Persuasive Wearable Technology Design for Health and Wellness

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***Abstract*—Given the world's obesity epidemic and battle with chronic illness, there is a growing body of research that suggests that a moderate physical lifestyle has significant impact on psychological and physical health. Wearable computing has the potential to encourage physical activity by increasing health awareness and persuading change through just-in-time feedback. This form of technology could help individuals manage lifestyle related factors and implement healthy routines. In this paper, we explore the benefits and tradeoffs of current wearable health technologies along with the persuasion methods employed by their designers to motivate healthy behavior change. We also discuss the challenges and limitations of implementing wearable technologies and suggest possible improvements.**

I. Introduction

The current healthcare system faces many challenges in view of the widespread obesity epidemic. In the U.S. alone, over 60% of adults are overweight [1] - a 3-fold increase since 1991. Apart from poor dietary choices, physical inactivity is a major contributing factor. Research has shown that engaging in moderate physical activity, such as walking, has many long-term health benefits [2]. Despite this modest requirement, the majority of the population fails to meet these recommended levels for good health. Research suggests that the over-reaching problem is one of self-motivation [3].

Wearable technology has the potential to build motivation by increasing health awareness through timely feedback. It can be a ubiquitous tool to help individuals manage their life style toward a more user-centric health management. More importantly, wearable computing can decentralize healthcare and wellness by giving more control to the patient and shifting the focus from treatment to prevention.

Recent technological developments have made it possible to obtain objective measurements of physical activity by means of pedometers, accelerometers, and various other devices. This form of automated data gathering and presenting has allowed the user to gain awareness into their physical activity patterns. While increasing awareness could lead to situations conducive for change, additional efforts are required to persuade actual behavior change. In the field of wearable computing, persuading change can take on the form of health monitoring information, such as blood sugar levels, and providing sensory feedback via visual and haptic output. The technology can encourage change by rewarding positive behavior through a variety of methods such as meaningful messages, attractive visuals or points in gaming system.

In this paper, we explore a small representative sample of wearable health technologies from industry and research with respect to their goals, how they gather and present information, and the persuasion methods they use. We investigate the various benefits and tradeoffs of the different designs and highlight some of the challenges and limitations faced by current systems. We conclude by suggesting areas for improvement and a discussion of future possibilities.

II. Taxonomy for Wearable Health Technologies

As a first step, we introduce a taxonomy for understanding wearable health technologies that highlights key aspects of each design. We examine wearable health technologies from three modest lenses that take a user-centered approach.

A. Goals and Users

In the area of health and wellness, the design of wearable technologies has predominately focused on diet and physical activity. Some of the goals here have been towards weight loss, motivating physical activity, maintaining exercise routines, and an overall better understanding of an individual's health. The implementation of these goals in the wearable device are in turn dependent on the target population. For example, in designs for children, the feedback mechanisms are especially important since research has suggested that quantifiable measurements are less likely to cause a connection with health [4]. Moreover, designs that have proven effective in motivating physical activity in adults might prove ineffective for children since they lack direct control over their environment. We cover the specific goals with respect to the target users, the evaluation methods used, and the corresponding results of each wearable technology.

B. Persuasion Methods

Motivation is a key element in any system designed to assist users in changing their health behavior. While there are some users who maintain active lifestyles, in most of the sedentary population, there is a strong need for external incentives and motivations. In relation to technology, BJ Fogg described this idea best as persuasive technologies - "*computer based tools designed for the purpose of changing people's attitudes and behaviors*" [5]. In this paper, we examine wearable health technologies from the perspective of three persuasion methods: self-monitoring, social influence, and fun interaction.

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In self-monitoring technologies, health awareness is typically accomplished through real-time sensors that continuously track a particular health parameter. When these systems are coupled with a digital journal, they help users maintain a routine by providing interactive goal setting and feedback on progress.

Group dynamics and social influences can also play a key role in motivation. Systems that support this form of interaction allow a group of friends or peers to share information (social networks), have common health goals, or compete against each other. As a result, an individual in the group reflects more on her daily activity due to the collective experience of sharing or competing with her peers.

Another way to motivate healthy activity is to make the desired behavior fun and enjoyable; this is often accomplished by providing a gaming experience. A good example is the Nintendo Wii Sport, where players use the Wii Remote to mimic actions performed in real sports, such as swinging a tennis racket. Another way to create enjoyable interaction is through music. Runners, for example, often listen to music on portable players for enjoyment and motivation during workouts.

C. Data Presentation

The data presentation layer is especially important in wearable technologies because the devices often have size and power constraints. These considerations differentiate wearable systems from traditional computing devices, such as PCs and laptops which have larger displays and established interaction mechanisms. In examining this aspect of the wearable health technology design, we study the mechanisms used in presenting data to the user, whether it be visual, auditory, or haptic. We also investigate the meaningfulness of the data and how the presentation layer conveys this information.

III. Wearable Technologies

There is a large body of research concerning body sensor networks (BSNs) and body area networks (BANs) for strict biomedical monitoring. These medically oriented wearable health technologies are generally used to provide real-time feedback of a patient's health to a medical professional. While this is a promising area of research, we focus on *preventative care wearable technologies for physical activity that are more user-centered and fit in users' everyday lifestyles*. As such, many of the wearable technologies discussed in this paper employ smart phones or PDAs to either offload the computational burden or to serve as a presentation layer.

A. Health and Wellness Applications

The two primary foci of health and wellness applications in the preventative healthcare space are physical activity promotion and diet. Wearable health applications have focused mostly on the former since automatically inferring diet still remains a challenging problem. As a result, almost all systems still employ some form of manual user input when tracking diet.

1) Commercial: In the commercial sector, one of the earlier more successful devices includes Nike+iPod (nikeplus.com), which employs a sensor in the runner's shoe and an iPod to keep track of the current pace and distance of a workout. In addition to tracking personal workout statistics, the runner can connect to an online community through the Nike+ website where she can track goals, compare running times with others, and challenge friends. While Nike+ is designed for the specific activity of running, FitBit (fitbit.com), BodyMedia Fit (bodymedia.com), and Jawbone UP (jawbone.com) track everyday activities like walking (steps taken), climbing stairs (number of floors), and sleeping (hours and quality of sleep). Much like Nike+, all these wearable devices, sync with an e-health application through a wireless base station. Additionally, they provide users with the ability to log individual foods and workouts from a smart phone or computer to track diet and exercise. BodyMedia Fit is geared towards weight loss and is worn as an armband, while FitBit and UP focus on smaller lifestyle changes, and are clipped to the waist, and worn on the wrist, respectively.

2) Research: Perhaps the most common device used by researchers to detect and promote physical activity is the pedometer. The three most notable studies in this area are Fish 'n' Steps [6], Houston [7], and Chick Clique [8]. In Fish 'n' Steps, the user's step count is mapped to the growth and emotional state of a virtual fish in a fish-tank. The tank, that also contains the virtual fish of other users, is displayed in a public kiosk. The users periodically enter their step counts in the kiosk and get feedback on calories burned, team rankings, and suggestions for improvement. In both Houston and Chick Clique, pedometers were coupled with mobile phones to provide users within a group the ability to share daily step counts; Houston also contained a mobile fitness journal for tracking personal goals apart from the group. While Houston was developed with adults in mind, Chick Clique was primarily developed for teenage girls.

A shortcoming of pedometers is that they are unable to infer other types of activity such as cycling or climbing stairs. To address this problem, the designers of UbiFit [7] employ a custom sensing device clipped to the user's waist to determine physical activity. Based on the activity level, the associated smart phone application displays an empty lawn at the beginning of the week with flowers growing as the user works out during the week. Users can set weekly workout goals and are rewarded with a butterfly when a goal is met. For active users, TripleBeat [9] employs a wireless heart rate monitor and a mobile phone to help users achieve healthy cardiovascular goals through real-time musical feedback. Based on the user's heart rate, it selects songs with specific tempos from the user's music library. TripleBeat also allows users to virtually compete with their past performances or with other partners. Taking a simpler approach, Pediluma [10] encourages opportunistic physical activity through a shoe accessory that varies the intensity of light in the wearable enclosure based on recent walking activity. In particular, the light brightens as the user walks more and slowly dims as they remain stationary.

B. Taxonomy Discussion

1) Goals and Users: It is difficult to evaluate many of the commercial systems with respect to their health goals since they lack accompanying research studies assessing their effectiveness. However, among these systems, BodyMedia funded a 9-month research study with 197 adults to evaluate their electronic armband for weight loss [11]. At the end of nine months, researchers found that the group-based armband program showed the most significant weight loss followed by the self-directed armband program. Interestingly, a few participants from the non-armband self-directed control group, also showed significant comparable reductions at the end of 9 months. Even though these individuals were assigned to the control group, they manually tracked their diet, weight and activity levels daily. It would be interesting to compare how these motivated individuals perform with and without technology since it is unclear what aspects are crucial to behavior change. Perhaps the key to these participants' success lies in the self-monitoring methods they employed as a result of their motivation.

Rather than a self-monitoring approach, the researchers behind Fish 'n' Steps employed social influence as the key motivator in their computer game. They assessed the effectiveness of their system on 19 adults that worked in their research organization over three and a half months. Unlike BodyMedia Fit, they used the Transtheoretical Model (TTM) of Behavior Change to assess participants' motivations and attitudes towards physical activity. They found that 14 of the 19 participants who completed the study either increased their step counts or positively changed their attitudes regarding physical activity or both. Similarly, the creators of Houston, found that in a three week study with 3 groups of women (N=13), comprised of 2 sharing groups and 1 personal group, that the sharing groups were more likely to meet their step count goals. However, the primary goal of this study was towards design requirements for physical activity promotion technologies rather than a quantitative evaluation of the system. In a similar trial, except with two groups of female teens (N=7), Chick Clique researchers found that while high school girls increased their step counts due to sharing, middle school girls took more steps when using it alone. These results seem to suggest that the effectiveness of social influence might be bounded by factors such as age, however it is difficult to conclude that this is the case without further research.

While not pedometer based, the creators of Pediluma employed a pedometer in evaluating their shoe accessory. Eighteen adults wore covered pedometers and were randomly assigned to one of four groups: control (just the pedometer), Pediluma (fully-featured shoe accessory), random light (shoe accessory that produced random lighting), no light (shoe accessory without any lights). The random light and the no light groups were included to test whether the mere presence of light or shoe-mounted device would increase physical activity. Over the course of the two week study, the researchers found that all except the Pediluma group decreased in step count; the Pediluma group step counts increased by approximately 8%. Interestingly, unlike Fish 'n' Steps, there were no significant changes in attitude towards physical activity and health. The investigators contend that the change in walking behavior with the Pediluma group might have been a subconscious decision since the device was peripherally visible at all times. Despite the lack of quantifiable evidence, there might be some basis to this claim as the designers of UbiFit observed that in their three month field study (N=28), participants with the glanceable display maintained activity levels when compared to participants without one. Additionally, participants confirmed the persistent and subtle effectiveness of the glanceable display during the qualitative portion of the study.

In a similar subjective analysis, the designers of TripleBeat, found that their system was mostly successfully due to its glanceable interface rather than its virtual competition. Towards helping runners achieve exercise goals, the researchers conducted a study with 10 runners in 4 outdoor running sessions and discovered that a majority of runners spent significantly more time in their respective training zones due to the glanceable display. Participants considered the virtual competition, however to be the most important contributor to enjoyment.

When examining the studies detailed above, we must be cautious in accepting some of the claims they make. From a quick cursory glance, it seems like all the studies were successful in accomplishing their goals. However, it is unclear what role technology actually plays in motivating change. When evaluating goal setting or self-monitoring through technology, we must also ask if a similar manual approach would yield the same results. There is no doubt that technology gives us the ability to continuously track difficult metrics like heart rate, and present the information through a variety of interfaces; but of what value is this data in motivating change? Moreover, is success in one study generalizable to the majority? Most of the studies we discussed were small field trials (excluding BodyMedia) with relatively small sample sizes of mid-to-high socioeconomic status individuals who were comfortable using technology. Furthermore, in some of the studies the participant groups were homogeneous; for example, in Fish 'n' Steps the participants all had graduate degrees, while in the Houston study the participants were all women. Even in the larger BodyMedia study the participant sample was a homogeneous group of highly educated (77%) women (82%) [11]. As a result, in evaluating these technologies, we must critically ask if these new systems really have the capacity to change people's behavior, especially given that research studies face problems such as participant attrition, novelty issues, and Hawthorne effects.

2) Persuasion Methods: The technologies presented in this paper fundamentally address the problem of motivating physical activity by raising self-awareness. The idea is that by becoming aware of the activity or lack thereof, individuals have opportunities for self-reflection. This act of self-reflection might in turn persuade them towards positive healthy behaviors. To this end, the technologies discussed earlier employ methods such as self-monitoring (including goal setting), social influence, fun interaction, or some combination of the three.

There is no doubt that our emotions, opinions, and behaviors are influenced by our family, friends, and co-workers. However, it is difficult to establish the social circumstances that lead to behavior change. While a number of studies including BodyMedia, Chick Clique, and Houston have shown the positive motivating effects of social groups, the boundary conditions of any such social influences are not well established. Understanding the boundary conditions is important because it allows us to predict how the social influence will be self-regulated across a range of social interactions. From a health perspective, this process of self-regulation can mean conscious personal health management where individuals plan, monitor, and evaluate personal progress towards their health goals. As Chick Clique seemed to suggest, social influence might be bounded by factors such as age; however, this is unclear as it could also be that middle school teens simply did not prefer interacting through the mobile phone, thereby limiting the effects of social persuasion. From a research methodology perspective, studying social influence and its boundary conditions can be a challenging problem in itself. For example, the researchers behind BodyMedia found that their non-band group weight loss program did not perform as well as other published studies. They posited that perhaps this was because participants were disappointed with their group assignments. In conducting studies that evaluate social influence, it is hard to guarantee the formation of social bonds or evaluate existing relationships.

We face similar problems when studying aspects of fun interaction. For example, in Fish 'n' Steps, participants thought that the competitive aspect of the game was unnecessary since they faced enough competition in real life, while in TripleBeat participants reported that competition was essential for enjoyment. Indeed, what is enjoyable is dependent on context, age, gender, culture and various other factors. Moreover, how do you guarantee sustained fun interaction? Some participants in Fish 'n' Steps perceived the game as increasingly repetitive as the study progressed. Perhaps as one game designer suggests, the answer lies in "cycles of tension and release," where players constantly experience emotional ups and downs during gameplay. The goal of the game in this case is to create tension but also provide the player the tools to overcome the tension, whether it be to score a goal or defeat an enemy. These cycles of tension and release are repeated hundreds of times throughout the game in both the overall story and moment-to-moment gameplay to keep players excited and engaged.

The issue of long-term sustainability also plagues self-monitoring approaches. For example, would users still respond the same way to the lighted enclosure in the Pediluma shoe accessory after 2 or 3 months? Self-monitoring health technologies have a tendency to constantly display or remind users about some aspect of their health. This form of electronic nagging might prompt some users to discard the device. Furthermore, constant biomonitoring technologies such as TripleBeat or BodyMedia might induce anxiety in some users where they are aware of bodily signals but cannot manipulate them for a desired effect. A more troublesome side-effect might be the increase of stress due to the constant bombardment of outside cues. What are the cognitive implications of receiving reminders about our heart rate every hour or hearing an audible alarm for passing certain physiological thresholds?

3) Data Presentation: Naturally, with issues such as stress and anxiety, feedback frequency and data presentation methods play a crucial role in wearable technology design. Most of the technologies presented in this paper increase self-awareness primarily through visual feedback with a few employing haptic and auditory methods. Does awareness imply self-reflection? Does being aware of step counts (pedometer) everyday consistently promote thoughts of physical activity? The results suggest that perhaps this is the case in the short term, but what about the long term? If pedometers were to be used for 6 months, would the step count number still be meaningful to the user? The user might be aware of their daily steps but it might not elicit a positive behavioral response. Therefore, data representations need to communicate the importance of the physical activity in meaningful and intuitive ways.

In this respect, a number of technologies presented here provide aesthetic representations of physical activity. Fish 'n' Steps uses a virtual fish as an anthropomorphic avatar to relay step count information through a desktop PC. By doing so, it tries to engender emotional and relational skills in the user and thereby motivate behavior change. Research has shown that while this may not lead to a significant difference in physical activity (when compared to non-relational groups), the users have a significantly greater desire to continue working with the virtual agent [12]. Similarly, FitBit uses a small virtual flower that grows and shrinks, depending on activity levels, and Ubifit abstracts physical activity through a virtual garden displayed on a smart phone. Perhaps the simplest abstraction of activity is light intensity as used by the Pediluma shoe accessory. It leverages social pressure by publicly presenting the information to onlookers (family, friends, and peers). However, this approach might lead to privacy issues for users who are uncomfortable with sharing their physical activity information. Regardless, all these implementations try to provide meaningful representations of data through glanceable displays that are minimally intrusive and present information simply without requiring too much user input.

For specific activities such as running, however it might be valuable to have particular metrics such as heart rate, current pace, time, and distance explicitly available to the user. Both Nike+Ipod and TripleBeat employ glanceable displays to provide these real-time metrics to support runners' goals. Nike+Ipod requires the user to be aware of their goals and monitor the Ipod display to adjust their pace. Triplebeat also provides a similar feedback display, but goes a step further and requires the runner to specify the workout in terms of intensity as measured by heart rate. It then motivates the runner by playing music that has fewer or more beats per minute. This audible feedback mechanism based on the runner's target heart rate frees her from constantly looking at the glanceable display and intuitively informs her on how to change her current pace. Apart from serving as an auditory cue, the music itself can serve as an influential component during a run.

While visual displays are often used as the primary method for data presentation in wearable systems, Jawbone's UP showcases haptic feedback. The UP wristband uses a small motor to vibrate inactivity alerts to its users. As opposed to a traditional visual indicator that requires the user to glance at a display or an audible tone that can disrupt others, UP's vibrotactile feedback mechanism is private, silent, and requires little change in user behavior. To summarize, the salient issues when designing wearable health systems are meaningful data abstractions and intuitive feedback mechanisms.

IV. Areas of Improvement and Possibility

Many individuals have had the experience of joining a gym or starting a diet only to give up soon after. These experiences emphasize the need to provide health technologies that support users in making small, gradual changes. But how do we support these changes, given varying levels of user motivation? For already motivated users who exercise regularly, wearable technologies might need to play a supporting role; these individuals might enjoy being able to track, quantify and analyze physical activity. For less motivated users, wearable technologies might need to play an encouraging role that is more peripheral to their everyday lives, one in which the technology slowly guides them towards increasing levels of physical activity. Both these assumptions, highlight the dependence of the wearable technology on the individual users. Indeed, as Maitland et al. have suggested, one of the problems with current physical activity technologies is in their failure to accommodate individual differences [13]. Moreover, existing wearable health technologies have focused primarily on pre-built devices that lack a sense of personal investment. The user has had little, if any, input into constructing the device or controlling how it responds. Why not allow this possibility?

By creating an ecosystem of modular wearable components, we can empower users to craft their own wearable health solutions. We can facilitate the design of novel wearable systems, tailored to each user through a plug-and-play component framework. This approach requires a well defined interface between all the plug-and-play computing components and an intuitive programming environment. Modular components are both tenable and well within our reach because of recent developments in open source electronics platforms such as the Arduino and drag-and-drop programming environments like Scratch for Arduino.

In many ways, health and wellness are personal issues that require a more dynamic approach than pre-built wearable technology. Fundamentally, users are learning new health habits that require time and effort. By providing users the ability to create their own technologies, we account for individuals differences and support progress at different paces. Additionally, we engender greater investment and commitment to the wearable device by providing them with the ability to express their own aesthetic sense. One of the advantages of this approach is that different devices can be created for monitoring and promoting health, based on the interest, mood and social group(s) of the user. By creating modular computing components we empower users to create wearable health sensing devices more diverse and novel than what we can imagine. In viewing wearable health systems as combinations of smaller technologies (components), we advocate an outlook where technology evolves to support a user's changing motivations and health needs.

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