iCalm: Wearable Sensor Platform For Long-Term Physiological Self-Monitoring

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Introduction

Long-term continuous monitoring of physiological data has great potential value to personalized health care; yet commercial technologies for this purpose are lacking. Commercial sensors have a short battery life, are expensive, lack wireless capability, and are often cumbersome [1, 2]. We present the design and implementation of iCalm: a comfortable wrist-worn, low-cost, low-power sensor module designed for continuous long-term physiological monitoring and compare its performance to an FDA-approved platform.

Materials and Methods

The iCalm sensor consists of a skin conductance and a heart rate sensor. The sensor band can be worn on the wrist or ankle. Sympathetic nervous system activity is monitored via changes in electrodermal activity (EDA). Heart rate is measured using a classic photoplethysmpograph electro-optical sensor. In addition, motor activity is measured using a 10-bit analog motion sensor and temperature is also measured using a standard digital sensor.

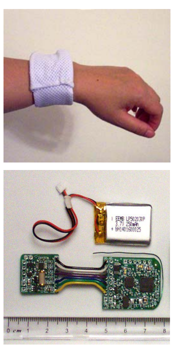

Figure 1: Internal components of sensor band (top); wearable package for wrist (bottom).

Physiological data is sampled at a rate of 2 Hz and transmitted to a laptop via the IEEE 802.15.4 wireless protocol at 2.4 GHz. This wireless standard was chosen since it is optimized for low power, low cost, portability, and good indoor propagation. The rechargeable 250 mAh 3V lithium-ion battery lasts over 30 hours.

Results

A series of tests (N=24) designed to obtain an EDA response from the subject were performed to compare the performance of the iCalm sensor to Thought Technologies' FDA-approved commercial FlexComp [3]. The data from one of these subjects is presented in Figure 2. Skin conductance values obtained from the FlexComp were slightly higher than that from the iCalm as expected due to placement of sensor on the fingertip instead of the wrist, which has lower eccrine sweat gland density. Despite the difference in magnitude, both signals contain all the same phasic features. The slow increase in the tonic value of the iCalm data is likely to be due to the electrode slowly making better contact with the skin over the first 15 minutes of wear.

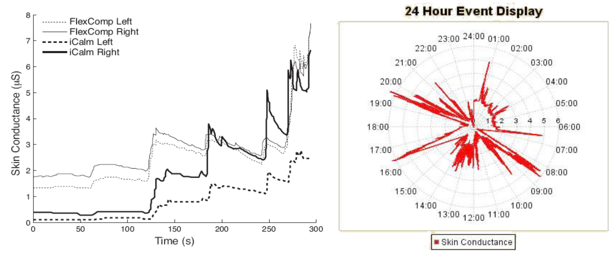

Figure 2: Comparison of EDA data between the iCalm and FlexComp platforms (left); 24-hr EDA data shown on radial data plot (right).

The heart rate signals obtained from the FlexComp and iCalm compared favorably when the subjects were at rest. However, both systems did not produce usable data when the subject was moving, due to strong motion artifacts. Error correction algorithms are currently being developed for improving this performance by making use of the motion sensor signal as real-time feedback to the algorithm [4-6].

The results of the human subject tests demonstrate that the iCalm sensor is capable of gathering data comparable to that obtained from a commercial, FDA-approved device. In conjunction with a mobile phone and web-page interface, this wearable sensor can be applied to a wide range of health applications and medical interventions, ranging from autism, drug abuse, obesity studies, congestive heart failure, and behavioral therapy.

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