Mood, Stress and Sleep Sensing with Wearable Sensors and Mobile Phone

Akane Sano, Sara Taylor, Natasha Jaques, Weixuan Chen, Daniel Lopez Martinez, Ehimwenma Nosakhare, Ognjen (Oggi) Rudovic, Terumi Umematsu and Rosalind Picard

Abstract—This paper highlights lessons learned from a four-year ambulatory study, developed to measure Sleep, Networks, Affect, Performance, Stress, and Health using Objective Techniques (SNAPSHOT), which was run in seven cohorts of college students (N=321), collecting continuous wearable and mobile phone data, typically for a month each. This paper overviews the objectives of this study, challenges faced, and some key findings focused on detecting sleep patterns and detecting and forecasting mood changes.

I. INTRODUCTION

Smart phones and wearable sensors have provided highly granular human data in daily life settings for digital phenotyping. Various populations such as college students [1], office workers [2], schizophrenic [3] and depression [4] patients have been targeted to investigate the relationship between mobility and sleep patterns, smart phone usage, physiological responses, and health and performance. In this paper, we introduce our SNAPSHOT study, a few encountered challenges and our data analysis and modelling results for mood, stress and sleep detection and prediction.

II. APPROACH

Our team has conducted ambulatory studies (SNAPSHOT study [5]) for college students using wearable sensors, mobile phones, surveys and laboratory measurement (7 cohorts, N=321). Our measurement includes skin conductance and temperature, acceleration, call/sms logs, location, screen on/off logs, application usage, sleep and daily activity timing, subjective mood, stress, and health, personality and health profiles and social networks. Our objectives are (1) to understand the relationships among traits, daily behaviors, physiology and outcome measures such as mental and physical health and academic performance, (2) to build machine learning models to detect or predict behaviors and health, (3) to provide interventions/suggestions based on an individual’s behaviors or measurement to lead people to better health conditions.

One of the challenges is to maintain good quality data throughout the study. We have developed tools to allow participants and study investigators to more efficiently and effectivly monitor the data collection process and check the quality of sensor and mobile phone data during the study. Another challenge is to maintain participants’ motivations.

Our participants receive financial compensation depending on their contribution. However, in designing longer-term and larger-scale studies, it is crucial to consider motivating participants by providing data visualization, insight into their data, or gamification. Third, if we consider providing suggestions or clinical interpretation, we need to develop interpretable or actionable features rather than black boxed features in modeling.

For data analysis and modelling, we have applied long short term (LSTM) recurrent neural networks to detect/predict mood, stress and sleep [6]. Additionally, multi-task learning [7] or domain adaptation [8] has been used to account for individual differences and build personalized models to predict next-day mood and stress. The proposed LSTM method achieved a sleep detection accuracy of 96.5%, and sleep onset/offset detection F1 scores of 0.86 and 0.84, with absolute mean errors of 5.0 and 5.5 min, respectively, with wrist acceleration, skin temperature and time features when compared with sleep state and onset/offset assessed using actigraphy and sleep diaries. We have also examined more accurately previous N day data can predict stress, mood and health in the future using LSTM models. The multi-task neural network models predicted tomorrow’s high/low mood, stress and health with accuracies of 78-82% using today’s data. We have also found 9.69/22% participants belonged to very poor/poor/good mental health based on Mental Component Score at the start of semester. Their mental health declined one month later (resulting in a 14/74/12% split in the 3 groups). The very poor mental health group moved statistically significantly shorter distances, sent sms later at night, and had a lower number of skin conductance peaks during sleep ($p < 0.05$) than other groups.

REFERENCES