Personal Informatics Can Be Stressful: Collecting, Reflecting, and Embedding Stress Data in Personal Informatics

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Abstract

In our research, we are examining how *pervasive continuous sensing* and *targeted ecological momentary assessment* can be used to unobtrusively collect stress data, and we are designing *personal health informatics* that can aggregate and visualize these stress data over time and for different audiences. In this position paper, we describe our recent and ongoing efforts in this area and articulate some of the open questions raised by our work and that we hope to discuss during the workshop.

Author Keywords

Personal informatics; stress; personal information management; pervasive healthcare; mobile computing

ACM Classification Keywords

H.5.m. [Information interfaces and presentation (e.g., HCI)]: Miscellaneous; J.3. [Computer Applications]: Life and Medical Sciences—Health

Introduction

In the 2011 *Stress in America* survey, the American Psychological Association warns that stress is becoming a public health crisis [1]. Most Americans are suffering from moderate to high stress, with nearly half reporting increased levels over the last five years. According to the APA, "job stress is estimated to cost U.S. industry

$300 billion a year in absenteeism, diminished productivity, employee turnover and direct medical, legal and insurance fees" [2]. We have seen evidence of the relationship between the use of computing technologies and stress in our own empirical studies of information workers, as well, noting a correlation between use of e-mail and increased stress levels (as measured by heart rate variability) [6].

However, since stress can be induced from a variety of sources (many of which are less intuitively obvious or visible than e-mail), it is often difficult for people to identify the specific causes of stress. The embedded nature of stress can make it more difficult for people to change their routines or behaviors to mitigate increases in stress levels. For example, a person's consistently high stress levels during the late afternoon could be caused by a standing meeting, anticipation of rush-hour traffic, the accumulated effects of caffeine throughout the day, or some combination of these factors. In our research, we are undertaking a variety of projects to examine how *pervasive continuous sensing* and *targeted ecological momentary assessment* can be used to unobtrusively collect physiological, environmental, and social data that can reveal sources of stress (corresponding to stage 2 in Li, Dey, and Forlizzi's model of personal informatics systems [4]). We are also designing *personal health informatics* that can aggregate and visualize stress levels over time, as well as providing individual and social support for managing work in ways that minimize the impact of stress on day-to-day life (corresponding to stage 4). Finally, we are interested in validating the use of sensed stress levels as a mechanism for evaluating the efficacy of personal informatics systems *in situ*.

Figure 1. *BeWell's* ambient display of sensed health information, including representations of physical activity (the speed of the clownfish), sociality (the number of blue fish in the surrounding school), and sleep (the amount of light shining through the water).

In this position paper, we enumerate some of our recent efforts to incorporate the collection and reflection of stress data in various personal informatics and personal health informatics systems. We conclude with a brief overview of our ongoing and future work in this area and some of the open questions raised by our work that we hope to discuss during the workshop.

BeWell
BeWell, a personal health application for smartphones, is designed specifically to help people manage their overall wellbeing [3]. BeWell continuously monitors multiple dimensions of behavior and incorporates user feedback mechanisms that are able to increase awareness about how different aspects of lifestyle impact the personal wellbeing of the user. BeWell uses commercial, off-the-shelf Android smartphones to automatically: (1) monitor a person's physical activity, social interaction and sleep patterns based on data collected with the smartphone's built-in sensors; (2) summarize the effect of the monitored behavior on wellbeing; and (3) provide feedback that enables users to effectively manage these three key aspects of their health. The system visualizes the various health data through a number of self-reflective interfaces: through numerical wellbeing "scores" that can be called up on command, through an animated aquatic ecosystem displayed as "live wallpaper" in the Android OS (Figure 1), and through a web-based portal where historical and trend information can be displayed.

StressSense
Variations in the speech production process are some of many physiological changes that happen during stress. Microphones, embedded in mobile phones and carried ubiquitously by people, provide an opportunity to

continuously and non-invasively monitor stress levels. We have developed an algorithm, *StressSense*, for unobtrusively recognizing stress from human voice using smartphones [5]. The StressSense classifier can robustly identify stress across multiple individuals in diverse acoustic environments.

A key challenge of this research is to enable continuous sensing on smartphones without adversely impacting battery life or usability. We have shown that it is possible to create reliable, personalized models of stress that achieves near–85% accuracy with as little as 2 minutes of labeled user data. We have also created a prototype implementation of the StressSense system running on Samsung Galaxy Nexus smartphones that can detect stress from audio in real time and can run for up to 32 hours (depending on the presence of human voice) on a single battery charge.

Ongoing and Future Work

While much of our existing research has been focused on developing the infrastructure through which an individual's stress levels can be continuously and unobtrusively collected, we are transitioning to focus on validating our approaches against known gold standards for measuring stress and exploring ways that the collected stress data can be reflected back to users. For this workshop, we are particularly interested in contributing to a conversation about the role that stress might play in the design and evaluation of personal informatics systems.

Validating Stress Detection in the Real World
This spring, we are beginning a deployment study of StressSense, validating its effectiveness in unobtrusively detecting stress levels in real-world

scenarios. Our study design involves the collection of self-reported stress data from participants using an ecological momentary assessment approach [7] in parallel with continuous, automated stress sensing. During each day of the study, we are periodically asking participants to complete Taylor et al.'s single-question, self-reported stress measure [8] in addition to selecting an image that reflects their current mood, using our previously-validated Photographic Affect Measure (PAM) [9]. This study will allow us to gather valuable data about the accuracy of our system through triangulation among these measures, as well as allowing us to build a corpus of real-world vocal stress data and enabling iterative refinement of our system to maximize performance on a single battery charge.

Embedding Reflections of Stress in Personal Informatics and Personal Information Management Tools
Another focus of our research moving forward will be to investigate how interactive personal informatics tools can be used to embed representations of sensed context (e.g., stress levels) into existing practices (e.g., information management). We envision designing, implementing, and deploying a suite of tools that enable people to automatically annotate their information artifacts with information about the physical locations, the people who were nearby, and the user's stress level when various information artifacts were last used (Figure 2). Not only would this kind of contextual metadata provide additional facets against which information artifacts could be sorted, filtered, and organized, but this kind of contextually-rich interface would also provide an embedded context for reflecting on one's own routines and the stress levels associated with information work. Furthermore, rather than requiring users to adopt separate tools for
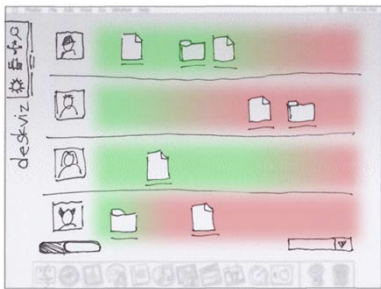

Figure 2. An early sketch of a personal informatics interface that allows users to organize information artifacts based on their various collaborations and indicates the levels of stress sensed by the system for each collaborator and artifact.

self-reflection, embedding this kind of sensed health information in the tools that are already used everyday may help to prolong engagement with the system and enable self-reflection about health and stress in a more grounded, and, therefore, more actionable manner.

Figure 3. An early-stage mockup of our *MoodRhythm* app, designed to assist individuals with bipolar spectrum disorder in monitoring and managing their stress levels and moods.

We are also investigating how automatically sensed stress levels might be incorporated into a smartphone app for helping individuals with bipolar spectrum disorder—that is, to help patients to better regulate their symptoms and assess the effect of changing medication levels on their day-to-day lives (Figure 3). Similar to the approach taken in the BeWell project, MoodRhythm reflects sensed stress levels and daily routines as part of a specialized smartphone app. It also encourages users to self-experiment by using therapeutically sound strategies to regulate their mood and receive feedback on the outcomes. Some of this project's challenges that are relevant to designing personal informatics tools in this sphere include: (1) designing feedback techniques that consider the sensitive nature of stress and mood information, (2) creating tools that might have to be used over long periods of time and still remain effective, and (3) adjusting to users' varied levels of engagement depending on how they are feeling. We are currently working with psychologists and clinicians to finalize the design of MoodRhythm, and hope to complete its implementation and begin a deployment study in a naturalistic setting over the next several months.

Participation in the CHI 2013 Workshop

We are excited that this year's personal informatics workshop is explicitly framed around the idea of "Hacking Habits for Health," since this topic closely resonates both with our recent research—developing a class of sensor-based mobile and desktop apps for self-reflection around stress and health—and with our ongoing and future research, which will involve deploying and evaluating these personal informatics "in the wild," with representative information workers and individuals with bipolar spectrum disorder. We look forward to bringing this expertise and our experiences to discussions about (1) the ways that personal health informatics data might be embedded more seamlessly into existing practices and (2) how these data might be made accessible in ways that protect users' privacy.

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