Position Paper on Using Contextual Information to Improve Awareness of Physical Activity

Ian Li, Anind Dey, and Jodi Forlizzi
Human-Computer Interaction Institute
Carnegie Mellon University
5000 Forbes Avenue, Pittsburgh, PA 15213
ianli@cmu.edu, {anind, forlizzi}@cs.cmu.edu

***Abstract*—Sedentary people have a hard time incorporating physical activity into their lives. Most physical activity monitoring systems focus on performance numbers. However, people need information beyond performance numbers to help them understand how their lifestyle affects how physically active they are. The main question of our research is how people can use contextual information from ubiquitous computing systems to help with awareness of how different aspects of one's daily life affects physical activity. We explore three aspects of this question: (1) What are the benefits of contextual information on becoming aware of 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 own behavior when contextual information is automatically recorded? We discuss lessons and future work in this area.**

Keywords-awareness; monitoring; physical activity; context; visualizations; interviews; field study

I. INTRODUCTION

Lack of physical activity is a common problem that increases the risk of otherwise preventable diseases, such as obesity, chronic heart disease, diabetes, and high blood pressure [1]. 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 [2]. People try to increase their physical activity, but many return to sedentary habits [3].

Lack of awareness of physical activity is one of the reasons people lead sedentary lifestyles [4]. Many monitoring technologies can increase awareness of physical activity level [5][6][7]. Pedometers, an example of such technology, have been shown to help increase physical activity [8][9]. These tools belong to the class of systems called *personal informatics*, systems that monitor and display information about people's behavior.

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. 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 [10][11]. This awareness may also help with finding active lifestyle activities (*e.g.*, walking vs. driving short distances or taking stairs vs. elevators) that are easier to incorporate into daily life [1][12] than structured exercise (*e.g.*, going to the gym).

The main question of our research is: *How can people use personal contextual information from computing systems to help with awareness of physical activity?* Most computing systems, especially ubiquitous computing systems, already collect various contextual information from sensor data 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 reflect on, so they may learn patterns in their behaviors that affect physical activity.

We explore three aspects of this question. We discuss lessons and future work for each aspect:

1. What are the benefits of contextual information on becoming aware of behavior that affects physical activity? From interviews and a diary study, we found that people need information beyond performance numbers to help them understand how their lifestyle affects their physical activity. Our first prototype showed that contextual information increased users' awareness of opportunities for physical activity. *Other benefits still need to be explored that pertain to long-term value of contextual information.*

2. How can we ease the burden of manually recording contextual information? Our first prototype required users to manually record step counts and contextual information. While users reported that they became more aware of opportunities for physical activity, they also reported that the system was harder to use than a system that only required recording of step counts. We developed a second prototype with mobile phones and GPS to automate recording of step counts and location and to ease manual input of activities and people. Our observations of users suggest that other contextual information (e.g., how busy the user is, weather) may also be useful. *What other contextual information might be useful?*

3. *What are the advantages and disadvantages to learning about one's own behavior when contextual information is automatically recorded?* While some automation in our second prototype produced rich historical data about users' physical activity, users were not as aware of opportunities for physical activity as they were when using the first prototype. We

hypothesize that automation led to less user engagement during monitoring, which the prototype did not supplement with sufficient feedback about behaviors that contribute to physical activity. *What are some effective feedback techniques so users may gain the full benefit from their data?*

The focus of our 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 many research studies [8][9]. Instead, we explore *what value contextual information can offer that performance numbers alone cannot offer*. Any significant changes to physical activity induced by the additional contextual information will require longer studies with more people than we have done.

II. Related Work

A. Physical Activity Monitoring

Many devices measure physical activity. Heart rate monitors measure intensity of physical activity by heartbeats per minute. Pedometers or step counters are the most affordable and easiest to use [4][8].

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 [5]. Shakra used GSM signal strength to detect minutes of activity (*e.g.*, sitting, walking, and driving) and displayed cartoon visualizations on a mobile phone [7]. Fish n' Steps used a public display visualization of fish in a tank [13]. 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. Our research builds on these systems by integrating contextual information.

B. Integrating Physical Activity and Context

Finding opportunities to be physically active remains a challenge for people [12]. Awareness of opportunities for behavior change is critical to circumventing them and making lasting behavior changes [10][11]. 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 physical states and what causes those states [14]. For example, diabetes patients need to be aware of their blood sugar level, but do not learn the behaviors that contribute to those levels [14][15].

Adding contextual information to physical activity 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, our work intends to increase users' awareness of opportunities for physical activity in one's daily life.

III. Approach

We focus on monitoring and providing information about people's physical activity to assist them in self-awareness and self-reflection. Knowing oneself has been shown to foster self-insight [16], to increase self-control [17], and to promote positive behaviors, such as energy conservation [18]. While physical activity information can also be used for social comparison, competition, goal setting, and having a coach, we focus on how people would explore behavioral information if the system simply provided the information.

We build systems for sedentary people because research suggests that they are less aware of how active they are and need more information about how to become active compared to active individuals [10][11]. Consequently, we also focus on walking as a physical activity because sedentary individuals can more easily integrate walking into their daily lives than other forms of physical activity [19].

While there are many kinds of information that can be added to step counts, we focus on three different kinds of contextual information that the ubicomp community have explored extensively: *activity*, *place*, and *people*. As technologies that monitor this information become more robust, they can be more readily integrated into physical activity monitoring devices.

We took a specific user-centered approach in conducting our studies. We started with user needs and then created prototypes to observe how users use the technology. This approach is similar to technology probes [20], where low-fidelity prototypes are used to observe how people might use a new technology. There were three reasons for using this approach. First, we wanted to understand how increasing awareness of context about physical activity affects the user *before* we invest time and money on developing more sophisticated technology. Second, we 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.

IV. Current and Future Work

In this section, we discuss the three areas we are exploring and discuss opportunities for future work.

A. Benefits of Contextual Information

We explored what information sedentary people wanted about their physical activity. We interviewed 5 sedentary individuals (A1-A5) to understand their experiences with monitoring their physical activity. We also asked about what they did to become physically active. We analyzed transcripts of the videotapes and our notes. We identified two major themes:

1) *People have difficulty monitoring their physical activity*. All participants have tried keeping track of their activity using a monitoring and/or writing down the kind of physical activity they performed. They noticed progress when looking at their record, but stopped recording after some period (A1, A3, A4) or did not know what to do with the numbers (A1).

2) *There are opportunities to be physically active within one's daily life: in regular activities, in places around them, and with people they knew*. All participants preferred physical

activities that could be easily integrated into their existing lifestyles. A1 described her physical activity plan this way: "To do what I love to do in a way that is fun." Her activities included walking her dogs and bicycling. A3 did not use exercise equipment, but used places around her, such as stairs, her local mall, and the distance between her house and bus stop. A2 walked with people at her community center and A3 planned waling lunches with a co-worker.

Before building prototypes, we conducted a diary study [21] to find out what people would do with contextual information about their physical activity. In the diary study, 4 participants (B1-B4) 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 to see their aggregated step counts in real time; and 3) participants saw detailed printouts of their physical activity (from the BodyMedia software) at the end of the day. There were two major results. 1) *If given contextual information, people will use it to create associations with their physical activity.* Participants routinely matched segments on the physical activity graph with activities that they recorded in their journals to understand how much physical activity they performed for different activities. For example, B2 associated her evening physical activity spikes with dancing around the kitchen. 2) *People can benefit from having both real-time information and a historical review of the time-stamped step data throughout the day and weeks.* Participants liked the detailed daily reports of time-stamped data from the SenseWear armband during the third week, but they missed the real-time feedback (especially, seeing the numbers increase as the day progressed) from the pedometer provided during the second week. For example, B2 said that the detailed daily reports from the BodyMedia sensors were useful because she can compare between different times, but she also missed the ability to check her aggregate step counts throughout the day.

With lessons from the previous studies, we developed a prototype system called IMPACT (Improved Monitoring of Physical Activity using ContexT). Similar to the last study, 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. We conducted a 7-week field study of the prototype with 30 participants. We compared the prototype to a system that collected and visualized step counts only (*Steps-Only*). From interviews and surveys, participants revealed the value of contextual information compared to step counts only; they reported (on a 5-point Likert scale) greater awareness of opportunities for physical activity (3.93 vs. 3.57, $F[1,58]=5.32$, $p<.05$). Participants noted the usefulness of the IMPACT prototype. C12 said, "It helped me realize which activities were more important. For example, I didn't understand the importance of walking home versus taking the bus."

While contextual information can increase 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 two months that we deployed the prototypes in my previous studies). We 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? Additionally, a study should also observe whether contextual information could also help with comparing the reasons why a person is more active from one season versus another.

B. *Easing the Burden of Manual Recording*

While participants considered the first IMPACT prototype the most useful, they also said it was the least easy to use. Participants reported that manually logging the extra contextual information was too tedious. Fortunately, the problem is addressable; 90% of the participants reported they would continue using the system if collection of context information were more automated. We created a second version of the IMPACT system 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 (Figure 1).

Our observations suggest that other contextual information (*e.g.*, how busy the user is, weather) may be useful and perhaps more relevant to the user. Our prototypes recorded activity, location, and people, but existing records, such as electronic calendars and weather reports, may be leveraged to provide other kinds of contextual information.

C. *Advantages and Disadvantages of Automatic Recording*

We deployed the second version of the IMPACT system to 35 participants for 8 weeks comparing it to other versions of IMPACT without contextual information. This time around, having contextual information was not better at increasing awareness of opportunities for physical activity, instead, awareness of opportunities increased for all users, regardless of the system that they used.

A follow-up study that we did six months later revealed the

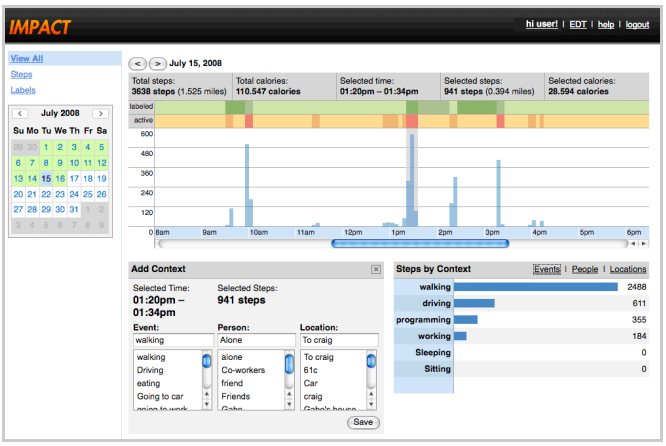

Figure 1. The second version of the IMPACT website. Steps graph (top) and context graph (bottom right).

value of the extra contextual information. All users were curious about the peaks they saw in their graphs, they wanted to know what they were doing during those times of peak activity. However, only users who had 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. These observations suggest that automatic labeling of contextual information is useful for reflection, especially, at a later time when users have likely forgotten their history. Another observation is that existing records, such as electronic calendars, may be leveraged to provide contextual information.

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. We observed from the prototypes that relieving the user of the responsibility to monitor contextual information by employing ubicomp technologies engaged users less. However, since more data has been 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 what the right amount of reflection is necessary to offset the loss of engagement from the automation of monitoring.

V. CONCLUSION

This research opens opportunities for the application and management of personal contextual information. First, there are opportunities to explore what role personal contextual information can play in giving users a better understanding of how their lifestyles affect their physical activity. Second, there are opportunities to create new systems to demonstrate how different computing systems can provide the necessary personal contextual information to improve awareness of physical activity. Lastly, there are opportunities to identify the issues that come with introducing manual and automated collection of personal contextual information to awareness of physical activity. We also hope that the results of this research will lead to better physical activity monitoring systems that will benefit people who are currently struggling to become active.

REFERENCES

[1] R. Pate, M. Pratt, and S. Blair, *et al.* Physical activity and public health: a recommendation from the Centers for Disease Control and Prevention and the American College of Sports Medicine. *JAMA*, 273, 1995, 402-407.

[2] Prevalence of Regular Physical Activity Among Adults United States, 2001 and 2005. *JAMA*, 299, 2008, 30-32.

[3] R.K. Dishman, W. Ickes, and W.P. Morgan. Self-motivation and adherence to habitual physical activity. *JASP*, 1980, 10, 115-132.

[4] C. Tudor-Locke, B.R. Bassett, A.M. Swartz, *et al*. A preliminary study of one year of pedometer self-monitoring. *Annals of Behavioral Medicine*, 28, 2004, 158-162.

[5] S. Consolvo, D.W. McDonald, T. Toscos, M.Y. Chen, J. Froehlich, B. Harrison, *et al*. Activity Sensing in the Wild: A Field Trial of Ubifit Garden. *CHI '08*, 1797-1806.

[6] S. Intille. A New Research Challenge: Persuasive Technology to Motivate Healthy Aging. *IEEE Transactions on Information Technology in Biomedicine,* 2004 September, 8(3): 235-237.

[7] J. Maitland, S. Sherwood, L. Barkhuus, I. Anderson, M. Chalmers, and B. Brown. Increasing the Awareness of Moderate Exercise with Pervasive Computing. *IEEE Pervasive Health Conference*, 2006, 1-9.

[8] M.S. Bravata, C. Smith-Spangler, V. Sundaram, A.L. Gienger, N. Lin, R. Lewis, C.D. Stave, I. Olkin, and J. Sirard. Using Pedometers to Increase Physical Activity and Improve Health: A Systematic Review. *JAMA*, 298(19), 2007, 2296-2304.

[9] B. Rooney, K. Smalley, J. Larson, and S. Havens. Is Knowing Enough? Increasing Physical Activity by Wearing a Pedometer. *Wisconsin Medical Journal*, 102 (4), 2003, 31-36.

[10] Physical Activity for Everyone: Overcoming Barriers to Physical Activity. Centers for Disease Control and Prevention, 2008. http://www.cdc.gov/nccdphp/dnpa/physical/everyone/get_active/overcome.htm

[11] J.F. Sallis and M.F. Hovell. Determinants of exercise behavior. Exerc Sport Sci Rev, 18, 1990, 307-330.

[12] J.A. Levine, M.W. Vander Weg, J.O. Hill, and R.C. Klesges. Non-Exercise Activity Thermogenesis: The Crouching Tiger Hidden Dragon of Societal Weight Gain. *Arteriosclerosis, Thrombosis, and Vascular Biology*, 26, 2006, 729.

[13] J.J. Lin, L. Mamykina, S. Lindtner, G. Delajoux, and H.B. Strub. Fish'n'Steps: Encouraging Physical Activity with an Interactive Computer Game. *Ubicomp 2006*, 261-278.

[14] J. Frost and B.K. Smith. Visualizing Health: imagery in diabetes education. *DUX '03*, 1-14.

[15] L. Mamykina, E.D. Mynatt, and D.R. Kaufman. Investigating health management practices of individuals with diabetes. *CHI '06*, 927-936.

[16] J.G. Hixon and W.B. Swann Jr. When Does Introspection Bear Fruit? Self-Reflection, Self-Insight, and Interpersonal Choices. *JASP*, 64, 1, 1993, 35-43.

[17] T. O'Donoghue and M. Rabin. Self Awareness and Self Control. *Time and Decision: Economic and Psychological Perspectives on Intertemporal Choice*, 2001, 217-243.

[18] C. Seligman and J.M. Delay. Feedback as a Means of Decreasing Residential Energy Consumption. *Journal of Applied Psychology*, 62(4), 1977, 363-368.

[19] G.J. Norman and P.J. Mills. Keeping It Simple: Encouraging Walking as a Means to Active Living. *Annals of Behavioral Medicine*, 2004, 149-151.

[20] H. Hutchinson, *et al*. Technology probes: inspiring design for and with families. *CHI '03*, 17-24.

[21] J. Rieman. The diary study: a workplace-oriented research tool to guide laboratory efforts. *CHI 1993*, 32-326.