality is typically good, except when the belt slips from the right position.

Devices collecting PPG are optical sensors (*e.g.* PulseOn). They measure HR by illuminating the blood vessels on a person's wrist with a LED in order to track blood flow. The measurement accuracy declines when a person is in motion, and it is not very precise, generally speaking, because blood flow does not provide a distinct "peak" similar to an electrical signal originating from the heart [5]. Optical sensors is thus less accurate than ECG-level devices. In addition, since the battery life is around 8 hours, depending on the user current HR, it can be a problem to monitor the complete night. The optical devices however could be the most comfortable for the user during the night.

These three devices allow to collect HR. It is then possible to analyze HRV and provide the user with a report about his recovery during sleeping.

III. Analytics and reports

Data collection is essential but not sufficient. Indeed analytics algorithms lead to filter data and permit to get rid of inconsistent signals.

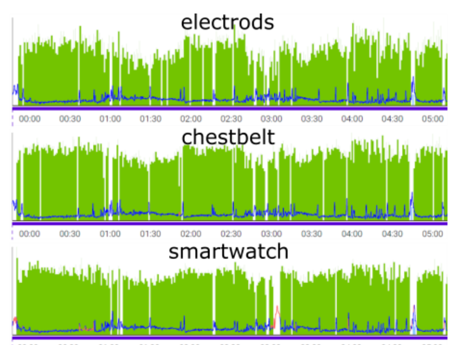

Figure 1: HR (blue line) and HRV (green area) from electrodes, chestbelt and smartwatch wear during the same night.

[1] http://www.thepreciousproject.eu/

To perform a quick test of the data reliability, one participant wore electrodes, chestbelt and smartwatch during the same night. After treatment, the electrodes report revealed 48ms of HRV and 88% of recovery during the time of sleep, the chestbelt report 87% and 48ms and the smartwatch 88% and 51ms. These reports took great advantage of the data filtering since the HRV from the raw data of the smartwatch was the inconsistent value of 174ms. The HRV from the raw data of the electrodes was the plausible value of 51ms. However our main concern did not focus on objective data reliability but on participants subjective perceptions.

IV. Acceptability

An appropriate device is a device that the user would accept to wear. Thus, we aim to assess the acceptability of the different types of devices. Technology Acceptance Model has been used extensively in research that looks at the acceptance of new technology [6]. The main idea of this model is that a device is acceptable depending on the relation between the "perceived usefulness" and the "perceived ease of use".

By this respect, the following experiment allowed us to gather some first clues to answer our main question “Which of the electrodes, chestbelt and smartwatch is the most acceptable device to monitor sleep quality?”

V. Method

A. *Participants*

Although we plan to propose this experimental protocol to 32 people, until now, only 12 participants’ results have been analyzed. This population is composed of 8 males and 4 females.

B. *Equipment*

The respective acceptability of the 3 following types of HR sensors were compared.

- The Firstbeat bodyguard 2 (2 points electrodes)
- The Suunto smart sensor (chestbelt)
- The PulseOn smartwatch (PPG)

C. *Situation*

Each participant first received instructions on how to use the device. Then s/he wore the sensor during the whole night. At the end, the HR report was generated and consulted by the participant with a specialist. Based on HRV analysis from the Firstbeat analytics algorithm, the report provided the users with their sleep time, the proportion of recovery during sleep and the quality of their recovery. Each participant tested the 3 HR devices in a counterbalanced order.

D. *Data Collection*

At the end, participants filled a comparison’s questionnaire to try to identify which device is more appropriate to monitor sleep.

VI. Results & Discussion

In brief, 12 participants slept with each device and consulted their respective reports. Then they filled a questionnaire to help us to identify which device is the most acceptable to monitor sleep.

First of all, only 6 participants on 12 found “useful” to use a heart rate sensor to monitor sleep activity. Here, interviews revealed that people who has not have sleep disorders do not need to monitor their night.

About ease of use, 7 participants found that the chestbelt is the easiest device to install, take off and charge. 3 persons claimed that the smartwatch is the easiest and 2 chose the electrodes as the easiest to use. Here the reason why the chestbelt obtained the best score seemed to be that the electrodes needed to be changed for each use and the smartwatch bracelet required to be tightened enough.

When we asked participant to check the device in which they trust, 10 participants on 12 found that the electrodes and the chestbelt are reliable while only 4 claims being confident in smartwatch data.

To date, chestbelt is perceived as the easiest device to use and is considered as reliable as electrodes. Taken together and in line with the Technology Acceptance Model, these results suggest that the chestbelt is the most acceptable HR sensor device. Even if this is consistent with participants spontaneous verbalizations, this preliminary finding must be interpreted with cautious because only a third of the expected participants currently performed the experiment. Taking this limit into consideration, it is interesting to note that 6 participants claimed that they would prefer to use the chestbelt in the future.

Acknowledgment

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