Towards Precision Stress Management:

The Design and Evaluation of A Practical Wearable Sensing System for Monitoring Everyday Stress

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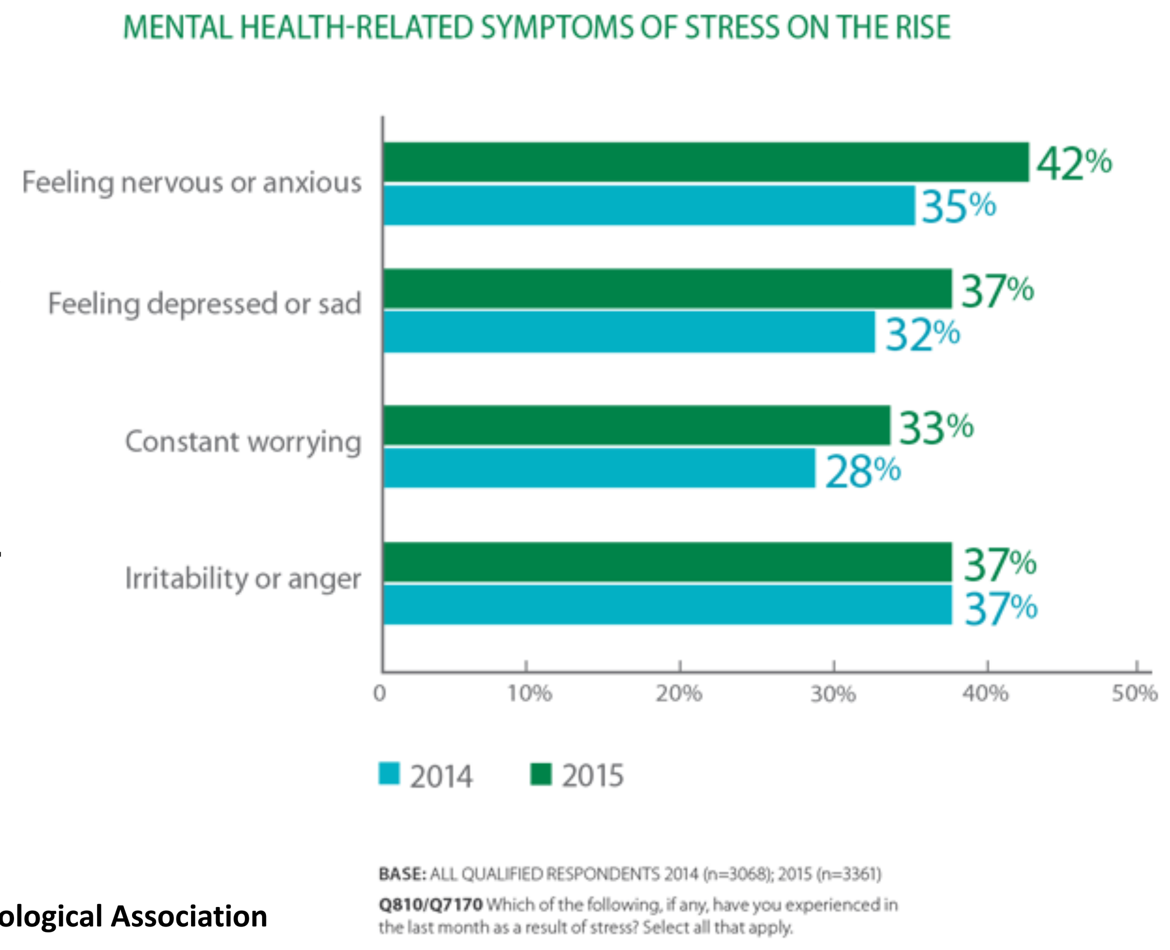
Motivation: Stress Is On The Rise

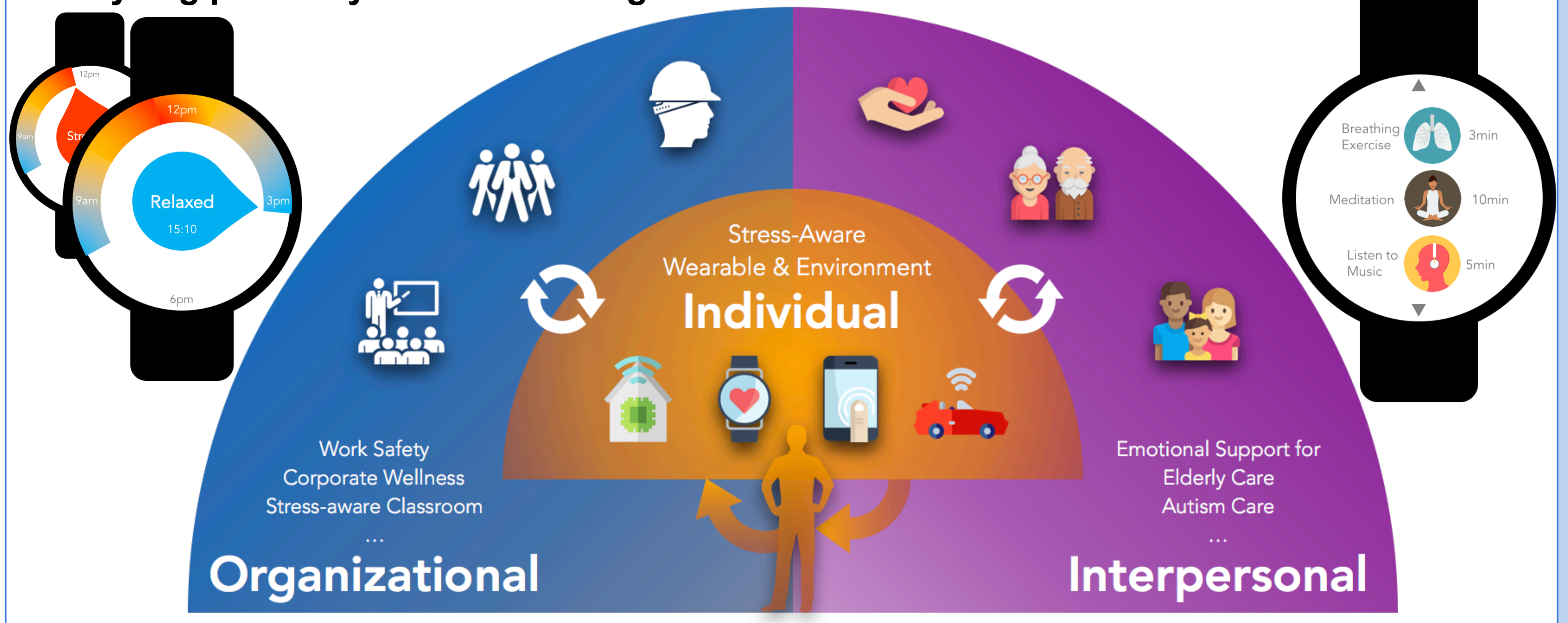
Overstress is becoming an epidemic issue in modern society, contributing to a broad range of health problems ranging from depression to cardiovascular diseases. According to a 2015 national survey by American Psychological Association, 75% of Americans reported experiencing at least one symptom of stress in the past month, such as anxiety and headaches. **Despite the growing evidence of stress's negative impact, there still lacks practical tools that can unobtrusively gauge and manage people's day-to-day stress.**



Source: 2015 Stress in America™ survey by **American Psychological Association**

Objective & Vision

<u>**Study Objective**</u>: The pilot study aims to design, develop and evaluate a practical wearable sensing system that can **continuously and reliably infer the wearer's stress level through analyzing passively obtained bio-signals**.



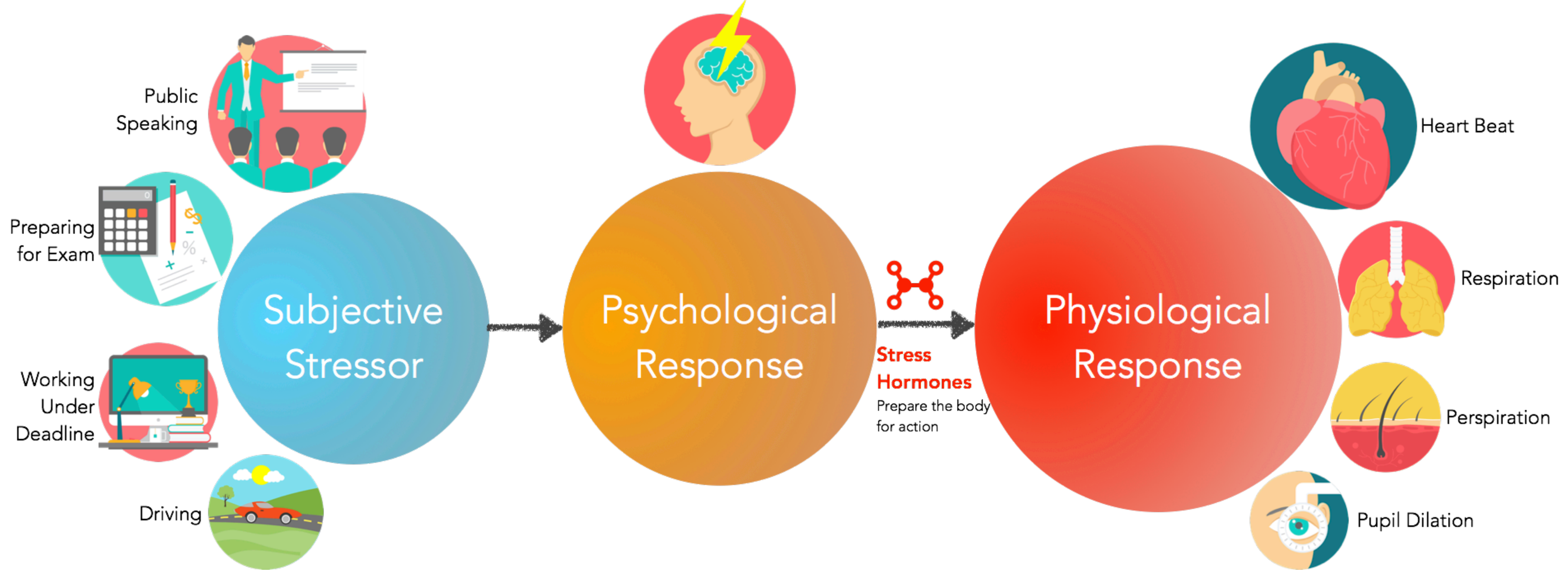
<u>**Vision**</u>: An ecosystem that supports **Precision Stress Management** and **seamlessly blends into everyday life**

- Timely awareness of elevated or prolonged stress;
- Personalized and actionable de-stress recommendations;
- Analytics that uncover insights from historical data to inform various decision makings.

Digitizing Daily Stress Using Pervasive Sensing Technology

We believe the key to better understanding and managing daily stress is being able to monitor and learn from its dynamic progression over time.

We leverage pervasive sensing technologies that transform passively collected bio-signals and contextual information into a Stress Index — a reliable real-time proxy of stress level.



Conclusion

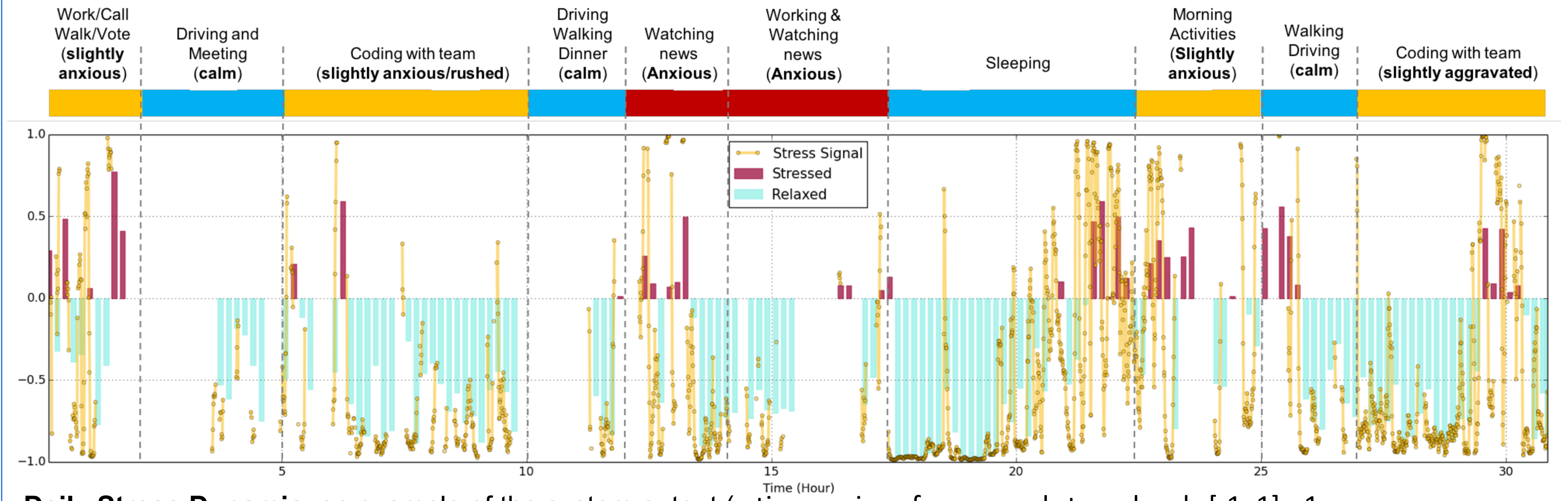
Our results suggest that the developed system can offer a reliable proxy of stress, and therefore holds potential in serving as a convenient tool for gauging and understanding daily stress dynamics.

In future studies, we will explore methods of leveraging the system's continuous stress level output to generate timely notifications and personalized recommendations. We will investigate ways to further enhance the system's accuracy and coverage with other biomarkers, contextual information, and Internet of Things technologies.

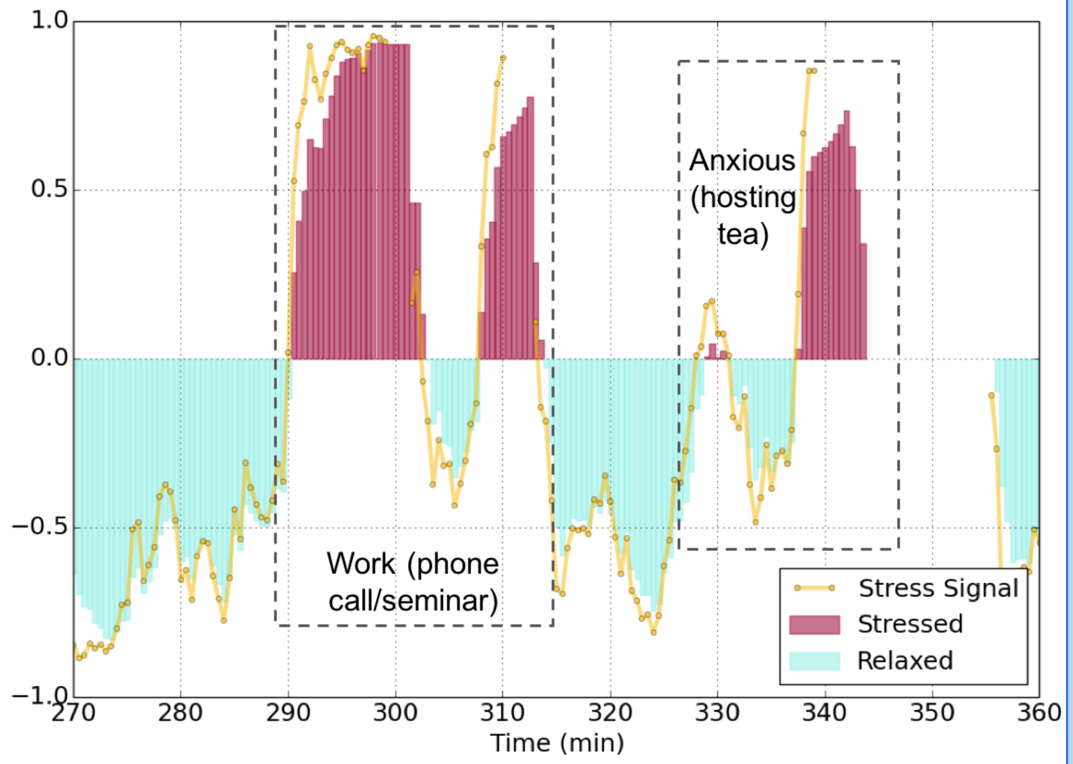
Methods and Preliminary Results

<u>**Method**</u>: We investigated the feasibility of using biomarkers based on heart rate variability (HRV) to infer stress. We developed algorithms that process signals from photoplethysmography (PPG) sensors (Empatica E4 wristband [1]) to extract an HRV-based biomarker that is indicative of stress. We then investigated the correlation between each subject's self-reported stress and the biomarker by conducting controlled, in-lab experiments designed to put subjects through structured periods of relaxation and stress. We also conducted in-field experiments to identify and deal with the practical challenges associated with measuring stress in real-life situations, such as unpredictable data quality due to motion artifacts. To evaluate the system's in-field performance, we compared the system's stress output and the self-reported stress associated with a particular daily event.

<u>**Results**</u>: A total of **17 subjects** were recruited for the initial data collection. We collected more than **300 hours of data** that contains activities such as working, giving a presentation, driving, doing cognitive challenges, etc. **146 activities** were annotated by the subjects with associated stress information. Compared with the reported stress information, results from the system achieve a **sensitivity of 92.1% (105/114)** and a **specificity of 50.0% (16/32)**.



Daily Stress Dynamic: an example of the system output (a time series of measured stress levels [-1, 1], -1 indicating very relaxed and 1 meaning very stressed) based on a **30-hour uncontrolled in-field recording**, plotted along with the annotated activities and stress information from the subject to compare their correlation.



Real-time Fine-grained Stress Information: system output based on in-field data and self-report activities showing detailed changes of stress level during a work phone call and a social event.

[1] Garbarino M, et al. Empatica E3 – A wearable wireless multi-sensor device for real-time computerized biofeedback and data acquisition. In Wireless Mobile Communication and Healthcare (Mobihealth), 2014 EAI 4th International Conference on 2014 Nov 3 (pp. 39-42). IEEE.