Beyond Counting Steps: Using Context to Improve Monitoring of Physical Activity

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Abstract
Incorporating physical activity into daily life is difficult. Most physical activity monitoring systems focus on performance numbers. My research explores how people can use contextual information from ubiquitous computing systems in addition to performance numbers to help with self-awareness of how one's daily life affects physical activity.

Keywords
Self-awareness, monitoring, physical activity, context, visualizations, interviews, field study

ACM Classification Keywords
H5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

Introduction
Lack of physical activity increases the risk of otherwise preventable diseases, such as obesity, chronic heart disease, diabetes, and high blood pressure [12]. A recent study by the Center for Disease Control found that more than half the adult U.S. population does not participate in regular physical activity [14].

Lack of self-awareness of physical activity is one of the reasons people lead sedentary lifestyles [18]. Many monitoring technologies can increase self-awareness of physical activity [1][8][15]. These tools belong to the class of systems called *personal informatics*, systems that monitor and display information about people's behavior to increase self-awareness.

Most personal informatics tools related to physical activity focus on performance numbers, *e.g.*, step counts, amount of energy expenditure, and heart rate. However, performance numbers are not the only information relevant to physical activity. Self-awareness of how lack of time, choice of activities, the environment, and social influence affects physical activity is critical to circumventing barriers to becoming active [13][16] and may help with finding active lifestyle activities (*e.g.*, walking *vs.* driving or taking stairs *vs.* elevators) that are easier to incorporate into daily life [6][12] than structured exercise (*e.g.*, going to the gym).

The main question of my research is: *How can people use contextual information from ubiquitous computing technologies to help with self-awareness of physical activity?* Most ubicomp systems already collect various sensor data and contextual information to perform tasks appropriately (*e.g.*, occupants of a room to change light settings, GPS location to notify users of a task). Users may also find these collected data useful to explore, manipulate, and digest, so they may learn patterns in their behaviors that affect physical activity. I explore three aspects of this question:

1. *What are the benefits of contextual information on becoming aware of one's behavior that affects physical activity?*

2. *How can we ease the burden of manually recording contextual information?*

3. *What are the advantages and disadvantages to learning about one's behavior when contextual information is automatically recorded?*

The focus of my research is not whether adding contextual information to step counts can increase physical activity; step-counting using pedometers has been shown to be effective in increasing physical activity in countless research studies [1][15]. Instead, I explore what value contextual information can offer that performance numbers alone cannot. Any significant changes to physical activity induced by the additional contextual information will require longer studies with more people. My studies so far demonstrate that adding contextual information to physical activity information does not deter physical activity and is as effective as pedometers at motivating physical activity.

Related work

Physical Activity Monitoring

Many devices measure physical activity. Pedometers or step counters are the most affordable and easiest to use [1][17]. Some mobile phones with accelerometers include step-counting software, *e.g.*, Nokia 5500 SportsTracker.

There is also research on the use of novel visualizations for displaying physical activity levels. UbiFit Garden

displays physical activity levels using a garden metaphor in a glanceable phone display [2]. Shakra used GSM signal strength to detect minutes of activity (*e.g.*, sitting, walking, and driving) and displayed cartoon visualizations on a mobile phone [8]. Fish n' Steps used a public display visualization of fish in a tank [7]. The Nike+iPod system (http://nikeplus.com) monitors running time and uploads the data online for visualizations. These systems do not go beyond performance numbers. My work builds on these systems by integrating contextual information.

Integrating Physical Activity and Context

Finding opportunities to be physically active remains a challenge for people [6]. Awareness of opportunities in one's life for behavior change is critical to circumventing them and making lasting behavior changes [13][16]. Focusing only on the amount of physical activity may be insufficient to help find opportunities for behavior change because there is a gap in understanding between the facts about such a physical state and what causes that state [3]. For example, diabetes patients are taught to be aware of their blood sugar level, but do not learn the behaviors that contribute to those levels [3][9].

Adding contextual information to physical activity enables users to correlate numbers of steps with specific activities. This is analogous to financial management software. As financial management software increases one's awareness over financial matters and of ways to save by making clear one's expenditures in different categories, my work intends to increase users' awareness of opportunities for physical activity in one's daily life.

Approach

My work focuses on monitoring and providing information about physical activity to assist in self-awareness and self-reflection. Knowing oneself has been shown to foster self-insight [4], to increase self-control [11], and to promote positive behaviors, such as energy conservation [17]. While people's physical activity information can also be used for social comparison, competition, providing explicit suggestions, goal-setting, having an expert as a coach, *etc.*, I want to focus on how people would use information about their behavior if the system simply provided the information.

I work primarily with sedentary people because research suggests that they are less aware of how active they are and they need more information about how to become active compared to active individuals [13][16]. Consequently, I focus on walking as physical activity because sedentary individuals can more easily integrate walking into their daily lives than other forms of physical activity [10]. While there are many kinds of information that can be added to step counts, I focus on three different kinds of contextual information that have been explored extensively by the ubicomp community: *activity*, *place*, and *people*. As technologies that monitor this information become more robust, they can be more readily integrated into physical activity monitoring devices.

I took a user-centered approach in conducting my studies. I started with the needs of users and then created prototypes to observe how users use the technology. This approach is similar to technology probes [5]. There were three reasons for using this approach. First, the primary goal of my studies was to

understand how increasing awareness of context about physical activity affects the user and what the benefits are compared to existing systems *before* I invest time and money on developing more sophisticated technology. Second, I wanted to make sure that our deployed technologies were robust enough to be used for a long period of time. Finally, the current state of most systems to track activity and people require wide infrastructure changes or require more devices than most of our users were willing to wear. I will continue this methodological approach with future studies.

Methodology and Next Steps

I discuss work I have completed and need to do in three areas.

Benefits of Contextual Information

I explored what information sedentary people wanted about their physical activity. I conducted interviews to understand their experiences with monitoring their physical activity and what they did to become physically active. I identified two themes: 1) *People focus on numbers instead of the behaviors that lead to those numbers*; and 2) *There are opportunities to be physically active within one's daily life: in regular activities, in places around them, and with people*.

Next, I conducted a diary study to find out what people would do with contextual information about their physical activity. In the study, participants logged a detailed record of their activities (time, type of activity, location, and people), which they explored along with physical activity data from the BodyMedia SenseWear armband. The study had 3 phases: 1) participants did not see their physical activity data; 2) participants carried a pedometer, so their aggregated step counts in real time; and 3) participants saw detailed printouts of their physical activity at the end of the day. There were two major results. 1) *People will associate contextual information with their physical activity.* Participants matched segments on the physical activity graph with activities in their journals to understand how much physical activity they performed for different activities. 2) *People can benefit from having both real-time information and a historical review of time-stamped step data.* Participants liked the daily reports of time-stamped data from the SenseWear armband, but they missed the real-time feedback from the pedometer.

With lessons from the studies, I developed a prototype system called IMPACT (Improved Monitoring of Physical Activity using ContexT). The system integrated physical activity monitoring with a journal for recording contextual information. The prototype used visualizations to help people to easily see the associations between their contextual information and physical activity. I conducted a 7-week field study of the prototype that revealed the value of contextual information compared to step counts only: participants reported greater awareness of opportunities for physical activity.

A more controlled study is needed to determine whether this awareness translates to some increase in overall step counts or other measures, such as self-efficacy and motivation. Another area of exploration is determining the benefits that contextual information provides in the long term (beyond the 7 weeks of the previous studies). I have some evidence that contextual information helps with recall of activities performed during peak levels of physical activity, but an open question is whether this will translate to more

physical activity. A study should also observe whether contextual information could reveal the reasons why a person is more active between seasons.

Easing the Burden of Manual Recording
While the IMPACT prototype was rated the most useful, it was also rated the least easy to use. Participants reported that manually logging the extra contextual information was too tedious. Fortunately, 90% of the participants reported they would continue using the system if collection of contextual information were automated. Thus, I created a second version of IMPACT that used a mobile phone and GPS to monitor step counts and the user's location. The mobile phone also has an easy-to-use interface to input what the user is doing and whom he/she is with. The contextual information was automatically uploaded to the IMPACT web site.

My observations suggest that other contextual information (e.g., how busy the user is, weather) may be more useful and relevant to the user. Existing records, such as electronic calendars and weather reports, may be leveraged to provide other kinds of contextual information.

Advantages and Disadvantages of Automatic Recording
I deployed the second version of the IMPACT system for 8 weeks and compared it with versions without contextual information. This version was not better at increasing awareness of opportunities for physical activity. In fact, awareness of opportunities increased for all users, regardless of the system that they used.

A follow-up study six months later revealed the value of the extra contextual information collected. All users were curious about the peaks in their graphs, they wanted to know what they were doing during those times. However, only users who collected contextual information were able to deduce what they were doing. Interestingly, some users pulled out their electronic calendars to see what they were doing on particular dates. This suggests that labeling of contextual information is useful for self-reflection, especially, later when users have likely forgotten their history.

The observations from the previous studies suggest several areas of exploration. First, the balance between burden of monitoring and richness of data for feedback needs to be further elaborated. I observed from my prototypes that relieving the user of the responsibility to monitor contextual information with ubicomp technologies engaged users less. However, since more data was collected about the users, the quality of feedback provided should be improved. What are some effective feedback techniques so users may gain the full benefit from their data? One idea is to make the system proactive in showing data to the user, *e.g.*, the system can provide feedback when the user needs the information most. Another idea is to set regular moments for users to reflect on their data. This technique would require determining the amount of reflection that is necessary to offset the loss of engagement from the automation of monitoring.

Contributions to Ubicomp

My work will offer several contributions to the ubicomp community. First, I will show the role that contextual information can play in giving users a better understanding of how their lifestyles affect their physical activity. Second, I will demonstrate how ubicomp technology can provide the necessary

information to improve self-awareness of physical activity. Lastly, I will identify the issues that come with introducing ubicomp technologies to the personal informatics of physical activity. I also hope that this work will lead to better physical activity monitoring systems that will benefit people who are struggling to become more active.

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