INCREASING PATIENT ADHERENCE TO HOME HEALTH-MONITORING SYSTEMS

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Abstract. Research indicates that behavior change interventions can assist patients' performance with respect to their health, and empower them to take a proactive role in their well-being. The objective of this research was to identify features that make remote health-monitoring systems more effective. To that end, a persuasive design approach was used to design a prototype application that encourages patients to consult their home monitoring devices appropriately. An exploratory user study was conducted to evaluate participants' opinions about the developed prototype, their preferences, as well as their concerns regarding the different components of the mockup. In addition to the exploratory study, a comparative study was conducted, in which a conventionally designed health application was compared with a newly designed engagement application. The results of the study showed no difference on quantitative measures but participant preferences still indicated the engagement design may have potential.

INTRODUCTION AND MOTIVATION

Each year more than 17.3 million individuals lose their life to a chronic health condition worldwide (World Health Organization, 2008). Congestive heart failure and hypertension are among the major chronic illnesses in the United States. In that country alone, about 5.8 million people have heart failure (Lloyd-Jones et al., 2009), and their treatment costs more than $40 billion each year (Yancy et al., 2013). High blood pressure (BP), one of the most common factors correlated with congestive heart failure (CHF), requires patients to monitor their blood pressure regularly. However, research shows less than 25% of patients actually maintain good control of their BP (Wolf-Maier et al., 2004).

Remote monitoring devices help patients and physicians manage a variety of chronic illnesses by gathering data about patients' status and relaying it to healthcare providers on a regular basis. These devices can reduce healthcare costs and improve quality of life (Cafazzo & St-Cyr, 2012; Seto et al., 2012); however, poor adherence to home monitoring interventions reduces the effectiveness of treatment regimens.

Prior studies have highlighted the fact that if designers pay attention to basic human factors in the initial stages of developing health monitoring systems, adherence can be enhanced. Thus, numerous research projects have studied the efficacy of various approaches, and found that systems fail because their designers did not account for non-technological aspects of patient adherence (Lehto & Oinas-Kukkonen, 2011). Understanding human behavior and designing systems to augment patients' adherence is challenging. In the past decade, considerable attention has been paid to behavior change in health domains. Researchers attribute poor adherence to a variety of factors such as low self-efficacy, denial, knowledge deficits, inadequate resources, and time constraints (Dick et al., 2011).

Research indicates that behavior change interventions can assist patients' performance with respect to their health, and empower them to take a proactive role in their well-being. To that end, many researchers have developed systems that are designed to help and motivate users to set goals, to keep track of their health, and also to provide them with the appropriate feedback and information about the consequences of their behavior (Cugelman, Thelwall, & Dawes, 2011). In many of those interventions, the methodology is based on human behavioral models and approaches such as goal-setting theory (Locke & Latham, 1997), the trans-theoretical model (Prochaska & Velicer, 1997), persuasive technology, etc. Among those approaches, persuasive technology has earned the most attention, and numerous studies have investigated its efficacy. The objective of this research is to identify features that make health-monitoring systems more effective.

THEORETICAL FOUNDATION

Persuasive technology is the practice of using technologies to change individuals' attitudes or behaviors (Fogg, 2002). Based on persuasive technology design principles, to make a certain behavior happen, not only should a persuasive system motivate individuals, but also simplify the target behavior for them. In addition to those two principles, there should also be an appropriate trigger at the right time to facilitate behavior change by reminding the person to take the necessary action. When these three elements converge, the chance that a person will attain the target behavior increases.

Fogg (2002) identified a set of features and strategies that can be used to create a persuasive system. Among those features are reminders, rewards, artificial companions, and the strategies include praising, suggestion, reduction, competition, recognition, tailoring, and personalization. These features and strategies are explained further in following sections.

RELATED WORK

Within the last decade, there have been a large number of research studies investigating the effect of home health monitoring systems in improving patients' health (e.g., Stinson et al., 2012; Kerby et al., 2012). Results of many of them demonstrate that these interventions can be beneficial to patients and affect their health, particularly when persuasive mechanisms are employed in the system design. The research of Logan et al. (2011) showed that in a randomized control trial where diabetic patients were provided with self-care messages via their mobile phones, their systolic blood pressure decreased. In the control group, where patients were not receiving self-care messages, no such effect was observed. Similar to the work of Logan, Seto et al. (2012) conducted a study where patients with heart failure were given mobile phones and had to answer to a series of health-related questions on daily basis to convey their health condition to clinicians. Based on those data, as well as their BP readings, patients received instructions about their health. Study results proved that the monitoring technology improved patients' quality of life. In both of these studies, suggestion was used as a the mechanism used to encourage patients to improve their health behavior.

In another study investigating the effect of a home health monitoring system, Cafazzo, Seto, and Jadad (2012) developed a mobile application for individuals with type 1 diabetes, where patients received incentives based on the frequency of their blood glucose measurements. Their measurement frequency increased by 50% per day, showing that this reward system motivated patients to take a more active role in their health.

Additionally, DeVries (2013) conducted a study for individuals with heart failure, who could monitor their health-related data at home using a web-based application, and also receive tailored health messages and education. The intervention decreases the number of patient re-admissions to hospital, again personalization and tailoring of health messages were the mechanisms used.

These studies, among many others, are growing evidence of the effective role of persuasive mechanisms in increasing patients' adherence to health interventions.

OUR APPROACH

As proposed and presented in prototype form, the system consists of various components such as Reminder, Daily Prescription, User's Progress, Health Trend, Social Portal, Entertainment, News, and Artificial Companion. Each feature is explained in more detail below.

Reminder. Every day an alert on the patients' tablet reminds them to check their daily prescription.

Daily Prescription. The monitoring application provides users with a list of all medications that they should take that day. To make it easy to understand, this interface categorizes the medications based on the time they should be taken, and also indicates the total number of pills to be consumed. This component implements the principles of reduction (Fogg, 2002).

User's Progress and Points. Praising users properly according to their health behavior is an important element to encourage them to move toward their target behavior.

Points are essential elements in designing a gamified application and are similar to reward programs we see in the real world like credit points, airline loyalty programs, etc. Levels help users know at each point in time where they stand relative to other users. Points and levels are both included in the prototype.

Health Trend. The system provides users with their current health status and also their health trend over a specific period, so they can compare their current condition to a prior one. When users receive this kind of feedback, they see a path toward achieving better health, and according to the theory of self-efficacy (Bandura, 1997), they start to believe that they have the capability to change their health condition. It gives them motivation and also a sense of empowerment.

Social Portal. This application includes features to help users build a web community. Social support has a major role in motivation and persuading people. Being in a support group helps people to improve their behavior through a variety of mechanisms. Generally, when people know that they are being observed or if they see that others are performing the behavior along with them, they are more likely to perform a target behavior (Fogg, 2002).

There are also other advantages to a social portal. For example, people will have greater motivation to perform if they are given information about how their performance compares with the performance of others, especially others who are similar to them (Fogg, 2002). Since competition is one of the most powerful motivators, people become energized in competitions, and they attempt to win even when there is no prize (Fogg, 2002). Although not all people are competitors, this behavior is very prevalent.

The social page of the application also includes a share button by which users might share their health milestones with family or friends. Sharing health milestones leverages normative influence and increases the likelihood that a person will adopt a target behavior.

Entertainment. The proposed application includes an entertainment section and when users gain enough points, they get access to variety of games, music, or videos on the tablet that they would not have access to otherwise. Rewarding users would encourage them to connect with their device more frequently, which can influence their adherence.

News. Users are provided with an opportunity to use the system for purposes other than receiving their daily prescription. By coupling a target behavior with a regular one, the system can increase users' chance of performing that particular behavior.

In addition to the above-mentioned components in the application, other features and strategies are also used to motivate users. These features include artificial companion, tailoring and personalization.

Artificial Companion. Research shows that users' ability to create a social relationship with an artificial agent can be a key factor in engaging their attention and increasing their level of involvement while interacting with system (Fogg, 2002; Kreins, 2012). In our prototype, we used a smiley face as an artificial companion.

Tailoring and Personalization. The application uses tailoring and personalization techniques to make the experience more engaging. This includes providing users with tailored messages, or customization options for more experienced users (e.g., the ability to change their screen background, etc.). The system offers users health-related suggestions based on their current health condition, for example, nutrition tips or instructions for physical activity. This should assist them to move toward their target behavior (Fogg, 2002).

USER STUDY

In this experiment, a conventionally designed (CD) health application was compared with our newly designed engagement design (ED) application to help us gain deeper insight into different aspects of user engagement with the new intervention. The CD was based on the user interface of a prototype for a similar application that was produced by one of our sponsor's research teams.

For measuring the level of user engagement as well as prototype usability, an adapted version of the User Engagement Scale (UES) (O'Brien & Toms, 2012), combined with the System Usability Scale (SUS) (Brooke, 1996) was used. The UES asks a series of questions exploring the engagement of a technology immediately and over time. We have adapted this scale to focus on questions that elicit immediate engagement, as lengthy interaction with the designs was not possible at this stage. As well, wording on the scale has been adjusted to fit the context of the designs, in this case a medication prescription page. The UES investigates a number of engagement attributes, including users' perceptions of the Usability, Aesthetics, Novelty, Felt Involvement, and Endurability aspects of the experience. Endurability means users' evaluation of their experience, their perceived success and whether they may recommend the application to others (O'Brien's & Toms, 2008). The scale was presented on a 5-point Likert scale format, from strongly disagree to strongly agree.

To evaluate participants' emotional response to the designs, they were asked to rate each design along a set of semantic differential pairs. These pairs, which were adapted from a scale created by Agarwal and Meyer (2009), investigate different dimensions of participants' emotions (pleasure, arousal, and dominance) while interacting with technology and help researchers to gain a deeper understanding of participants' reactions to each design.

Equipment

For the purpose of this study a Motion Computing CL910 Tablet running Microsoft Windows 7 was used.

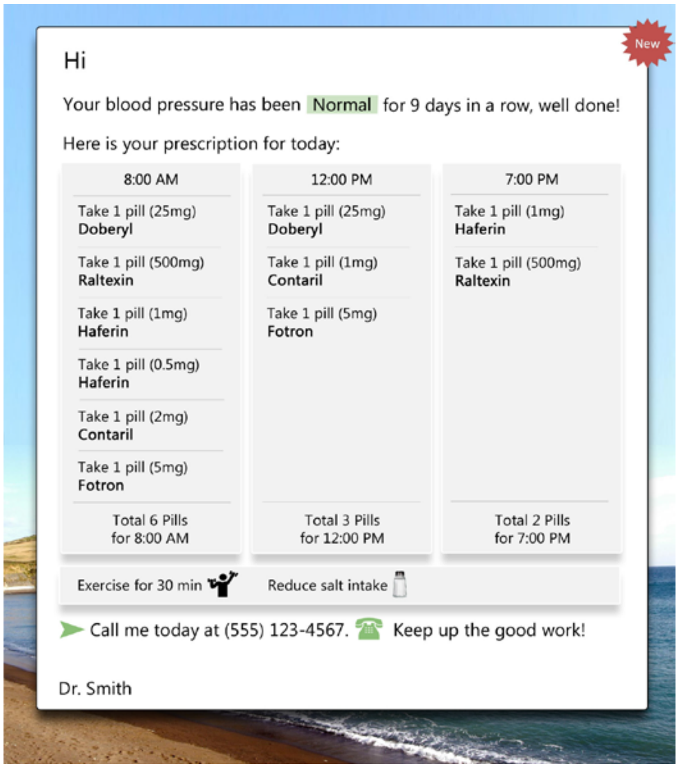

Figure 1. Screenshot of the monitoring application (daily prescription page) in the ED condition

Participants

Ten patients (4 females, 6 males) with heart failure (NYHA class II and III) were recruited (Mean Age = 67.4, STD = 7.18) through St. Mary's General Hospital, Kitchener, Canada. Three of them had never used a computer or tablet before. For those who had done so, their use included a variety of tasks such as watching videos, reading news, listening to music, playing games, Facebook, and web browsing.

Phase 1

At the beginning of the testing session, all participants were fully briefed regarding the purpose, details, risks, and benefits associated with the experimental protocol, before being asked for their written informed consent. After they signed the consent form, a researcher asked a series of questions to find out their hobbies, patterns of technology use, and adherence to medical regimens.

Subsequently, participants were randomly assigned to one of two groups, Group A or Group B. Group A experienced ED first, then the CD. Group B experienced the CD first, then the ED. This swap was to balance the effects of presentation bias that occur from having experienced one application design before the other.

Participants were asked to perform the task of checking a daily medical prescription using both the CD and ED. The daily medical prescription consists of a single screen that outlines what medications a typical patient might take that day. In this particular task, the screens had been designed with the same information, the only difference being the engagement techniques applied on the ED. After performing the task with the first design, participants were asked a series of questions on their impression of the design. They then performed the same task using the other design and answered the same questionnaire and open-ended questions again. During the task, participants were requested to think aloud.

During the evaluation of both designs, participants were engaged in open-ended discussions about the designs. The discussion were focused on eliciting why the participants may have rated one design differently than the other.

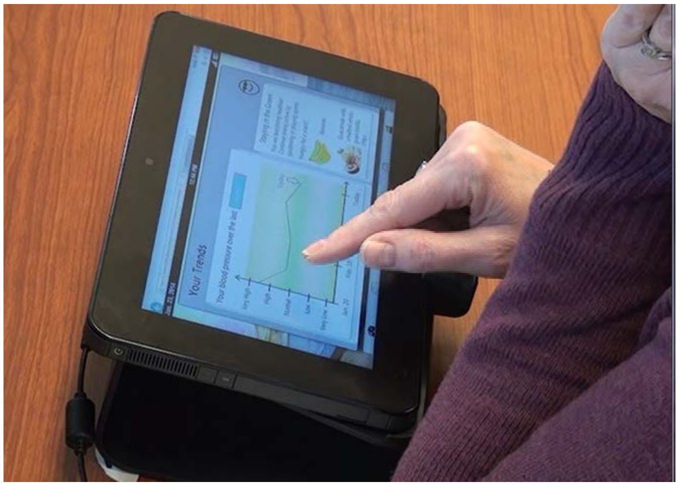

Figure 2. Participant interacting with the device

Phase 2

In this phase, the researcher walked participants through the ED and also through the additional parts of the application where other engagement elements have been applied. The researcher also asked them certain open-ended questions.

Subsequently, the researcher placed six sheets showing screenshots of the six main sections of ED in front of the participants and asked them to order those sheets according to their preference. This exercise was used to determine participants' preferences with respect to different components of the application and to initiate an open-ended discussion with them and identify why certain features were preferred, or not. At the end of the entire session, participants were compensated for their time and effort.

RESULTS

Participants' responses to the questionnaires and sematic differential pairs were aggregated and compared. Table 1 shows that nine out of ten items in the questionnaire scored better for the ED than for the CD, and in Figure 3 it can be seen that five out of six items of the adjective pairs scored higher for the engagement design application.

Participants' opinions regarding different components of the engagement-design application were analyzed and are listed here:

Reminders. Generally, participants like the concept of receiving reminders to take their pills. However, they believe it should be an optional feature.

Participant: "It would be good if there were a feature telling me that I missed taking a pill, but not nagging at me all the time."

Participant Questionnaire Responses

	ED (Mode)					CD (Mode)				
Question	1	2	3	4	5	1	2	3	4	5
1. I felt frustrated while using this program	●	○	○	○	○	●	○	●	○	○
2. I thought the program was easy to use	○	○	○	○	●	○	○	○	●	○
3. I think that I would like to use this program frequently	○	○	○	○	●	○	○	●	●	○
4. I think I would need the support of a technical person to use this program	●	○	○	○	○	○	●	○	○	○
5. Checking the *daily prescription* did not work out the way I expected	●	●	●	○	○	○	○	●	○	○
6. I would recommend this program to my friends and family.	○	○	○	○	●	○	○	○	○	●
7. The experience of checking the *daily prescription* was rewarding	○	○	○	○	●	○	○	○	●	○
8. Checking the *daily prescription* was fun	○	○	○	○	●	○	○	●	○	○
9. I felt interested in exploring the program further.	○	○	○	●	○	○	○	●	○	●
10. The program interface is attractive.	○	○	○	○	●	○	○	○	●	○

Responses were on a 5-point Likert scale from Strongly Disagree (1) to Strongly Agree (5)

Table 1. Participants' responses to the questionnaire for both types of designs

Prescription Page. Participants found the prescription page of the ED easier to understand, particularly because of the clear time divisions on when to take the pills, and also the feature showing the total number of pills that needed to be taken at each time. They also suggested some extra features. Three participants suggested a checkbox next to each pill's name, so when they take the pill they can check that box, and make sure the pill is already taken. Three participants suggested a feature that lets them know what each pill is for, what possible interactions it may have with other drugs, and if it should be taken with food or water.

One participant suggested: "It would be helpful if cells of the prescription tables looks like a pill box." Another participant suggested showing pharmacist's contact information, when their pills are expiring [running out] and when they need to refill their medication, to help them remember to contact the pharmacist either by phone or email.

Another participant suggested a feature where by a patient can enter comments about how they feel each day and their doctor can be able to see that information. This participant said “One thing I really like about this [application] is that it will make me more engaged with my medical regimen, because someone on the other side will see this, so I am more motivated to use the application. That would make me feel like I really matter.”

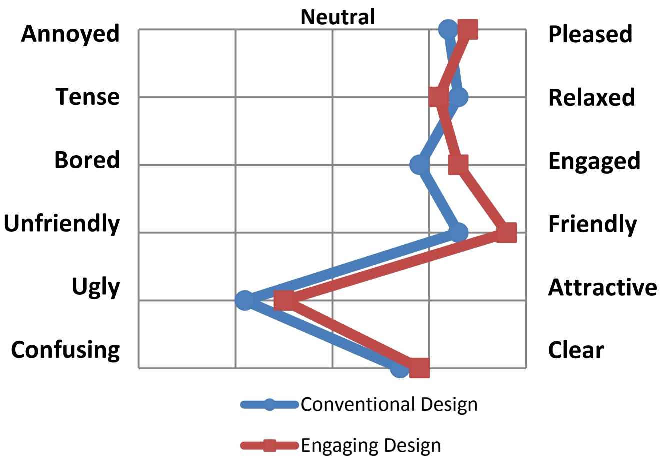

Figure 3. Comparison of the mean values of the semantic differential pairs, based on participants’ responses to the CD and ED applications

Artificial Companion and Praising Messages. Almost all participants responded positively to this feature. Said one participant, “It is good to have a pat on the back.” A second participant commented, “ I like the encouragement I get from the application.” They mentioned that it gives them a sense of accomplishment. However, opinions on the artificial companion were not all positive. One participant considered the smiley face “appropriate for kindergarteners.”

Health Trend. Not all participants favored the possibility of monitoring their health trend. Participant: “What if the patient is not doing well. It will be discouraging”; or “I don’t think I care much about my past blood pressure, I just care about my current blood pressure”; or “I go so often to hospital that I don’t need this”. Three participants liked the feature and also wanted to be able to monitor their weight by using the application. Participant: “It would be good to be able to also chart my weight”; or “One important thing is to keep track of your weight, fluids and sodium intake, because your prescription changes as those change, so it would be good if the system could track that like it does right now with blood pressure.” They found the graph coloring helpful with its normal range depicted in green and abnormalities in red. One participant wanted to see the exact numbers of her blood pressure in the graph. Another participant suggested it should also indicate the normal ranges for females/males and age groups.

User Progress. A majority of the participants showed interest in tracking their progress and receiving points. One participant said: “It motivates people to do better.” In answer to the question about what they might like to redeem their points for, they answered groceries, gas, travel, medication, music, games, and generally anything that would reduce the cost of living. One participant though did not find the concept engaging and mentioned he does not need these kinds of motivation to take his medication.

Social Portal. Seven participants showed disinterest in this feature. Participant: “I don’t like to share my health condition. What if other people are doing better than me? That can be discouraging”, or “I think most people are afraid of insurance companies finding out about their condition, people scamming them, or companies spamming them to try to sell them their product for their condition, so this social page I would never use. I am concerned about my privacy”, or “I imagine lots of people might like that, but I don’t like people to know about my health.” Some suggested that the feature be optional. Two participants liked the feature. One considered it to be an opportunity to find new friends, another said: “I can communicate with [other] people and tell them how I feel that day. They could also share with me how they felt on certain drugs, etc.”, or “a little support from friends is good”.

Health Messages. A majority of participants were interested in receiving health messages tailored to their health condition. Said one participant, “I like getting health tips”, or “It is good to know this info comes from your doctor.” Some were not interested though: “receiving general news is better than health related news.“

Ranking of Application Components Based on Patient Preferences	
1	Daily Prescription
2	Patient’s Progress[1]
3	Health Trend
4	News (weather, health, etc.)
5	Entertainment
6	Social Portal

[1] Patient’s progress in monitoring BP regularly and maintaining BP in normal range

Table 2. Ranking of application components based on participants’ preferences

News. Participants considered the news feature a useful option. One participant said: “[the application] should show the weather channel, since old people love watching the weather channel.” Three participants thought it would be nice if they could get their favorite recipes on the application.

Entertainment. Only a few participants showed interest in the entertainment components. One participant said “I’m not into games, so I don’t care. Not for me but I can see other people might like it.”

Participants also provided researchers with some high-level comments about the concept of using this application to monitor their health. The majority of them showed interest in having an application like this one. One participant mentioned: “I hate making appointments to come to the hospital, so this application would be great since I don’t have to leave home”, or “If clinicians have access to this health trend it would be helpful and valuable.” Some had a quite different opinion though; one said: "One big problem with this application is I don't have to come in as often to the hospital. This means that I lose the social factor from being able to get out of my house and interact with people at the hospital. In a way, it isolates me. People at my age like to talk to other people, and this application does not help with that."

Table 2. shows the ranking of application components according to the participants' preferences.

DISCUSSION AND FUTURE DIRECTIONS

The small observed difference in the results might be attributed to the method of study, where participants expressed their opinion on ED and CD designs in a face-to-face interview setting. Generally, in this kind of setting, there is a possibility that interviewees want to answer in a way that they believe would please the interviewer.

The main goal of this study, though, was to identify participants' preferences and opinions with respect to each type of design, and those designs included persuasive features. Therefore, more research is necessary to examine the effects of each of the persuasive components in remote health monitoring systems. For example, previous research has indicated that a social support feature in a home health-monitoring system could act as a engagement mechanism and increase patient adherence to medical technologies (Dhillon, Wünsche, & Lutteroth, 2013); however, based on the results of our study, patients may not be interested in sharing their health-related data with their peers.

The next step of this research should be a longitudinal study where the frequency of the blood pressure measurement of the participants in an intervention group (the group whose participants are provided with an ED monitoring application) will be compared with the frequency of the blood pressure measurements of a control group.

Finally, it is important to note that before conducting a randomized control trial to measure the efficacy of home health-monitoring interventions, studies investigating the use of monitoring devices are needed (Ure et al., 2012). These types of studies are necessary, becasue they can potentially reveal technological issues that may affect patient adherence, as well as human behavioral problems regarding the use of monitoring technology, factors which can threaten the validity of an RCT if not addressed properly (Cafazzo et al., 2012).

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