Using Mobile & Personal Sensing Technologies to Support Health Behavior Change in Everyday Life: Lessons Learned

Predrag Klasnja[1], Sunny Consolvo[1,2], PhD,
David W. McDonald[1], PhD, James A. Landay[1,2], PhD, & Wanda Pratt[1], PhD
[1]University of Washington, Seattle, WA; [2]Intel Research Seattle, Seattle, WA

Abstract

Lifestyle modification is a key facet of the prevention and management of chronic diseases. Mobile devices that people already carry provide a promising platform for facilitating these lifestyle changes. This paper describes key lessons learned from the development and evaluation of two mobile systems for encouraging physical activity. We argue that by supporting persistent cognitive activation of health goals, encouraging an extensive range of relevant healthy behaviors, focusing on long-term patterns of activity, and facilitating social support as an optional but not primary motivator, systems can be developed that effectively motivate behavior change and provide support when and where people make decisions that affect their health.

Introduction

Although pharmacological advances have made great strides in decreasing morbidity and mortality from chronic diseases, lifestyle modification remains a key aspect of effective chronic disease management. Interventions that target lifestyle modification have been shown to be effective in the prevention and management of heart disease,[1] diabetes[2] and obesity.[3] Yet, patient compliance with lifestyle modification remains low. For example, fewer than half of heart disease patients continue to exercise six months following the completion of cardiac rehabilitation.[4] Numbers are similar for compliance with dietary recommendations.[5] Why is behavior change so difficult to achieve? Simply put, it is a complex process. Even a single change, such as increasing physical activity, likely requires the individual to restructure her priorities as well as her daily and social routines, such as finding time for exercise in the midst of work and family obligations. Encouraging health-promoting lifestyle change requires that interventions be integrated into everyday life, with support available when and where individuals make decisions that affect their health.

Mobile technologies that individuals routinely carry, such as mobile phones, may be a particularly effective platform for delivering such encouragement as they are likely to be with the individual when she most needs the support.[6,7] Over the past several years,

Figure 1: Houston (left) and UbiFit (right)

we have conducted early stage field studies of mobile technologies designed to encourage physical activity. In this paper, we describe key lessons learned from that work in an effort to help others who are designing systems to support health behavior change. We conclude with methodological reflections about how to design such systems so that they smoothly integrate into users' everyday lives while effectively encouraging lifestyle change.

Systems and Field Studies

We have designed two mobile phone-based systems to encourage regular physical activity: Houston and UbiFit. *Houston*[8] (Figure 1, left), the first system we designed, uses a mobile phone application and a pedometer to encourage users to increase their daily step count. The phone application provides a journal where users can review trends of their daily step counts, add comments to their step counts, receive small rewards for reaching their daily goal, share their step counts with 'fitness buddies,' and exchange messages with those buddies. We conducted a three-week field study of Houston with 13 participants, comprised of three groups of female friends from pre-existing social networks. Each participant was interviewed at the beginning of the study, after the first week, and at the end of the study.

Based on our experiences with Houston, results from other persuasive technology research, and behavioral and social psychological theories,[9] we designed *UbiFit*[10,11] a system that uses a mobile phone and a sensing device to encourage regular and varied physical activity. Two of UbiFit's components run on the user's mobile phone: (1) an *interactive application* used to journal physical activities, review activities done on any given day, and track progress toward a weekly goal, and (2) a *glanceable display* that uses an abstract, stylistic representation of the physical activities the user performs each week, displayed on her phone's background screen. The glanceable display provides weekly goal attainment status, physical activity behavior, and a subtle, persistent reminder of her commitment to physical activity. In our implementation, the display uses a garden metaphor to represent a week's worth of physical activity behavior. The garden blooms with different types of flowers to represent the different types of activities the user performs: walking, cardio, strength, flexibility, and other non-exercise physical activities (e.g., housework). Upon reaching her weekly goal, a large butterfly appears. Up to three smaller butterflies represent goal attainments for the prior three weeks (Figure 1, right).

In addition to the mobile phone components, UbiFit uses the Mobile Sensing Platform (MSP),[12] a pager-sized, battery-powered computer that uses a barometer and three-dimensional accelerometer to automatically detect the duration and start time of walking, running, cycling, stair machine, and elliptical trainer activities. When the MSP is worn on the waistband and within Bluetooth range of the phone, these activities are detected automatically. As they are detected, the activities appear both in the interactive application and on the glanceable display.

We conducted two field studies of the UbiFit system: a three-week trial and a three-month experiment. In the *three-week trial*,[10] 12 participants used UbiFit and provided feedback on the system and the automatic activity detection. As with the Houston study, each participant was interviewed at the beginning of the study, after the first week, and at the end of the study. Based on the results, we redesigned elements of the system, including improving the activity detection.

The revised version of UbiFit was evaluated over the winter holiday season in a *three-month experiment* with 28 participants.[10] Participants were randomly assigned to one of three experimental conditions: interactive application and sensing device only (no glanceable display), interactive application and glanceable display only (no sensing device), or interactive application, glanceable display, *and* sensing device (full system). Each participant was interviewed at the beginning of the study, at the end of the first month, and at the end of the study.

In the following sections, we discuss key lessons learned from these two research projects.

Lessons Learned

Four lessons from our work are particularly relevant to the design of mobile systems for encouraging health behavior change. These are the importance of (1) supporting persistent cognitive activation of health goals, (2) encouraging an extensive range of relevant healthy behaviors, (3) focusing on longer-term patterns of activity, and (4) facilitating social support as an optional but not primary motivator.

Supporting Persistent Activation of Health Goals

An important result of the three-month experiment of UbiFit was the significant difference in the weekly activity level between participants who had and did not have the glanceable display. The former group maintained their activity levels throughout the study, even though the winter holiday season is known for physical *in*activity. In contrast, the activity levels of the latter group decreased significantly. This result is consistent with the social psychological literature[13] on automatic goal activation. This literature finds that goals can be activated through environmental cues, and that such "primed" goals can effectively guide goal-directed behavior. The glanceable display kept the physical activity goals chronically activated, enabling participants who had the display to stay engaged with their commitment to physical activity. A participant explained:

[The garden] *was a constant reminder…whereas if you didn't have a* [garden]*, you probably—I wouldn't think about* [physical activity] *as much, you know.* [With the garden] *I think about it maybe subconsciously every time I look at my phone.*

Supporting this kind of persistent activation of health goals can be a powerful means of fostering health behavior change. Although a number of commercial mobile phone applications enable users to track their diet and physical activity, they are likely to yield results similar to those of our *no glanceable display* condition because they do not provide the persistent visual reminder. UbiFit is, to our knowledge, the only health application to date to use the phone's background screen to provide users with continuous feedback about a behavior they are trying to change. In addition, the stylized nature of UbiFit's display allowed users to maintain some level of privacy should their phone be seen by someone else.

Future directions. UbiFit's glanceable display subtly reminded participants about their commitment to physical activity *and* it provided feedback about their recent activities and goal attainment. Future work should investigate whether the former is effective without the latter. Other types of representations, for example, providing an encouraging message or drawing from a loved one, could be explored. Assuming the user strongly associates the representation with her health goals, it could be effective at achieving persistent goal activation. Whether such representations are sufficient on their own or if explicit, persistent feedback about recent activities is necessary should be further examined.

Encouraging an extensive range of healthy behaviors

Our work suggests that the system can substantially influence *how* the individual engages in health behavior change. Specifically, the activities that the system supports or encourages can become the focus of the user's efforts, potentially to the exclusion of other relevant activities.

An example will help clarify this point. Following health science literature on the effectiveness of pedometers, Houston attempted to encourage physical activity by helping users track their daily step count. Users could add comments to their step count (e.g., "Went for a bike ride"), but the system provided no other explicit functionality for tracking other forms of physical activity. This resulted in an unintended, negative side-effect. Several participants realized that the pedometer did not capture cardio activity well—for example, running three miles yields a lower step count than walking the same three miles and cycling yields no steps at all. As a frustrated participant explained, "*my main source of exercise* [rock climbing] *doesn't register*." Similarly, the pedometer did not distinguish between steps made while walking on a flat surface or up hills—although these activities differ in their intensity and in their ability to help individuals lose weight.

Because the system did not provide *proper* credit for these types of exercise, several participants simply chose not to do them. A participant noted, for example, that the pedometer did not "*care whether you went up and down hills or whether you walk on flats, so why kill yourself?*" This outcome was not what we intended. Based on this experience, we trained UbiFit's sensing device to detect a wider range of activities (walking, running, cycling, elliptical trainer, and stair machine), *and* we allowed participants to journal any other physical activity in the interactive application. As a result, 26 types of cardio activities were performed by participants in the three-month experiment, including skiing, cardio classes, dancing, swimming, and ice skating.

This experience highlights an important lesson that needs to be considered when designing systems for the support of health behavior change. Such systems not only help users track and modify their behavior, but insofar as the user becomes invested in using the system, the system also shapes how she thinks about the behaviors she is trying to change. The type of credit that the system provides could inadvertently encourage the user to focus only on activities that the system supports, potentially at the expense of activities that might be, from a health perspective, equivalent or even more important.

Future directions. With Houston, we tracked step count only; with UbiFit, we tracked and encouraged the range of relevant physical activities. To continue this trajectory, the range of healthy behaviors that are encouraged by the system could be further expanded, especially when the system is targeting the prevention and management of chronic diseases. In the case of heart disease, for example, a patient might not only need to increase physical activity, but also change her diet, reduce stress, *and* stop smoking. Our findings suggest that an effective system will support an extensive range of the healthy behaviors within the relevant areas of lifestyle change.

However, it is unlikely that every user will need to focus on changing all of those aspects of her life, or at least not all at the same time. Providing customization that allows the user (or health care provider) to select aspects of the system that are appropriate for the user's current needs, and adjust the system as her needs change, may improve the effectiveness of the system over time.

Focusing on long-term patterns of activity

Behavioral economics claims that individual actions can have a very different value than the *patterns* of those same actions.[14] If, while on her morning coffee run, an individual is deciding between ordering a black coffee (0 calories) and a caramel frappuccino (380 calories), the tasty frappuccino might appear much more appealing. However, if she is deciding which of those beverages to have every morning of the week, she may decide that the 2660 calories from seven frappuccinos are not worth it. The difficulty is that in the moment that decisions are made, individuals tend to focus on the current decision, and not on the pattern that such decisions form over time.

With UbiFit, the week's worth of activities and month's worth of goal attainments represented on the glanceable display encouraged participants to think about physical activity not as a one-off choice (e.g., Do I *need* to work out today?) but rather in terms of patterns of behavior (e.g., What did I do last week? What have I done so far this week? What can I still do to have an active week?).

Helping participants reflect on a week's rather than a day's worth of activity in the display meant that even if the participant had a couple of sedentary days, she would not necessarily be discouraged, as she could still have a good week. Just as importantly, seeing a week's worth of activity helped many realize how inactive they were—this awareness surprised most participants—and take concrete steps to be more active. A participant explained:

I used [the glanceable display] *to increase my awareness of what I was doing…'cause like…after about two days, you kind of forget, like 'did I really do that or am I just dreaming or was that last week?'*

Encouraging users to reflect on how each choice they make forms a pattern of behavior over time can be a powerful way to encourage health behavior change. Mobile devices offer an advantage over Web-based tools as they are often with the user when decisions are being made. A participant explained:

I liked having [my garden display] *be on the phone…something I have with me…*[with] *a Web site, it's so easy, 'oh, I didn't do anything, I'm not going to click on it.' It's so easy to ignore it. But on the phone, you can't really ignore it as easily…Otherwise, it's just…out of sight, out of mind.*

Over time, such tools could help users learn to conceptualize choices naturally in terms of how they create patterns, thus helping users internalize one of the most powerful means of ensuring self-control.[14]

Future directions. Future systems could further explore supporting reflections on patterns of behavior. For example, a system could help the user realize how other factors affect her healthy and unhealthy activities (e.g., location or other people). Similarly, a context-aware mobile tool could learn over time what challenges the user faces in trying to lead a healthy lifestyle and proactively provide support when she most needs it.

Facilitating but not depending on social support

Houston explicitly facilitated social support by providing features that enabled users to share step counts, goal progress, and messages with their fitness buddies. What we discovered in the Houston study, however, was that social support was a double-edged sword: participants enjoyed sharing their step count when they were being active and were motivated by positive feedback and seeing their buddies do well. But participants were often not comfortable sharing when they were less active, and some felt that sharing introduced too much competition. The effect of social support on users' motivation was decidedly mixed.

Based on these findings and similar results from others,[15] we realized that while social support can be helpful, it should not be the primary strategy used to motivate health behavior change. With UbiFit, we designed a system to motivate users to engage in physical activity without using social support as a primary motivator. However, sharing regularly took place anyway. Participants routinely showed their gardens to family and friends, and for some, family members helped to encourage physical activity. A participant explained,

[My daughter] *would really encourage me to* [be active] *and she would ask me for pink flowers all the time...She was very excited, and she wanted* [me to get] *the butterflies*.

Similarly, family members and friends who participated in the study together often compared their gardens, somewhat replicating the sharing functionality explicitly facilitated by Houston. As with Houston, however, UbiFit participants felt uncomfortable when someone would ask to see their garden when they had not been very active.

Future directions. While social support can be a powerful strategy for encouraging behavior change—and users engage in it even when the system does not facilitate it—it can also hamper motivation and even introduce social friction (if, for example, someone initially shares her data, then later decides to stop). Although health behavior change systems could benefit from facilitating social support, they should not depend on it. In addition, future work should explore *how* to incorporate social support. For example, while the system should allow users to determine what to share with whom, an open design challenge is how to allow the user to adjust these settings easily as circumstances change. Without such control, social support can backfire, ultimately leading to system abandonment.

Discussion & Conclusion

Unlike technologies that individuals have to use—as part of their jobs, for example—the use of technologies for health behavior change is often discretionary. For such systems to be effective and continue to be used, they must be well designed with careful consideration given to how they will fit into everyday life. *How* functionality such as journaling, feedback, or social support is designed can make or break the effectiveness of a system, and even lead to system abandonment (and, potentially, abandonment of the behavior the system was trying to encourage).

Designing for integration into everyday life while effectively encouraging health behavior change is complicated. Important effects of a system's design often cannot be anticipated in advance. When a system is used in the field by individuals from the target audience, even for a short period of time (e.g., a few weeks), important issues surface that cannot easily be predicted or found during initial system design or in usability lab evaluations.

In our work, we follow a user-centered design process, common to the field of human-computer interaction (HCI). We engage target users early and often. We employ surveys, as well as beta testing with the research team and friends and family for weeks to months. Following beta testing, we employ short-term field studies (e.g., a few weeks) with small numbers of participants (e.g., 12-15) who are asked to use the technology in their everyday lives. We redesign our systems based on these results prior to going into the field with more formal, long-term experiments. In our studies, we combine quantitative data collection methods with qualitative methods, where participants are often interviewed in depth about their experiences with the system. The insights we have gained from the qualitative methods have been critical to our developing a system that has effectively encouraged health behavior change.

Such HCI-style practices could greatly improve the effectiveness of technologies developed for medical informatics research. It is through rich qualitative data and use in the field that subtle, yet critical, design problems are often revealed, the timely discovery of which may determine how effective a system proves to be in clinical trials. (See [16] for a discussion of the value of such data even in RCTs)

As the prevalence and cost of chronic diseases continue to rise, the need for lifestyle modification as a means of prevention and treatment becomes greater. In this paper, we have argued that carefully designed mobile interventions can be a powerful way of fostering health behavior change. By supporting the persistent activation of health goals, encouraging an extensive range of relevant healthy behaviors, focusing on patterns of activity, and facilitating optional social support, effective systems can be designed to help people live long, healthy lives.

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