Overview

Introducing smartphones to the health care process is a “natural and necessary” component of 21st Century global health that makes good on the promise of personalized medicine regardless of individual economic status/developing nation status. The “always-on” and “always-worn” status of smartphones makes it possible to collect real-time behavioral signatures as indicators of health and disease with resolution spanning from the individual to the population. These signatures, akin to genetic fingerprints or cardiac rhythms, provide up-to-the-minute indicators of individual and population health status, which can be utilized by a doctor who is helping an individual patient reduce stress in their life, or by an epidemiologist who is studying a populations cardiovascular disease risk factors. By personalizing behavioral interventions and diagnoses for health management and research, smartphones facilitate equal access to the benefits of personalized medicine globally.

Engaging participants through self-monitoring in general has been shown to be critical to succeed in behavioral intervention programs [Donovan and Marlatt 2005; Marlatt and Gordon 1985]. But more affordable, engaging, valid, reliable, and feasible tools to self-monitor behaviors are required to address the limitations of current methodology. To minimize error in self-reporting behaviors, a technique called ecological momentary assessment (EMA) was developed to monitor affect, cognitions, and behavior in real time in a persons natural environment [Shiffman et al. 2008]. EMA has been shown to greatly increase the validity and reliability of patient reported data. Smartphones can significantly increase the power of EMA by providing information on contextual, spatial, or temporal associations to behaviors, and with reduced burden on the user. Yet, phones have not been sufficiently utilized to track and measure health behaviors through space and time [Story et al. 2009].

We have developed AndWellness in order to enable rapid prototyping of end to end EMA systems, and to continue to engage participants in data collection. We extend the definition of EMA, which traditionally is limited to survey based data collection, to include data collected from the numerous monitoring devices that are now available both on the phone (e.g. GPS, accelerometer, camera) and off the phone (e.g. wireless heart rate monitors, blood pressure cuffs). Using AndWellness, a researcher can ask a participant, for example, to monitor exercise, stress, and blood pressure several times a day using a combination of human-in-the-loop measurements and automated monitoring; view all the data together; and then update the monitoring ‘prescription’ as needed. Further, AndWellness makes it possible to measure a participants timely adherence to the data collection process, and configure when and why a participant is queried to collect data. Both are necessary to ensure high quality and unbiased data collection. AndWellness aims to make it easy for doctors and researchers to conduct rapid experience sampling studies to study individuals or populations in situ.

Approach

The design of AndWellness is driven by interviews with key behavioral researchers, focus group sessions with over 60 diverse potential users of a mobile self monitoring system like AndWellness, and surveys of breast cancer survivors and young moms who have used AndWellness in several research studies to self-monitor diet, exercise, mood, and stress. Through all of these intensive interactions, we have observed a desire for individual customizability (of interest to both researchers and end users), minimal user burden (especially of interest to end users), and validity and reliability of measures (especially of interest to researchers). As a participatory sensing application, AndWellness provides customizable spatial-, social-, temporal-, and mobility-triggered reminders, assessments, and interventions that can be designed by the user, and are relevant to a wide array of behavior change objectives.

System(s) Description and Experiments

AndWellness includes five system mechanisms to facilitate rapid prototyping of participatory health data collection, storage, and analysis: 1) low-power data collection services (e.g. mobility) for automated data collection without...
draining the battery; 2) Survey authoring; 3) a toolkit of generic visualizations that provide a quick snapshot of each users data; 4) a composable and extensible trigger framework that makes it easy to launch survey data collection based on time, place, or a users activity; and 5) a phone top ‘button’ that allows a participant to capture a quick emotion (such as a ‘stress button’ to document stress events) – and the time and location surrounding that event – without having to go through the burden of answering an entire survey.

Mobility
We have a mobility classification module which classifies a participant’s activities into ‘still’, ‘walk’, ‘run’, ‘bike’, and ‘drive’ using features computed on the phone based on continuously sampled GPS and accelerometer data. A number of research areas are based on improving the customizability, power consumption, and adaptability of this classifier, discussed in other sections. In this section, we discuss our efforts in improving achieving high accuracy classification for the AndWellness deployments. C4.5 decision tree algorithm is used for classification. Our experience demonstrates that this decision tree must be trained using data collected on the same platform that will be used to collect data during classification (e.g. Android, or Nokia), to accommodate differences in accelerometer hardware and driver software. For example, when the decision tree classifier is trained with data collected on a Nokia platform, and then run on data collected on an Android platform, classification for a set of scripted activities is approximately 75%, with classification of ‘run’ having the worst performance. This accuracy increases to 90% or more, when the decision tree classifier is trained and then run on data collected on the Android platform.

Researcher Oriented Survey Authoring.
To design a campaign with a set of surveys, the author creates an XML configuration file conforming to a provided schema. The server validates the configuration when it is loaded into the system. To increase the modularity and generalizability of the system, this XML configuration file is also used by the data visualization system to dynamically create visualizations. Each prompt type is mapped to a specific type of visualization. The web-based visualization client can then the XML file to dynamically create visualizations for each survey, providing quick out-of-the-box visualizations for any campaign. The data point API provides a general interface to access data.

Datapoint API
Our data point abstraction format meets three requirements. First, the format is amenable enough to represent all prompt data type and mobility data. Using the datapoint API, data consumers are able to obtain all necessary context about the data without requiring separate or additional configuration information. That is, each individual data point is meaningful on its own. This allows a data consumer to query for multiple streams of data without needing to first query for survey or campaign specific information. Finally, the format is extensible to all types of metadata using JSON objects.

Trigger Framework
The reminder framework in AndWellness supports reminders that are based on time, activity, or location, and can be extended to other modalities. This reminder service provides programatic and graphical based authoring and configuration of reminders: The main design goal for this framework is to provide a uniform experience in creating and managing triggers of any supported type.

Buttons as Lightweight Survey Abstractions.
Participants in our focus groups frequently expressed the concern that surveys would be difficult to answer, and requested a lightweight method to record a specific event quickly. This notion of a desktop ‘button’ has evolved, and has become especially important to capture events that are unplanned, such as stressful events, or are not on a regular schedule, such as eating. We are exploring two buttons for deployment. First, a stress button, which records time and location when pressed. Second, a food button, which launches a short survey including the option to take a picture.
Evaluation
Main metrics for evaluation are battery usage and accuracy. We have outlined a battery testing methodology to address hurdles presented by using different phones with different batteries, usage scenarios, and configuration when comparing energy usage. Validity and accuracy evaluated through a number of behavioral health studies, discussed in the next AndWellness section.

Future Directions
In the coming year, we plan to complete the design and implementation of the AndWellness system, and release the code as open source. This release will enable any researcher, with minimal technical capabilities on staff, to install, author, configure, and initiate an EMA campaign using Android smartphones. The AndWellness server application will additionally be serving as the back-end for a number of the major smartphone and participatory sensing efforts undertaken at CENS, including Mobilize and What’s Invasive.