Designing Health-Promoting Technologies with IoT at Home

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CHI'18 Extended Abstracts, April 21–26, 2018, Montréal, QC, Canada.
ACM ISBN 978-1-4503-5621-3/18/04.
http://dx.doi.org/10.1145/3170427.3188561.

Abstract

Health-related IT products (e.g., Fitbit) support persuasive technologies to reinforce an individual's desired behaviors. While these products are dedicated to certain health behaviors, such as walking or specific types of sports, IoT at home can be integrated more broadly throughout one's daily life. To address this opportunity, this paper aims to shed light on the use of domestic IoT that can foster changes toward healthy behaviors through a 3-week explorative field trial. This paper reports two major goals of health-promoting technologies using IoT as well as different persuasive techniques according to the temporal phases of before, during, and after the health behaviors.

Author Keywords

Health promotion; IoT; smart home; persuasive technology; design

ACM Classification Keywords

H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous;.

Introduction

People endeavor to sustain healthy lives by exercising regularly, sleeping well, drinking enough water, and so on. It takes a lot of willpower to maintain a healthy lifestyle without the support of a clinician. Thus, various health-related devices have adopted persuasive

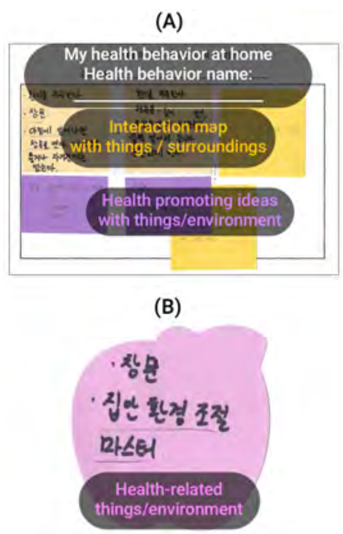

Figure 1: Worksheets for the preliminary study: Health habit interaction map for health promoting ideation (A) and health-related things/environment (B).

technologies that present messages, alarms and information that can inspire healthy behaviors.

Healthy behaviors include exercising and sleeping, as well as salient home-based behaviors, such as applying lotion after cleansing or sitting with good posture. Earlier works have demonstrated opportunities for promoting behaviors in everyday life by creating health applications with smart home technology [6, 10]. To further the study of this subject, we seek a new design space of domestic IoT that supports health-promoting systems. What if the fridge could keep users from eating midnight snacks? What if the lighting could praise users for achieving their daily health goals? In this paper, we uncover insights that could help designers gain greater knowledge of health-promoting techniques with IoT through a 3-week explorative study.

Background & Related Works

Without the help of a clinician, health behavior change could be achieved by continuous encouragement from the system. In HCI research, there has been considerable research on health-promoting methods for effective behavior change. For example, related works have deployed psychological theories [3], recommendations from experts [2], or “just-in-time” messaging [5] to develop motivating techniques. Detailed design suggestions were made by Consolvo et al., providing health application designers with well-established theory-driven guidelines [1].

Working toward enhancing the health of users while at home, the use of domestic IoT showed possibilities of enabling people to augment their everyday activities at home. Earlier work of Lee, et al. [6] asserted that construction of responsive home environments could lead to innovative solutions for users’ uniquely personal behaviors. Woo and Lim also revealed one of the motivations for creating applications in the do-it-yourself (DIY) smart home to be health care [10]. However, prior works have given little attention to guidelines which designers could apply while designing health-related persuasive technology within domestic IoT. Thus, this explorative study was conducted to suggest design considerations for such initial guidelines.

Preliminary Study

We conducted a preliminary study to discover what can help users come up with health-promoting ideas for IoT. The discoveries inspired the main study setup, in which we aimed to identify what factors to consider when adopting health-promoting techniques for IoT at home.

Study Method

For the study, we recruited four participants with different interests related to health and IoT technology: two dieting people, one activity tracker user, and one DIY smart home enthusiast. Prior to the ideation session, participants were given printed worksheets to complete at home (Figure 1). The handouts asked participants to reflect on their current health habits and to note related interactions with artifacts and environments in their homes. During the ideation session, each participant created health-promoting ideas pertaining to their needs that could be provided by everyday objects (including non-digital objects) and their surroundings. The ideation sessions were done individually, followed by interview sessions to understand the rationales behind their ideas. The gathered data was organized through a thematic analysis, in which we grouped techniques for generating health-promoting ideas.

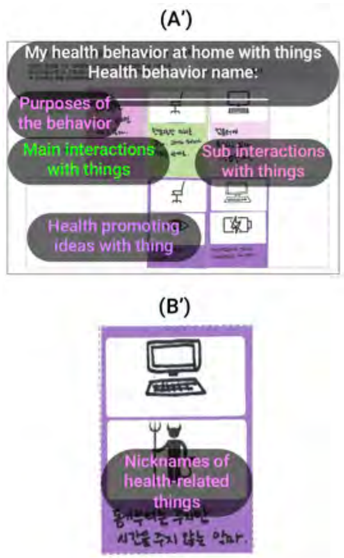

Figure 2: Revised worksheets for the main study: Health habit interaction map with things for health promoting ideation (A') and giving nicknames to health-related things (B').

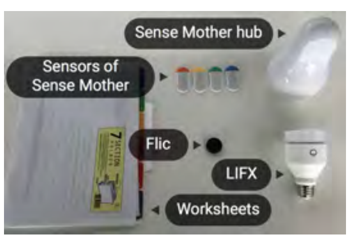

Figure 3: Off-the-shelf IoT products

Findings

Our findings revealed that participants chose everyday *things,* rather than their surroundings, as sources for health-promoting ideas.

We found that participants *assigned health-related roles to things* to generate health-promoting ideas. Designating the roles that best matched with the characteristics of the objects helped participants to devise more creative ideas. For example, one of the participants whose domestic routine was to open the window regularly to ventilate his living area labeled the window as the "home environment master control." He created an idea in which the window notified him when to open/close it according to the indoor air quality compared to the outdoor air quality. The act of assigning perceived roles to things helped participants recognize objects as supporters for enhancing their health. We applied this finding to the main study worksheets by asking participants to give nicknames to things in order to explore characteristics and clear-cut roles of the things effectively (Figure 2).

Another finding was that *health-promoting ideas given to objects at the scene were more acceptable* to the participants. Participants created most of the health-promoting ideas with things in the environment where the behavior was taking place. One of the participants whose target behavior was to do kettlebell workouts while watching YouTube said, *"If my laptop sends me workout reminders when I click a video on YouTube or if I have to swing my kettlebell to play it, I think I'll definitely start the workout."* He indicated that intervention of the things in a physical setting acted as triggers to fix the current problems. This finding highlighted that employing relevant objects to modify behaviors in the moment is a crucial factor for designing health technologies with IoT. We applied this finding to the details of the main study worksheets by adding different-colored sticky notes to prioritize the things related to one's health behaviors (Figure 2), so that participants could determine relevant objects and the best timings for the interventions.

Main Study

For the main study, a 3-week qualitative study with eight participants was conducted to probe the users' experiences with promoting healthy lifestyles via IoT.

Study Materials

The study materials consisted of two main components: worksheets, and off-the-shelf IoT products (Figure 3). The purpose of the worksheet was to help participants reflect on their health behaviors and generate ideas for health promotion using IoT, as described in the preliminary study section.

We selected commercial IoT products' sensors and actuators for the participants to create and experience their ideas with: sensors for the detection of current behaviors, and actuators for providing cues for desired behaviors. For sensing, we chose the home automation kit "Sense Mother [8]," which uses multifaceted sensors to detect motion-related input (e.g., movements, sleep, and activity). For detecting behaviors other than motion, we adopted the wireless smart button "Flic [4]," to sense those behaviors by manually clicking a button. Sensors were attachable to participants' everyday objects. Considering tangible cues for the IoT to deliver, we chose a smart light bulb "LIFX [7]" for light prompts and the hub of a Sense Mother [8] for making various sound effects (Figure 3). All selected products were

Figure 4: An example of health application with IoT: If the foam roller moves(left), then lighting changes to rainbow colors accompanied by cheerful sound effects (right).

P1	male, 26 graduate student	activity tracker user, DIY smart home enthusiast
P2	female, 29 graduate student	dieting person
P3	male, 29 graduate student	DIY smart home enthusiast
P4	male, 29 graduate student	DIY smart home enthusiast
P5	female, 27 graduate student	dieting person
P6	male, 26 graduate student	DIY smart home enthusiast
P7	female, 27 product designer	dieting person
P8	female, 27 product designer	dieting person, activity tracker user

Table 1: The demographic information of the main study participants and their interests related to health and IoT technology.

compatible with the IFTTT platform, which is an end-user programming tool using trigger-action (if-then) rules. Participants implemented their IoT health applications through the IFTTT service (Figure 4).

Study Method

A total of eight participants were recruited for the main study (Table 1). We refer to each participant by their participant number (e.g., P1). Throughout the three-week study, participants were asked to create and iterate their health applications by using the IFTTT platform and the IoT devices. Every week, we conducted a semi-structured interview to gather feedback and plans for the following week. From the 3-week experiment, we collected 133 intervention ideas, 62 IFTTT applets, about 26 hours of interview recordings and videos, and 49 photos and 4 videos of the installation of sensors and actuators. The gathered data was analyzed through a thematic analysis focusing on which health-promoting application ideas worked well and which did not—and the reasons why participants modified them.

Findings of the Main Study

We discovered two major goals of promoting health behaviors with IoT: *encouraging desired behaviors* and *regulating existing behaviors*. Under these two major goals, persuasive techniques for health with IoT differed through the temporal dimensions of *before, during, and after* the health-related behaviors [9]. These stages are widely applied approaches of behavior change research: *before* for an *antecedent-oriented* approach, *during for a behavior-oriented* approach, and *after* for a *consequence-oriented* approach [9]. Based on the findings, design considerations for promoting health behaviors with IoT were proposed accordingly.

For Encouraging Desired Behaviors

During the *before* phase, which is the motivation stage of the behavior, health promotions from IoT acted as ambient reminders for triggering the target behavior. We discovered that participants preferred non-intrusive tones of IoT at this phase, because they did not want their current tasks to be interrupted by an annoying intervention. In P6's case, he created an application so that his desk lamp would blink every hour as a reminder to drink water on a regular basis. Since this gently reminded the target behavior through a non-invasive one-blink alarm per hour, P6 felt the IoT to be supportive, as IoT provided the option of whether to take the action or not.

In the *during* phase, which is the moment a behavior takes place, participants regarded IoT feedback as cheerful reinforcements. They designed these types of applications particularly for workout sessions, since these demanded constant motivation. Unlike the ideas created in the *before* phase, participants adopted lively tones for the *during* phase. P7 created feedback that caused the lighting to change to rainbow colors accompanied by cheerful sound effects while she was stretching with her foam roller (Figure 4). Adding some delight to the experience resulted in participants' engagement with their desired behaviors.

In the *after* phase, which takes place upon the completion of the behavior, participants designed health applications that gave them credit for what they had achieved. For example, P3 created a confirmation feedback idea for riding a bicycle by sending a mobile notification when his bicycle arrived at home. He said although he could check for himself whether he'd ridden his bike or not, a neutral confirmation from an

Figure 5: Different *roles* and *tones* of interaction with IoT according to the *behavior change goals* and *temporal phases of the behaviors*.

object helped remind him of his small accomplishments. Although health activity promotion by IoT required neither a great reward nor a compliment, a simple confirmation from another object helped participants gain self-satisfaction and motivation to engage in the behavior again.

For Regulating Existing Behaviors

Unlike the techniques adopted for encouraging the desired behaviors, during the *before* phase participants created aggressive regulations to prevent themselves from engaging in improper actions. For example, P7 created an uncomfortable situation to prevent herself from going out and buying midnight snacks. For the implementation, she assigned the movement of her wallet as a trigger for red lighting and a siren-like sound from the Sense Mother. She mentioned that this coercive setting was so annoying that she avoided going near her wallet during the day.

In the *during* phase, health reminders for regulating existing behaviors acted as messages to be aware that a situation was not good. P7 ideated with her trash bin to scold her for eating late at night. Movement of the trash bin triggered the lighting to blink red and the hub of the Sense Mother to make a deep sighing sound, which made the snacking experience unpleasant. However, she described the technique as quite a success because it made her realize that the behavior was bad in the moment. Similar to the findings of the before stage, applying an aggressive technique to the during stage worked as well.

Interestingly, during the *after* phase, participants who had committed undesirable behaviors were reluctant to be punished by the IoT. After waking up late, P3 did not want the mobile phone to confirm the fact that he woke up late. During the *after* phase, he felt he had no authority over what had already happened. Instead, he preferred the IoT to trigger self-reflection of his behavior. This means not intervening the moment he wakes up late, but instead triggering awareness of his behavior at some other point during the day. At this stage, instead of scolding the users, supporting self-reflection seemed to be more helpful.

Design Considerations for Promoting Health Behaviors with IoT

Based on our findings, different techniques for health promotion that employ the IoT are summarized in Figure 5. Extending the design strategies of behavior change technologies [1], we revealed that persuasive techniques of domestic IoT varied based on the *types of behavior change goals* and the *temporal dimensions of the behaviors.* These two criteria played a pivotal role, as the goals represented the purposes and the temporal dimensions represented the correct timings of the interventions, resulting in different *roles* and *tones* of interaction with IoT. Hence, to deliver the intended messages, both criteria should be considered during the ideation stage of designing IoT techniques.

Discussions & Future Studies

Discussions would lead to established guidelines for designing persuasive health technologies with IoT. As mentioned earlier, tones of IoT differed (e.g., gentle, cheerful, coercive, and neutral) according to the intentions of the health-promoting ideas. Although we limited actuator usage to light and sound for the study, we could already discover various roles and tones of IoT feedback. Therefore, additional techniques for expressing the delicate nuances of IoT could be further explored. For future studies, an application of other actuators, such as vibration (for aggressive regulations) and voice (for direct messages) could be adopted to discuss what extent the techniques of health-promoting IoT could involve. This would lead to setting advanced behavior change goals when designing health applications for IoT devices.

Additional assessments are still needed, as the study was conducted with a small number of participants who are members of a single household. However, giving emphasis to the engagement with IoT for health, this study contributes to the HCI research in that it extended the design space for persuasive health technologies to be supported by domestic IoT.

Acknowledgements

This work was supported by Institute for Information & communications Technology Promotion(IITP) grant funded by the Korea government(MSIT) (R7124-16-0004, Development of Intelligent Interaction Technology Based on Context Awareness and Human Intention Understanding).

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