Wearable Sensing Approaches for Stress Recognition in Everyday Life

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1. PROBLEM DOMAIN

Wearable, sensor-equipped devices – often referred to as wearables – became increasingly available and ubiquitous in recent years. The rising social acceptance of body-worn technology is a driver for the increasing adoption of wearables on the consumer level. Especially, the health and fitness sector is popular, since wearables can offer continuous sensing of various aspects of our lives, like e.g. physical activity or heart rate.

In our modern, hectic lives, stress becomes an in- creasing factor diminishing our health. Chronic stress is highly related health issues and a shortening of lifespan [3]. Successful, ubiquitous sensing technologies could support the detection and prevention of stress in everyday life.

2. RELATED WORK

Stress and emotions are very complex processes and states which are can influence our well-being. Stress is a reaction to high demands and challenges. This reaction is called *fight or flight effect* and can be considered as a positive reaction which helps us to meet the challenges in stressful situations. But long-term and chronic stress has negative effects on well-being and health [11]. There are different approaches on sensing stress and emotional states, using remote, mobile or wearable sensing.

MoodScope, which recorded the user's current mood, has utilised phone usage data, like calls/SMS, GPS and application usage to correlate emotional states of users [5]. Another project used the mobile phone usage data enriched with weather data and personal traits to predict stress with a 72% accuracy [2]. Mobile phone usage data was also used to detect boredom [6] – the affective state opposite stress/excitement on the arousal scale in the in the Circumplex Model of Affect [9]. Their model reached an accuracy of 74.6% to 82.9%.

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Compared to mobile sensing, wearable sensing offers the benefit of a closeness to the body; this not just provides a higher chance of continuous sensing data compared to mobile phones, which are sometimes left behind, but it also enables biosignal sensing. Biosignals, which can be unobtrusively measured by wearable sensors in a non-invasive manner, can be used to determine current stress and emotional levels [1, 8]. Two very common biosignals are the Heart Rate/Heart Rate Variability and the Electrodermal Activity.

Electrodermal Activity (EDA) describes the changes in the electrical properties of the skin. The most commonly used property is the skin conductance (often called Galvanic Skin Response (GSR)). EDA is linked to emotional and cognitive processes and it is often used for emotional measurements [7]. The easiness to measure the skin conductance, makes it a good tool for wearable technology.

Heart Rate and Heart Rate Variability (HRV) are a common features to detect different internal states of the body and it is often used to detect stress states [10, 12].

Modern consumer wearables are increasingly fit with optical heart rate sensors for fitness monitoring purposes. But evaluation of this data for stress detection is still outstanding. Compared to medical sensors, consumer devices mostly lack the fine-granularity of the data and throughout evaluation, but on the contrary they are affordable and widely used and are offering new data sources for research in everyday life.

3. PURPOSE AND RESEARCH QUESTION

Wearable technology offers the great advantage over mobile phones, that devices can be easily and continuously worn, while personal mobile phones are sometimes left behind at the desk. Furthermore, they open up new data sources like bio-signals, which have a long history for being used in research setting to detect arousal and stress states. While professional devices to measure these stress signals used to be mostly expensive and specialised, advances in consumer technology opened up new opportunities. Those consumer devices are mostly targeted at fitness tracking and are mainly not validated for stress sensing. The purpose of this project is to evaluate those devices and develop new methods utilising not just primary stress-related signals but also contextual data obtained from mobiles/wearables such as movements, location, social environment with the aim to get a bigger picture how users experience stress in the wild.

The main question I want to investigate in my project, is *"Can we effectively use sensing data from consumer wearable devices to detect stress in everyday life situations?"*

4. METHODOLOGICAL APPROACH

The goal of this doctoral project is the evaluation of suitable wearable sensing technologies for inferring stress states and influencing factors of users in in their natural environment, with the greater goal to support personalised stress management in everyday life.

One key part is the evaluation of suitable wearable sensing technologies to infer current stress states as well as influencing factors such as environmental or social factors. This involves the correlation of sensing data with user-provided experience samples, diary notes and questionnaire results.

Though the sensing data obtained from consumer devices is expected to be less reliable and fine granular then data gathered in controlled lab experiment, additional data about environment, personality or context could improve the accuracy of stress detection algorithms.

During the first year, I researched current developments in wearable technology for behaviour changes. This work focused on how data from wearable devices has been used to influence health behaviour of participants and identified potential future developments. Furthermore, I conducted an online survey on how useful people would perceive stress management support through wearable devices.

During my second year, I focused on developing a prototype for the Apple Watch to collect mood experience samples from participants throughout the day and sensing data from the wearable and phone. The aim is to evaluate the suitability of the Apple Watch sensor data to classify emotional states. Surprising results of the pilot study included that the perceived stress before and after the study decreased (n=4) or stayed constant for all participants (n=6). This finding has to be evaluated further in a larger study. The results from a larger study with this app are still outstanding.

5. PROGRESS AND FUTURE PLAN

I am in my third year of my PhD. Currently, I prepare a lab experiment which focuses on instigate stress situation, using Mental Arithmetic Task stimulation wich has been shown to induce a stress response physiological signals [4]. During this experiment, we will record those signals (heart rate, heart rate variability and skin conductance) from 3 consumer wearables and one medical grade device. The aim is to compare the sensor data to the medical grade device and develop machine learning models for classifying stressed and relaxed phases.

Furthermore, I have planned a larger study with an Apple Watch app. This app collects sensing data throughout the day, as well as, experience sample data on current emotional and stress states of the wearer.

6. EXPECTED CONTRIBUTIONS

I intend to make the following contributions with my studies:

1. Compare consumer wearable device data to medical grade data in terms of reliability in a controlled lab setting.
2. Provide new ways of sensor data fusion to increase the accuracy stress prediction based on wearable sensing data (including movement data)
3. Show the ability of consumer wearable devices to detect stress in everyday life settings.

In the long-term, I would like to investigate ways in which wearable sensing data on emotional states and stress can enhance human subject studies in the wild.

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