BeActive: Encouraging Physical Activities with Just-in-time Health Intervention and Micro Financial Incentives

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ABSTRACT
Encouraging patients with cardiovascular disease to be more active is one of the critical challenges in conventional rehabilitation programs. Rehabilitation programs are mostly offered at specific times and locations (e.g., clinical facilities or in-home exercise programs), which are the root causes of participation barriers. We envision that use of mobile and wearable technologies can overcome such spatial/temporal restrictions and offer novel opportunities for promoting physical activities in their everyday lives. In this work, we introduce BeActive, a mobile-based intervention platform that delivers just-in-time intervention messages to help patients to be more active in their daily lives. The key innovation of BeActive is to leverage fine-grained tracking of user behaviors to deliver just-in-time feedback and to incentivize health behavior maintenance via micro financial rewards. To show the feasibility of BeActive, we conducted a preliminary study for seven days (n=5), and presented several design improvements for just-in-time health intervention.

Author Keywords
Just-in-time health intervention; rehabilitation system; micro financial incentive; prolonged sedentary

CCS Concepts
•**Human-centered computing** → **Empirical studies in ubiquitous and mobile computing;**

INTRODUCTION
Cardiovascular diseases (CVD) such as heart attacks and strokes is one of the leading causes of ill-health and disability worldwide. The unhealthy behaviors in everyday lives (e.g., lack of physical exercise and poor dietary habits) are the main reasons for cardiovascular diseases. To reduce cardiovascular risks for CVD patients, rehabilitation programs (e.g., self-management and secondary prevention programs) are commonly recommended. Existing rehabilitation programs are typically hosted in clinical facilities or community centers. However, CVD patients often face significant barriers to participate in such rehabilitation programs due to lack of time, motivation, and social support. For example, Jin *et al.* [7] found that many people refused to participate in rehabilitation programs because of time conflicts and difficulties in commuting to rehabilitation centers.

Overcoming the barriers to participation is one of the holy grails for successful rehabilitation. As a promising solution, researchers explored home-based rehabilitation programs, which can significantly reduce the burden of patient participation [4]. This approach, however, still shows a limitation on everyday lives outside the home because of their physical constraints (e.g., rehabilitation devices mostly located at home). According to the literature, everyday physical activities known as non-exercise activity thermogenesis (NEAT), such as walking or doing chores play a critical role in increasing metabolic rates for controlling body weight [10]. In our work, we explore how mobile and wearable technologies can be leveraged to help improve NEAT activities along with traditional rehabilitation programs (e.g., clinical facilities and in-home programs), thereby greatly lowering spatio-temporal barriers of existing solutions.

Toward this goal, we introduce BeActive, a mobile-based health intervention platform that supports just-in-time (JIT) health interventions and micro financial incentives for promoting physical activities in everyday life contexts of CVD patients. BeActive also provides a web portal for clinicians or caregivers, such that they can provide exercise prescription, monitor CVD patients' behaviors (e.g., checking status), and provide social support for goal achievements. Combining mobile devices with web portals is the key challenge of our work. To overcome these issues, we built a prototype system and conducted a preliminary study for seven days to examine feasibility. We interviewed the participants to uncover usability issues. Our results revealed several areas for design improvements in intervention delivery and micro-incentive mechanisms.

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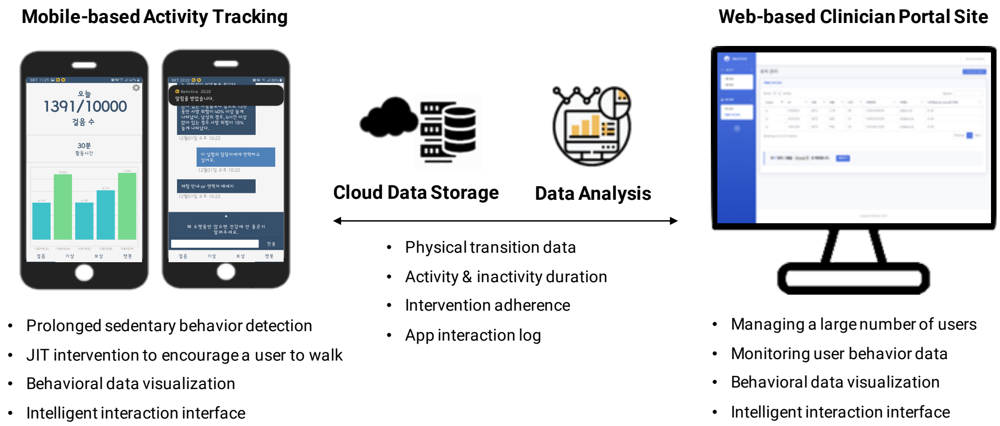

Figure 1. BeActive System: the mobile app (left) and the web portal (right)

BACKGROUND AND RELATED WORK

As smartphone and wearable technologies have advanced dramatically over the past decade, there have been several attempts to use mobile technologies in rehabilitation programs for CVD patients [5]. Among those attempts, JIT interventions were one of the most common strategies to help patients in rehabilitation programs [11]. Sensor data from mobile devices were used to identify opportune moments for health intervention delivery (e.g., problematic situations, or most available time slots). Existing examples of JIT interventions include smoking cessation [14] and stress management [16].

Many researchers have tried to maximize the effectiveness of the intervention. Specifically, offering financial incentives is a well-known motivator to encourage physical activity, such as walking [2]. In addition, the intervention for physical activity can be more effective when performance feedback was integrated [1]. In our work, we incorporate financial incentives and performance feedback with sensor-based activity tracking. We expect that by sending performance feedback with the amount of reward they receive, users are to be more adherent to interventions.

Digital therapeutics is a subset of digital health tools to prevent, manage, or treat a medical disorder or disease. Software-based therapeutic intervention requires clinical validation with randomized clinical trials. Effective therapeutic intervention should be able to incorporate clinicians or caregivers in the loop; these stakeholders not only provide specific guidelines for behavioral changes but also emotional and information support. Active participation of such stakeholders can effectively deal with major obstacles, such as lack of time [9] and information overload [6] for CVD rehabilitation. Thus, tracking and managing patients is essential for clinicians to properly prescribe required physical activities, track patient progress, and provide feedback in rehabilitation programs. However, many clinicians experience difficulties in offering suitable data-driven consultations based on the condition of patients. Therefore, it is important to develop an intuitive user interface for data-driven prescription/maintenance that enables clinicians to understand patients' exact history and current status. Kim [8] found design implications for a clinician interface through a workshop and implemented a novel interface called DataMD, which supports data-driven tracking and consultation. Our goal is to extend this work by connecting missing links between web portals and mobile devices so that clinicians can check patients' behavior, such as physical activities or adherence rates, with rich visualization graphs and prescribe suitable exercises in real-time.

BEACTIVE SYSTEM

BeActive consists of a mobile app and a web portal (see Figure 1). BeActive mobile app encourages users' physical activity via JIT intervention/feedback and micro financial incentives. Users' physical activity data are collected into the cloud data storage. The collected data are then analyzed for visualization that helps clinicians to monitor and interact with the patients.

BeActive mobile app continuously monitors user's physical activities and identifies users' prolonged sedentary behaviors using Google's Activity Recognition Transition API [1]. When a user's smartphone remains stationary (i.e., no physical activities for an hour), the system delivers a JIT intervention in the form of push notification (e.g., a simple contextualized suggestion for walking).

To improve a user's adherence to prompted interventions, BeActive offers micro financial incentives associated with fine-grained physical activity outcomes, as shown in Figure 2. We give 300 points for standing up after intervention delivery; 200 points for walking extra 500 steps after intervention delivery; 400 points for voluntarily moving around 10 min before the scheduled intervention delivery; and 100 points for every 1,000 steps walked (no intervention prompts delivered). BeActive mobile app offers a rich visualization UI to helps users to self-monitor physical activities and track adherence history and reward amount.

The web-based portal helps clinicians to monitor BeActive mobile users' physical activity data in real-time and interact

[1] https://developer.android.com/guide/topics/location/transitions.html

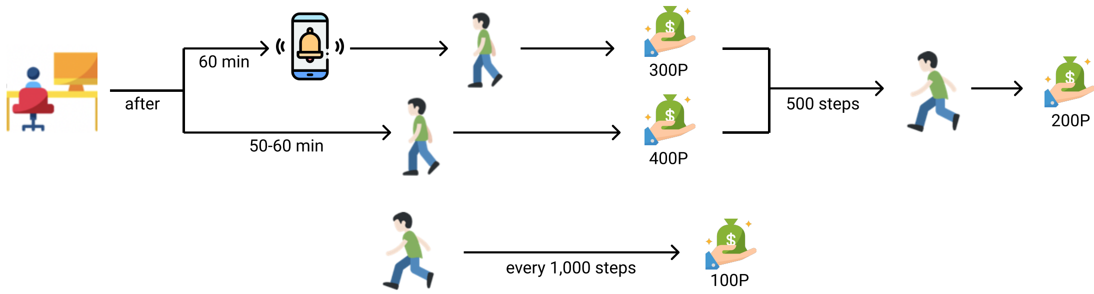

Figure 2. BeActive micro-incentive mechanism

with the users via chatting interfaces. For example, the web portal shows the number of prompted interventions and adherences, and durations of sedentary behaviors. Clinicians can refer to the data to properly prescribe physical activity levels and help maintain their behaviors via a chat interface implemented on the web portal. For example, clinicians can interact with users, such as giving advice and feedback. These can alleviate the users' barriers to participate in rehabilitation programs such as work or time conflicts and difficulty with the commute to a rehabilitation center.

For system development, we used a user-centered design method. We first came up with basic design ideas via a design workshop. After extracting key features, we built paper-based low-fidelity prototypes for the mobile app and web portal. We also went through several rounds of small-scale user studies to improve the usability of the prototypes. We made a computer-based low-fidelity prototype with a prototyping tool, called Figma. Finally, we built a minimum viable product that includes the key features illustrated above.

We conducted a preliminary study to evaluate the usability of our prototype system. We recruited 5 participants (one female) who had no difficulty in walking, and their ages ranged from 23 to 34. These users have been using at least one mobile fitness app, such as Samsung Health. We asked them to use the BeActive mobile app for seven days. All participants received $10 by default and additionally rewarded based on their points collected during the study: 10,000 points = $1. After the preliminary study, we interviewed all participants to evaluate their user experiences.

Adherence rate of the JIT intervention

All participants expressed positive opinions about JIT health interventions for promoting physical activities. During the study period, our participants received on average of 3.1 (SD = 0.9) intervention messages per day. Their adherence rates, however, were mere 9.4% (SD = 5.0) on average. Our participants attributed the low adherence rates to receptivity. Receptivity is defined as the conditions where users can receive, process, and use the prompted intervention [12]. The participants often missed many intervention messages, because they become insensitive due to the frequent intervention messages (known as intervention fatigue) [13]. One participant said, *"I became insensible to feedback because there were so many similar messages I received."* (P1) Availability is critical for receptivity; our participants stated that there are many instances that they could not follow the interventions even if they successfully received the messages. One participant told, *"I thought I should get up after receiving a notification, but the intervention was often delivered in the situations where I could not do so, which embarrassed me."* (P4)

Effects of the incentive mechanism

During the preliminary study, the participants received 5,620 points (SD = 2,720). All participants mentioned that they were satisfied with the incentive mechanism. However, they mentioned that, in some cases, the incentive did not motivate them enough to walk, in particular when they were busy or tired. One participant mentioned, *"I did not walk because I was busy at the time of intervention and it was cold outside."* (P5) Another participant also expressed, *"Accomplishing walking reward is not easy in the workplace, because it takes longer to complete than other situations. So, I want more reward for that."* (P3)

DISCUSSION AND FUTURE WORK

We introduced BeActive, the JIT mobile health intervention system, and we showed the results of the preliminary user study. BeActive can track user activities for prompting JIT interventions and offer micro financial incentives for maintaining adherence rates. Despite its potential, our user study revealed several directions for improvements.

First of all, receptivity issues are critical to intervention adherence. Intervention delivery should be scheduled at opportune moments. For example, Sohn et al. [17] found that a context-aware reminder is effective to make people be aware of a task. We can also consider users' contextual factors to find opportune moments for better intervention receptivity. Choi et al. [3] revealed that there were many contextual factors (including whether or ongoing tasks) related to a user's availability and adherence.

For adherence enhancement, we found that, in some cases, users did not adhere to the intervention, even though they were able to follow the intervention. In some cases, our participants wished to have more rewards if interventions were delivered in unfavorable situations (e.g., colder than usual weather). This observation offers a new direction for dynamically controlling incentive amounts based on contexts. We can also consider using loss-framed incentives, which were reported to be more effective than gain-framed ones to increase adherence rates [15].

In our preliminary study, we only considered limited user segments due to our limited accessibility to CVD patients. However, we expect that it is important to better understand their needs for system development and deployment. We plan to involve CVD patients who will provide invaluable feedback from their personal experiences. Also, we will use a wrist-worn wearable device such as FitBit for accurate activity tracking.

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