How to Improve the Efficacy of Persuasive Systems: Investigating a Tailoring Technique

by

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Preface

My first encounter with Persuasive Technology was when I took the course "Design for User Engagement." I was hoping that the knowledge I gained in that course would assist me in developing an engaging user interface for the health-monitoring system that I had to design. The project, sponsored by Medtronic Inc., was to design a home health-monitoring intervention that assists patients with cardio-vascular disease to monitor their blood pressure regularly and to comply with their treatment regimen. The main objective was to design a system that would lead to higher medical adherence, and the target users were patients who had to interact with a mobile application on a daily basis to learn about the changes in the dosage of their medication prescription.

Generally, in designing a solution for patients with chronic illnesses, the goal is to develop a system not only with high usability, but also with an engaging user experience that encourages consistent use. However, within the last decade, researchers' ambitions have gone beyond that horizon, and they have now started creating technologies that can influence individuals' attitude and change their behaviour. Researchers have developed many interventions that can assist individuals to change their behavior for the better in a variety of domains, particularly healthcare and well-being.

The possibility of creating technologies that help people move toward a more desirable lifestyle was very appealing to me, and I decided to choose persuasive technology as the topic of my doctoral research. I started my journey with investigating how home health-monitoring systems can be designed to increase patients' adherence. During the course of my research; however, I learned that this relatively new emerging field, still holds many potential contributions that scientists can make to further develop the initial framework, and as a result, I shifted the focus of my research toward expanding the field. My new goal is to explore strategies for designing adaptive persuasive systems.

From an in-depth literature review, I learned about the huge number of persuasive interventions that have been developed for health monitoring of individuals with chronic disease. Consequently, I developed a prototype and conducted a qualitative user study in St. Mary's General Hospital to acquire users' perception of an application developed based on Persuasive Design. The study helped me to understand the potential challenges that hinder the use of technology. Moreover, I learned that depending on the type of users, the context of use, and the nature of a behaviour, employing some of the persuasive techniques in the system's design would be more beneficial than employing others.

My most significant finding came along with that experience: the fact that these systems can be most engaging (and therefore most effective) when they are designed to have the best fit to their users' needs. This finding has been acknowledge by many researchers, including Hawkins, Kreuter, Resnicow, Fishbein, and Dijkstra (2008); Fjeldsoe, Marshall, and Miller (2009); Schubart, Stuckey, Ganeshamoorthy, and Sciamanna (2011), etc. However, present literature about persuasive technologies has little on this issue, and this gap creates an opportunity for researchers to explore solutions and make contributions to the field. For that reason, I have decided to focus on this matter in my doctoral research and have chosen a specific persuasive technique, called *tailoring*[1], to investigate how systems can be designed to be more adaptable to their users' need and therefore be more effective.

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[1] According to Hawkins, Kreuter, Resnicow, Fishbein, and Dijkstra (2008): "Tailoring means creating communications in which information about a given individual is used to determine what specific content he or she will receive" (p. 1).

The outline of my proposal is as follows: First, I explain the research problem and the objectives of my work, and I discuss the potential contributions that I am hoping to make. Then, I explain the theoretical foundation, followed by a chapter discussing the related work. Subsequently, I briefly describe the previous work that I have done during the course of my doctoral study, and at the end, I discuss my proposed approach, the experiments, and the timeline for research.

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Abbreviations

APS: Adaptive Persuasive System

CWA: Cognitive Work Analysis

BCSS: Bahviour-Change Support System

PSD: Persuasive System Design

PrevMR: Prevention-Message Recipient

ProMR: Promotion-Message Recipient

RFQ: Regulatory Focus Questionnaire

STPS: Susceptibility to Persuasion Scale

1. Introduction

The past decade has seen considerable attention paid to the design of technologies that support behaviour change in a variety of domains, such as health and well-being (Griffiths, Lindenmeyer, Powell, Lowe, Thorogood, 2006; Fjeldsoe, Marshall, & Miller, 2009), energy saving (Kluckner, Weiss, Sundström, & Tscheligi, 2013), safe driving (Meschtscherjakov, Wilfinger, Scherndl, & Tscheligi, 2009), environmental protection (Schrammel, Regal & Tscheligi, 2013), etc. Any system that aims to help users change their behaviour is a persuasive system. Fogg (2003) defines persuasive technologies as "computational systems that can influence user's attitude and behavior through persuasion and social influence but not through coercion." However, these systems are not just limited to explicitly using persuasion and social influence, but can use goal directed information to encourage behavior change.

Based on a behavioral change model, developed by Fogg in the late 1990s, many persuasive systems have been developed to help people take better care of their health. Examples of these systems are those designed to assist individuals to quit smoking (Shahab & McEwen, 2009), lose weight (Stevents et al., 2008) or adapt to a more nutritious and healthy diet (Kaptein, De Ruyter, Markopoulos, & Aarts, 2012). Many are designed to aid patients with chronic diseases like diabetes (Cafazzo, Casselman, Hamming, Katzman, & Palmert, 2012) or hypertension (Seto and colleagues, 2012a), and so better comply with their medical regimen. However, efforts have not been limited to the design of technologies that promote physical health; numerous studies focus on developing technologies that promote mental health and help individuals with conditions such as depression or anxiety (Amstadter, Broman-Fulks, Zinzow, Ruggiero, & Cercone, 2009; Langrial, Oinas-Kukkonen, Lappalainen, & Lappalainen, 2014).

Like any other type of technology, persuasive technology has evolved over time. Simple persuasive systems that were basically using phone conversations as a persuasive communication medium (Noar, Harrington & Aldrich, 2009) have since been transformed into advanced web-based and mobile applications accompanied by wearable activity trackers such as FitBit[2] or JawBone's Up[3].

Investigating techniques to increase the efficacy of these behaviour-change support systems is of great value because of many benefits that have been attributed to them, especially in the domain of healthcare (Lehto, 2013). Some of those benefits include reduction of the cost and inconvenience for patients (Lehto and Oinas-Kukkonen, 2011), reduction of healthcare service costs due to the preventive nature of persuasive technology (Strecher, 2007; Cugelman, Thelwall, & Dawes, 2011), reduction of stigma and isolation of users due to the anonymity provided by the technology (Griffiths et al., 2006), etc. These advantages come through the following characteristics of persuasive systems (Fogg, 2003, p.7): being interactive, being persistent, offering anonymity, using many modalities to influence users, scaling easily, going where humans cannot go, and finally capability of managing large volumes of data. I will discuss the characteristics and benefits of persuasive systems further in Chapter 2.

[2] http://www.fitbit.com

[3] https://jawbone.com/up

1.1 Motivation and Problem Statement

Researchers have indicated that different individuals may react to the same persuasive message differently (Batra, Keller, & Strecher, 2010; Khaled, Barr, Noble, Fischer, & Biddle, 2006; Kaptein, 2012) and believe that in order to increase the efficacy of behavior change support systems, persuasive communication should be adjusted to individuals' characteristics (Noar, Harrington, & Aldrich, 2009; Kaipainen, 2012).

Although Fogg emphasized the importance of tailoring as a feature to make these interventions more influential, he did not provide sufficient guidance on how to employ this technique. Few of the many systems implemented over the last decade, such as in the work of Kaptein, Markopoulos, de Ruyter, and Aarts (2009) and Orji and Mandryk (2014), have accounted for user differences in their design, differences that exist both at the cultural or individual levels. (Systems that used tailoring as a persuasive mechanism are explained further in section 3.2.2.)

More importantly, because keeping users engaged with the system over an extended period of time has proven to be challenging (Eysenbach 2005; Cugelman, Thelwall, & Dawes, 2011; Kaipainen, 2012; Lehto, 2013), it is essential to identify features that are capable of promoting sustained engagement. In addition, it should be noted that individuals' psychological characteristics may vary in different situations or over time (Scholer, & Higgins, 2011), and therefore, a system that can adapt to such changes can potentially decrease user attrition[4] (Kaipainen, 2012; Kaptein, 2012).

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[4] According to Eysenbach (2005), attrition happens when participants lose interest in an intervention and stop using it. Generally, factors such as the type of technologies used in the design of behavior-

It is proposed that these issues could be improved by increasing the fit of persuasive messages to the users' characteristics and interests. However, in order to do so, more studies are necessary to investigate different methods of tailoring and their effects on users. In this doctoral research, I will investigate a particular tailoring technique and propose that behavior changes will be more probable and sustainable if persuasive messages are tailored to individuals' needs.

This proposal suggests a program of research that aim to examine the efficacy of a tailoring approach, with the goal of building a set of design rules that can assist engineers to develop adaptive persuasive systems that account for individual differences, and therefore, facilitate the broader adoption and sustainable use of these systems by users.

1.2 Potential Contributions

The topic of my research stands at the intersection of three major disciplines: 1) Technology design and development, 2) Social psychology, 3) Healthcare and well-being. As a result, the potential contributions of this interdisciplinary work can be categorized into three main areas.

1.2.1 Contributions to Technology Design and Development

As mentioned, the initial theoretical framework introduced by Fogg provided little guidance on how to develop persuasive systems. Although other scholars, such as Kaptein (2012), Oinas-Kukkonen and Harjuma (2009) have since made efforts to expand the framework, there is still a need to further investigate and define a set of design rules. Such

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change interventions, as well as the type target behavior, contribute to the rate of user attrition (Lehto & Oinas-Kukkonen, 2010; Lehto & Oinas-Kukkonen, 2011).

guidelines can assist developers to identify requirements and employ the best approaches in building a persuasive system. I am hoping that the findings of my doctoral research will lead to such a rule set.

1.2.2 Contributions to Social Psychology

My proposed research is expected to provide new insight into the relationship between the regulatory-focus theory[5], persuasive message construction, and behavior change. The experimental design suggested in this proposal is novel from a variety of perspectives: contrary to the prior studies on regulatory-focus theory, in which priming participants with persuasive messages occurs once or few times during the experiment, in the studies proposed here, individuals will be exposed to influencing messages repeatedly. Additionally, their reaction (outcome behaviour) can be measured objectively instead of subjectively—as is the norm in psychological studies—and then can be analyzed in real-time. Such novel features (regular messaging, real-time objective measurement and analysis) are now possible only due to the emerging novel technologies.

This would be the first study to examine a persuasive communication while collecting data from participants, and would present a new form of research structure in this field.

1.2.3 Contributions to Healthcare and Well-being

Although there has been extensive research on exploring the best methods of framing persuasive-messages in the domain of health communication, no clear results exist on the most effective strategy (Cho, 2012). This lack of clear results may be due to studies with small

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[5] Regulatory-focus theory is a behavioral theory formulated by Higgins (1997). See section 5.1 for more detail.

sample size or participants' limited exposure to persuasive messages, which in turn may lead to insufficient statistical power to detect an effect.

However, with the advent of persuasive technologies and because persuasive systems can scale easily, health education scholars can test different persuasion strategies, at large scale (Kaptein, 2012). Since these systems are interactive and can manage huge amounts of data, researchers can use *big data analytics* to explore participants' reactions to the persuasive contents and gain deeper insight about the efficacy of different persuasion mechanisms.

In summary, the main objective of my research is to advance the design of effective adaptive persuasive systems by developing a model for automatic tailoring of persuasive communication. My findings will also inform the design of future experiments related to persuasive communication, and will add to the current persuasive technology literature.

1.3 Research Objectives

Within the course of this doctoral research, after reviewing the current literature to explore the tailoring mechanisms used in prior persuasive systems, I will focus on a specific tailoring strategy to build a persuasive communication framework and then investigate its efficacy. I will seek answers to the following questions:

1. Do persuasive systems work more effectively when their communication strategy is tailored to the users' psychological characteristics? To be more specific, does message tailoring increase the chance of users performing the target behavior?

To answer that question, I need to know whether participants receiving tailored persuasive messages during the period of the study would perform the target behavior more frequently than those receiving non-tailored messages.

When I find answers to those questions, I will then investigate:

2. How a system can dynamically observe users' psychological status over time to adapt the communication strategy appropriately and without requiring users to fill out questionnaires repeatedly?
3. Does the frequency of performing the target behaviour in each category of systems (adaptive vs. non-adaptive) decrease at the same rate over time? (In other words, does a statistically significant difference exist in the user attrition of those two types of systems?) I hypothesize that the proposed adaptive persuasive system will increase the efficacy of behaviour-change support systems and in general will decrease the user attrition rate.

The following section discusses the background and theoretical foundation for this work.

2. Theoretical Foundation

According to O'Keefe (2002) persuasion means "[an] intentional effort at influencing another's mental state through communication in a circumstance in which the persuadee has some measure of freedom"(p. 5). Briñol and Petty (2009) highlight the fact that persuasion, which happens in a particular context, requires an intervention such as a persuasive message (or a persuasive image).

Scholars, including Oduor, Alahäivälä, and Oinas-Kukkonen, (2014), believe that when it comes to persuasive interventions, interactive communication is the best mechanism to employ, especially if such interventions function in an adaptive manner. They also indicate that because computational technologies are becoming pervasive and have different communication modalities, these technologies can act more effectively than humans to persuade individuals.

Fogg explains that persuasive systems adapt three key functional roles while interacting with humans. They can act as tools that facilitate task performance; or act as media, which can influence users' perspective; or function as social actors, which means they can emulate the role of a social entity and by doing so can trigger a social response in users (Fogg,1998).

Fogg's behaviour change model is the theoretical foundation of Persuasive Technology. The model, itself, is based upon a broad set of psychological theories, including (Fogg, 2015): the Self Determination Theory (Ryan and Deci, 2000), Theory of Reasoned Action (Fishbein, 1979), Hierarchy of Needs (Maslow & Herzeberg, 1954), etc. Each of these theories models human behaviour from different perspectives and defines different determining factors to predict human action or behaviour. The next section explains the main principles of Fogg's behavioral change model.

2.1 Fogg 's Behavioural Change Model and Persuasive System Design

According to Fogg's model (2009), "[t]hree elements must converge at the same moment for a behaviour to occur: motivation, ability, and trigger" (p. 1). Fogg explains that if behaviour does not happen, at least one of these three elements is missing (Figure 1). Thus, it is important that the trigger occurs in a space where a user has sufficient motivation and ability to perform the task related to behaviour change. For example, if a user is highly motivated but not capable of performing the task, issuing a trigger (e.g., a reminder) does not lead to task accomplishment.

Therefore, Fogg's model can be used to identify obstacles that inhibit people from performing a specific behaviour. He suggests that for creating change, designers should start questioning whether users are triggered sufficiently, or at the right time. If not, they should try making the behaviour simpler, and if that still does not lead to change, they need to re-design the system so as to increase users' motivation.

Fogg (2009) has outlined an eight-step procedure to guide designers of persuasive systems: 1) choose a simple behaviour, 2) choose a receptive audience first, 3) find what prevents the behaviour, 4) choose a familiar technology channel, 5) find relevant successful examples, 6) imitate successful examples (consider how they address motivation, ability, and trigger), 7) test and iterate quickly, 8) expand on success (scale the intervention to support a more difficult behaviour or different audience).

In addition to these high-level guidelines, he has listed a set of strategies to be used in designing persuasive technologies. Although helpful, his list does not provide sufficient information on where to employ what type of persuasive mechanisms. For that reason, other researchers have created other frameworks.

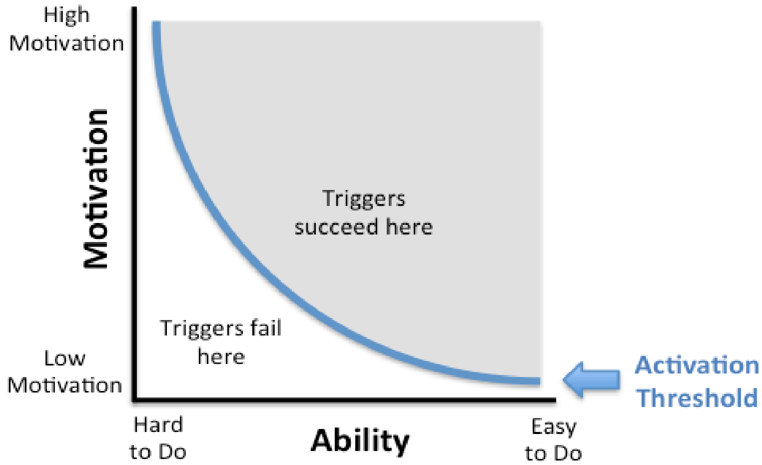

Figure 1. Fogg's Behavioral Model for User Design[6]

2.2 Persuasive Systems Design Model

Based on several behaviour change models, including Fogg's, Oinas-Kukkonen and Harjumaa (2009) built a design and evaluation framework, known as the Persuasive Systems Design (PSD) model. It presents a set of persuasive design features and, moreover, it identifies the intent, the event and the strategies that can be used to persuade. They classify design features into the following four categories (Table 1):

- Primary task support: Features that support users in performing their primary task
- Dialogue support: Features that support users while interacting with the system
- Credibility support: Features that make systems more credible and, therefore, more persuasive
- Social support: Features that motivate users by increasing social influence through the system

[6] Fogg's Behavioral Model for User Design. Retrieved from http://captology.stanford.edu/resources/paper-behavior-model-for-user-design.html

	Persuasive Design Features			
Persuasion Context	**Primary Task Support**	**Dialogue Supports**	**Credibility Supports**	**Social Support**
The Intent: Persuader; Change Type	Reduction	Praise	Trustworthiness	Social learning
	Tunnelling	Rewards	Expertise	Social comparison
The Event: Use context; User context; Technology context	Tailoring	Reminders	Surface credibility	Normative influ nce
	Personalization	Suggestions	Real-world feel	Social facilitation
	Self-monitoring	Similarity	Authority	Cooperation
The Strategy: Message; Route	Simulation	Liking	Third party endorsement	Competition
	Rehearsal	Social Role	Verifiability	Recognition

Table 1. Persuasive Systems Design Model (Adapted from: Oinas-Kukkonen & Harjumaa, 2009)

Although Table 1 shows many different features to employ in the design of a persuasive system, it is important to note that not all of those features are necessarily useful in developing a health-related intervention. According to Kaptein (2012), employing multiple strategies to deliver a persuasive message does not always increase the persuasiveness of that message. For that reason, researchers need to investigate which set of techniques would be most beneficial based on the domain of use and the user demographic. Here, I explain some of those features that are most relevant to the research I am proposing:

2.2.1 Persuasive features: primary task support

Persuasion techniques that support users in performing an intended task belong to this category (Oinas-Kukkonen & Harjumaa, 2009). Some of those features include:

Tailoring[7]. Oinas-Kukkonen and Harjumaa (2009) defined tailoring as providing persuasive information, tailored to the needs and interests of a user group.

Personalization. Psychological research shows that when users are provided with systems that are tailored to meet their own specific preferences and needs, they view the system as not only more engaging, but also more persuasive (Leto & Oinas-Kukkonen, 2011). Currently, many technologies use this principle including the Fitbit or Jawbone activity monitoring application.

Self-monitoring. Self-monitoring involves including technological features in the system to track personal behaviour or health status and, therefore, eliminate the laborious work of continuous monitoring by users themselves (Fogg, 2003). Personal glucose or blood pressure monitoring devices are examples that use this technique.

2.2.2 Persuasive features: dialogue support

Persuasion techniques that support a user while interacting with the system, belong to this category. These techniques include:

Reminders. Reminders are necessary to trigger user motivation and reinforce them in working toward to their target behaviour (Fogg, 2003).

Social Role. As mentioned earlier, computing systems can function as social entities and simulate human-to-human types of interaction (Fogg, 2003). By doing so, they can be as

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[7] In the science of marketing or communication, the term tailoring is used to describe the process of designing the communication messages based on individual users' characteristics, whereas targeting means to design the communication messages based on the characteristics of a user group. Unlike the common practice, Oinas-Kukkonen and Harjumaa have used the terms tailoring and personalization to describe these two strategies instead. Throughout this documents, however, the term tailoring is used according to its common usage.

persuasive as their human counterparts. Examples of this feature are the virtual coaches in apps that promote physical activity, or the virtual clinicians in health-related interventions.

Suggestion. When systems provide users with suggestions that align with their efforts toward their goals, the chance of users adapting target behaviour rises (Fogg, 2003). For example, a remote health-monitoring app suggesting healthy nutrition choices to people with cardio vascular disease, is employing this feature.

Similarity. The more a system resembles its users, the more it has the potential to persuade them (Fogg, 2003). For example, health interventions developed for young adolescents are more persuasive when communicating in slang (Lehto & Oinas-Kukkonen, 2011).

Liking. According to Fogg (2003), when systems are visually appealing and attractive they are also perceived as more persuasive. This principle has been applied for decades in the design of software applications.

Rewards. This strategy has been used for a very long time. It is based on the principle of operant conditioning, which explains the strong effect of positive reinforcement on shaping new behaviours (Fogg, 2003). Examples of this feature are virtual trophies and badges that players can earn based on their performance, in the world of digital games.

Praise. The psychological impacts of praising are well-known; when a system praises users upon a desired behaviour, those users are motivated and continue performing that behaviour (Fogg, 2003).

2.2.3 Persuasive features: credibility support

Fogg (2003) explains that if a user perceives a system to be credible, there is a higher possibility that s/he will be positively affected by that system. The PSD model defines features that increase system credibility. For example, software apps that show their content is created by experts are more convincing. A health intervention that provides its users with health-related recommendations will be deemed more reliable—and therefore more persuasive—when its users know the suggestions are created by clinicians/scientists. Also, the very first-hand impression of a mobile app or website shapes users' attitudes on its credibility (Fogg, 2003). Software systems with an unprofessional or amateurish look will not successfully attract users.

2.2.4 Persuasive features: social support

Based on the knowledge drawn from social psychology, the social influence strategies that can be imitated by computing systems are placed in this category. Those features include providing system users with the possibility to compare their behaviour with the behaviour of others in order to motivate to progress toward the target behaviour (Fogg, 2003). This feature, called Social Comparison, is used in many apps that encourage individuals to perform physical activity, such as the Jawbone Up.

3. Related Work

This chapter discusses the persuasive systems that use tailoring mechanisms as an influencing strategy. Although extensive research has been conducted to investigate the efficacy of tailoring in persuasive systems, still little has been done to explore its efficacy when is done based on users' psychological characteristics.

Three categories of the research are discussed here: first, studies related to persuasive communication in the domain of health education; second, examples of persuasive systems that are designed to promote healthy behaviors—particularly those that used tailoring; and finally, research related to the adaptive persuasive systems.

3.1 Studies related to health promotion in public health communication

This section outlines empirical findings from research related to the design and tailoring of persuasive communication in the domain of health and well-being.

3.1.1 Roles of psychological models in health promotion and communication

Over the last decades, scientists have employed different psychological models to frame health messages for educating the public and promoting healthy behaviours. Some of these models include: the Trans-theoretical Model (Prochaska & Velicer, 1997), Health Belief Model (Becker, 1974), Social Cognitive Theory (Bandura, 1991), Elaboration Likelihood Model (Petty & Cacioppo, 2012), Self-Determination Theory (Ryan & Deci, 2000), and the Theory of planned behaviour (Ajzen, 1991).

However, many researchers including O'Keefe (2012) have highlighted that applying these models—even when widely accepted—is not a straightforward task and does not necessarily result in effective persuasive communication. Updegraff, Rothman, and Salovey

(2012) indicate that the mechanism by which persuasive messages impact individuals' attitude and behaviour is still unclear. According to Noar, Harrington, and Aldrich (2009), although many studies have claimed that the message formulation was done based on a particular behavioural theory, not all components of that model were employed, or additional components not related to the theory were added, which in turn made investigating the efficacy of that particular theory impossible. Alternatively, in others, combinations of components from different models were used to formulate messages, which again made determining the most significant influential factors impossible. Therefore, the best strategies for tailoring and formulating a persuasive messages are still undetermined.

One of the most-used theories has been Prospect Theory[8]. O'Keefe and Jensen (2006) conducted a meta-analysis of 165 studies, in which Prospect Theory and two psychological phenomena (negativity bias and loss aversion) were used to frame persuasive health messages. These two constructs were employed to design (either loss-framed or gain-framed) health messages, and the empirical findings showed that loss-framed messages have a stronger impact than gain-framed ones in persuading all individuals (Gallagher & Updegraff, 2012).

However, these researchers pointed out that the observed effect size difference in the two types of framing—although statistically significant—was very small (O'Keefe & Jensen, 2006; O'Keefe, 2011b; Gallagher & Updegraff, 2012; O'Keefe, 2015), and that small size might be attributed to moderating factors such as type of behaviour, or individuals' perception

[8] Prospect theory explains that because, in general, individuals are more affected—emotionally—by losing rather than gaining something (loss-aversion), when making decisions they would rather avoid potential losses rather than potential gains (Kahneman & Tversky, 1979).

regarding potential risks (Updegraff, Rothman, & Salovey, 2012). Researchers believe, accounting for these factors should lead to a larger effect size. For example, the average effect size for a detection behaviour such as self-examination to detect breast cancer were r = -0.052, and for a prevention behaviour like controlling weight were r = 0.037[9] (Gallagher & Updegraff, 2012).

O'Keefe and Jensen (2007, 2009) conducted two other meta-analyses and reviewed 146 studies, to investigate the assertion that loss-framed messages can more effectively promote disease detection behaviours, and gain-framed messages can more effectively promote disease prevention behaviours[10]. Their findings revealed that although statistically significant differences were observed in the average effect of these two approaches, again, the effect sizes were trivial (for the disease prevention studies r = 0.03, and for the disease detection studies r = -0.04).

O'Keefe and Nan (2012) underline that resolving this problem (small observed effect size) requires more data, produced by large sample sizes[11], as well as replication to reach reliable results As we can see, all three requirements can be met by utilizing modern

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[9] According to Cohen (1988), for research related to the social sciences r = 0.1 represents a small effect size, r = 0.3 represents a medium, and r = 0.5 represents a large effect size.

[10] Encouraging regular self-examination to detect breast cancer and reducing daily salt intake to prevent cardiovascular disease are examples of disease detection and disease prevention types of behaviours.

[11] According to O'Keefe and Nan (2012), "in small-sample designs, a statistically significant result will necessarily involve a relatively large effect size . . . Statistically significant effects in a small-sample design may simply be outliers, results that exaggerate the true effect . . . The remedy for these weaknesses is straightforward: more and better data, in the form of larger samples" (p. 781).

technology—ones that are capable of measuring and recording a large number of individuals' data everywhere, and over long periods of time.

Additionally, worth mentioning is the limitation in the approach used in those studies: researchers did not tailor the health messages to address different types of audiences. I elaborate more on this constraint in the next section.

3.1.2 The importance of tailoring

Considering the ambiguity of the findings as described in the previous section, a group of scientists have decided to inspect each element of persuasive communication in further detail.

Noar, Harrington, and Aldrich (2009) emphasize that instead of using a combination of models and elements to formulate a message, it is important to bring down the research question to a very basic and clear one, in which the effect of controlled elements can be meticulously investigated. They detail that persuasive communications rely on elements such as a message's source, its receiver, medium, content, and the context in which it is delivered. They also explain that because people's reactions to identical message coming from the same source and in the same context are not identical, it is important to pay attention to the individuals' differences and the factors that cause their different reactions.

Health communication scholars have been investigating the effects of tailoring messages for a long time, and verified that tailoring increases the impact of persuasive health messages (Hawkins, Kreuter, Resnicow, Fishbein, and Dijkstra, 2008). According to De Vries, Kremers, Smeets, Brug, & Eijmael, (2008, p. 417) "[tailored messages] are more likely to be read, saved, remembered, and discussed" by receivers.

Noar, Benac, and Harris (2007) conducted a systematic review of 57 studies in which participants were provided with tailored health messages. According to the review, the participants considered tailored messages more engaging and relevant. The impact of the tailored messages on behaviour change was larger, as well. The average effect sizes across the studies were r = 0.074 (e.g., for smoking cessation studies r = 0.086 and for diet related interventions r = 0.084). Yet, the elements of the tailored messages that made them effective were still not clearly identified. As Noar, Harris and Aldrich (2009) indicated: "[there is a] need for many more basic message-design studies (as opposed to larger field trials) as well as meta-analyses to synthesize this large literature and help us to parse out the 'active ingredients' of effective tailoring" (p. 412).

Modern technology makes tailoring—and studying its effect—easier. Wearable devices or cell phones that accompany individuals almost 24/7 are useful tools for collecting data and transmitting them to the servers where tailored messages can be created or picked out in real-time, then sent to users—at opportune moments—to increase their effectiveness.

3.2 Persuasive Systems

Based on the persuasive design model, researchers have developed a large number of behaviour-change support systems, including health and wellness interventions to improve individuals' behaviour toward better health. Some of the persuasive techniques that were commonly used and found to be effective include reminders, self-monitoring, and praise (cf., Seto et al., 2012b, Stinson et al., 2013; Chatterjee, 2012). Many of these technologies used reward systems as a persuasive mechanism, such as those interventions developed by Stinson et al. (2013), Cafazzo, Casselman, Hamming, Katzman, and Palmert, (2012), and Volpp (2009). Some used social portals, where users could receive social support from their peers or care-givers (Cafazzo et al., 2012; Consolvo, Everitt, Smith, & Landay, 2006; Toscos, Faber, An, & Praful Gandhi, 2006; Consolve, 2008; Dhillon, Burkhard, Wünsche, Lutteroth, 2011; Stevens et al., 2008; Kutz, Shankar, & Connelly, 2013; Baumer et al., 2013; Khalid & Abdallah, 2013). Others used embodied conversational agents[12] as a component to engage users with the technology (Vardolakis, 2013; Grolleman, Van Dijk, Nijholt, & Van Emst, 2006; Eyck et al., 2006).

In general, all persuasive health interventions 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 consequence of their behavior (Cugelman, Thelwall, & Dawes, 2011); however, many of systems fail by not considering personal differences in their design and implementation. To be more specific, there is a significant need to investigate how technology can communicate health-related messages to individuals more effectively by tailoring the communication to increase the chance of their adaption to the target behavior.

Although, public health researchers have studied a wide variety of approaches for tailoring health messages more effectively, their findings have not been employed broadly in the design of persuasive systems.

In the rest of this subsection, first, I introduce examples of persuasive health interventions that utilized tailoring based on the user's physiological condition —in addition to other persuasive techniques. Then, I detail those studies that have employed tailoring technique based on users' psychological condition.

3.2.1 Tailoring based on physiological condition

In a study designed for individuals with heart failure, Seto and colleagues (2012a) examined the effectiveness of particular persuasive features that contribute to an effective

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[12] Embodied Conversational Agents are animated figures in computer applications, with which users can have conversation (Cassel, 2000).

blood pressure monitoring system. They conducted a randomized control trial with 100 participants (50 in the intervention and 50 in the control group). Heart failure patients in the intervention group received health instructions on their mobile phones, tailored to their health, over the period of six months. The instructions were based on patients' physiological data and the symptoms they reported. The researchers used qualitative methods such as interviews and surveys to identify components that increased patients' engagement with their blood pressure management. Additionally, researchers used the Self-Care of Heart Failure Index[13] (Riegel, Lee, Dickson, & Carlson, 2009) to investigate whether the designed system increased patient self-care in the intervention group. A statistically significant difference ($p = 0.03$) emerged between the levels of self-care in each group. Moreover, patients reported that receiving tailored feedback messages made them felt more empowered in managing their condition, and therefore have less anxiety than the patients who did not have access to the persuasive system.

In a randomized control trial, Logan and colleagues (2012) designed and developed a persuasive health intervention for diabetic patients with hypertension to reduce the blood pressure by increasing their medication adherence. The system regularly sent patients self-care messages on their mobile phones, and the messages was formulated to respond to the their blood pressure trends. The study was conducted with 110 blood pressure patients over the period of one year with 55 patients experiencing the self care messages and 55 patients receiving no messages. The results showed that at the end of the study the systolic blood pressure of the intervention group decreased significantly (by 9.1 ± 15.6 mmHg, $p = 0.0001$).

[13] The SCHFI is a survey that measures patients' level of self-care in managing their heart failure.

In addition to tailoring, other persuasive techniques were used in their system including self-monitoring, reminders, and suggestions. As a result of the multiple persuasive techniques, the effect of the tailored messages could not be isolated.

A large number of similar studies exist, where using tailored health messages—among other techniques—proved to be beneficial in promoting patient health. However, the fact that researchers used multiple influencing strategies makes it impossible to specify the exact effect of each strategy—particularly tailoring. Studies that focus on the efficacy of tailoring strategy when used alone and not in combination with other strategies are necessary, in order to isolate the effect of tailoring as an intervention. Moreover, although many researchers (cf., Seto et al., 2011; Agarwal, Anderson, Zarate, & Ward, 2013) highlighted the important role of patients' psychological conditions (such as their self-efficacy) in patient self-care, those factors were not accounted for in the design of the interventions mentioned above. It can be hypothesized that if in addition to tailoring based on patient physiological condition, systems tailor messages based on their psychological condition, then patients would become better persuaded and therefore more engaged in their self-care.

3.2.2 Tailoring based on psychological characteristics

In the persuasive technology literature, the number of studies that employed user psychological characteristics for tailoring is relatively small. In this section, I describe some of those studies.

Tailoring based on personality traits: Halko and Kientz (2010) conducted a survey with 240 individuals to investigate the user perception of persuasive strategies and its relation with the individuals' personality traits, based on the Big Five personality traits.[14] By reviewing persuasive technology literature, these researchers identified eight different strategies that were commonly used to promote healthy living by means of mobile apps. They presented these eight different approaches in the form of storyboards to the participants. Each storyboard represented one of the eight persuasive strategies. Then participants were asked to fill in a questionnaire that solicited their opinion about the strategies depicted in the images. Following that, participants had to fill out a Big Five inventory questionnaire, so their personality type would be identified. The result demonstrated a significant correlation between a participant's personality and the type of persuasive strategy she or he preferred ($p < 0.05$).

Tailoring based on gamer types: In an effort to design a persuasive health game that improves individuals' eating habits, Orji, Mandryk, Vassileva, and Gerling (2013) developed a model that associated gamers' types (such as achiever, conqueror) with gamers' health behavior determinants (such as self-efficacy, perceived benefit, perceived severity)[15]. To develop their model, Orji and colleagues recruited 642 computer- or video-gamers and conducted an online survey in which participants' gamer types, as well as their health behaviour determinants were identified. The survey data showed that the influence of each of these health behavior determinants on an individual differs based on what type of gamer that person is. For example, when designing a game to assist smoking cessation, indicating the risk

[14] The Big Five traits represent a taxonomy of five varied types of personality: Extraversion, Agreeableness, Openness, Neuroticism, and Conscientiousness. For more information, see McCrae and Costa (1987).

[15] Rosenstock (1974) developed a health behaviour change model, named Health Belief Model that describe individuals' behavioural patterns with respect to the health related behaviours.

associated with smoking has the most influence on *achievers;* or in a game that promote physical activity, presenting the benefits of being more physically active has the most influence on *conquerors*. Moreover, these researchers provided a classification of game mechanics that helps game designers choose the best game technique when designing games. At the end, these researchers indicated that further studies are necessary to validate their model in different health behaviour domains.

Tailoring by susceptibility to persuasion: One of the most systematic work in tailoring based on psychological characteristics is the research of Kaptein, Markopoulos, de Ruyter, and Aarts,(2009). Based on a psychological construct named Need for Cognition (Cacioppo & Petty, 1982), Kaptein and colleagues developed a Susceptibility to Persuasion Scale (STPS) that measures individuals' susceptibility to six different influence strategies such as commitment, scarcity, authority, and consensus. After validating the scale, Kaptein, De Ruyter, Markopoulos, and Aarts (2012) used it in a two-week study with 73 participants to examine a persuasive system with the goal of changing user behavior in daily snack consumption. At the beginning of the study participants filled out the STPS questionnaire so their persuasiveness characteristics would be identified. Then over the period of study, they received tailored messages that fit their persuasiveness characteristics. The results showed that tailored messages affected users' behavior and led to less snack consumption ($p < 0.001$).

These experiments were example of studies, in which tailoring of the persuasive communication was done based on psychological characteristics of the users. These researchers tried to build new models for developing persuasive systems based on well-accepted psychological theories; however, the validity of those proposed models is still to be determined.

3.3 Adaptive Persuasive Systems

Kaptein and Eckles (2010, p. 84) define adaptive persuasive technologies as "technologies that aim to increase the effectiveness of some attitude or behavior change by responding to the behavior of (and other information about) their individual users." These systems are capable of selecting the best persuasive strategy simply by evaluating user's prior response to each strategy.

In general, these systems are divided into two main categories: end-adaptive versus mean-adaptive adaptive persuasive systems (Kaptein & Eckles, 2010).

The first category, end-adaptive, include the type of technology that observe individuals interests and preferences in a particular domain (e.g. online shopping) and based on prior user's selections, makes personal profiles to be used by intelligent agents to predict other items that might be of user's interest. Examples of this strategy are recommendation systems of the e-commerce websites.

The second category, mean-adaptive technologies, includes the type of systems that observe individuals' behaviours in response to different persuasive strategies and create personal profiles according to those observations, which can be used to persuade users in future events. The important characteristic of this category of adaptive persuasive systems is being domain independent.

Kaptein, Markopoulos, de Ruyter, and Aarts (2015) identified four major requirements for the design of mean-based adaptive persuasive systems. First of all, it is crucial that the system be capable to identify the type or condition of its user. Not knowing the characteristics of the user make it impossible to determine the type of the strategy it should employ at each point in time to influence. Second, by recognizing user's need or condition, the system should be capable to adapt and represent the persuasive message accordingly. Third, the system should be able to measure user's reaction to the employed strategy, and finally, in situations when multiple influencing strategies are used simultaneously, the system should have the ability to identify user's reaction in response to each particular employed persuasive mechanism. Otherwise measuring the independent effect of each mechanism would not be possible.

The aim of this research is to investigate strategies that lead to increase of efficacy of mean-based adaptive persuasive systems. In the following chapters, first, I briefly explain the research I have done that lead to the current work, and then I describe of my proposed adaptive system and the suggested experiments.

4. Previous Works

To identify effective persuasive features for developing a home health monitoring systems, I conducted an exploratory study (sponsored by Medtronic Inc.) in which a prototype of a remote blood pressure monitoring system was created and presented to elderly adults with hypertension.

The first step to develop the interface of a monitoring application was to conduct an in-depth analysis of the problem domain in order to gain a better understanding of the variables, actors, data flow, as well as the full functionality of the system. Cognitive Work Analysis (CWA) (Rasmussen, Pejtersen, & Goodstein, 1994; Vicente, 1999), a framework for analyzing and modeling complex sociotechnical systems, was used for this analysis. CWA provides designers with a set of tools to analyze the environment and the problem domain. It also assists in modeling actors' behaviour and different strategies they can choose while interacting with the system, as well as interacting with each other. Moreover, it models actors' cognitive competencies by classifying their performance into three categories of skill-, rule-, and knowledge-based behaviour.

Since blood pressure monitoring systems are complex, in order to determine the design requirements of the interface, I applied CWA framework and conducted a work domain analysis using Rasmussen's abstraction-decomposition hierarchy. The result of this analysis (a collaborative effort with Prof. Catherine Burns) is published in the proceeding of HFES Healthcare 2014, and can be found in Appendix 9.1.

The prototype was built based on the Persuasive Design Model (Oinas-Kukkonen & Harjumaa, 2009). It incorporated a variety of persuasive mechanisms and was presented to ten elderly patients with high BP at St. Mary's General Hospital in Kitchener, Ontario.

Participants' opinions about the mockup, their preferences, as well as their concerns regarding the different components of the prototype were collected. This study gave me an insight about the type of features that can potentially engage users to monitor their blood pressure regularly. It revealed that not all mechanisms suggested by Fogg could necessarily be useful in the design of a home health monitoring system for elderly adults with hypertension. For example, the majority of the participants did not favour the idea of sharing their health progress in a social portal provided by the application where they could receive recognition from their peers. The study method and its results are published in the proceeding of HFES Healthcare 2014, and can be found in Appendix 9.2.

5. Proposed Research

The results of my preliminary user study had a significant role in determining which persuasive features might be less and which might be more suitable for designing an engaging blood pressure monitoring system for elderly people with hypertension. I learned that not all persuasive strategies are appropriate for all types of applications and all types of users. Most importantly, I realized the necessity of focusing on each technique separately and studying its effects in order to define a set of clear design guidelines for the persuasive design framework. Therefore, I decided to focus on tailoring techniques related to persuasive communication and to investigate one of those influence mechanisms that is deemed promising in the design of persuasive systems. The chosen approach, developed based Higgins' Regulatory Focus Theory (Higgins, 1997), will be used to create an adaptive persuasive system that promotes physical activity.

In this chapter, first I explain Higgins' theory; then I discuss how it has been used in the context of persuasive communication; and finally, I describe how the implications of this theory have served public health educators in encouraging healthier living.

5.1 Higgins' Regulatory Focus Theory

Regulatory Focus Theory, introduced in the late 1990s by Tory Higgins, describes two different self-regulatory orientations that individuals are inclined to while pursuing their goals: promotion-focus and prevention focus. Individuals with chronic promotion-orientation employ a motivational strategy that focuses on accomplishment and potential gains, whereas individuals with chronic prevention-orientation employ a motivational strategy that focuses on safety and security, preventing potential losses.

According to Higgins' theory, when people are moving toward their goals, if their goal pursuit strategy matches their regulatory focus (or as he calls if there is a regulatory fit), they will be more motivated and engaged in the goal pursuit process.

5.2 Framing Health Messages Using Regulatory Focus Theory

Higgins' theory has played an important role in persuasion (Cesario, 2008) and has been used in a variety of domains, including marketing and public health education. As it was mentioned in previous sections, health messages can be framed in either negative or positive words. Example of a negatively frame message (loss-frame message) is: "if you don't undergo screening test for cancer, your survival will be shortened" (Block & Keller, 1995, p. 193), and example of positively frame message (gain-frame message) is: "if you undergo a screening test for cancer, your survival will be prolonged" (Block & Keller, 1995, p. 193). Research shows that for individuals with chronic prevention-orientation loss-framed messages, and for promotion-oriented people gain-frame messages would be more effective when communicating health messages (Batra, Keller, & Strecher, 2010).

5.3 Previous Studies

Since 2000 researchers have started conducting studies and examining the persuasiveness of health messages that are designed based on regulatory fit theory. In this section, I introduce some of those studies.

Latimer and colleagues (2008a) conducted a study with 518 participants, in which consuming fruit and vegetable was promoted. At the beginning of the study, participants' regulatory orientation was measured by means of Regulatory Focus Questionnaire (RFQ) (Higgins et al., 2001). Consequently and over the course of three months, participants randomly received either promotion- or prevention-oriented messages three times (at weeks one, eight, and 12). The researchers found that when there was a fit[16] between the messages and individuals' regulatory focus, fruit and vegetable intake increased. However, this was not the case for the non-fit condition. The reported effect size for the study was r = 0.14.

In another study, Latimer and colleagues (2008b) examined the theory by persuading individuals to perform physical activity. Two hundred and six individuals with sedentary lifestyle were recruited, and were asked to complete the International Physical Activity Questionnaire (Craig et al., 2003) in order to record their level of activity at the beginning of the study as a baseline measure. Then they received a letter containing persuasive content to promote physical activity. Similar to the previous study, the contents were formulated either in promotion- or prevention-oriented format. At the end of a two-week follow-up period, participants completed the RFQ, so their regulatory focus could be identified. The results showed that promotion-oriented participants became more active when the messages matched their regulatory focus. However, for the prevention-oriented group, a fit between their regulatory focus and the type of message they received did not result in a statistically significant outcome.

Some of the limitations of those works include: first, in prior experiments the study durations were fairly short and therefore, investigating the validity of this persuasion strategy over longer periods of time is necessary; second, not all of the studies have measured the actual desired outcome—which is the behaviour itself—but rather other possible measures

[16] The "fit" condition means that the messaging strategy matched participants' regulatory focus (either promotion-oriented×promotion-message or prevention-oriented×prevention-message). "Non-fit" means that the messaging strategy and participants' regulatory focus were mismatched (either promotion-oriented×prevention-message or prevention-oriented×promotion-message).

such as behavioural intention, attitude, perceived pensiveness; and finally, in none of those studies, were the participants exposed to persuasive messages provided to them in a regular repetitive manner.

Ludolph and Schulz (2015) conducted a systematic review to determine whether message framing and tailoring—based on regulatory focus theory—were effective in promoting healthier living. They examined 30—out of 2127—studies published between 2000 and 2013 and found that the theory could increase the efficacy of persuasive communication and therefore individuals' health. Their review suggests that tailoring based on regulatory fir theory may be an effective strategy in delivering persuasive communication.

Consequently, I describe the schema of the proposed adaptive persuasive system that I will develop to conduct an experimental study and investigate the validity of the proposed approach.

5.4 Proposed Adaptive Persuasive System

Based on Higgins' regulatory focus theory, and Kaptein's (2015) description of adaptive persuasive systems, I propose the following structure for my system (Figure 2).

As shown in the diagram, the self-reported and sensor-generated data go to a mobile-/web-based application and from there to a central system, where information for all users will be analyzed and stored. Once the central system receives user data, the data processing will start. Based on the newly received data, the system identifies whether the previously applied approach (the framing structure) acts successful in persuading a user or not. If successful, the system continues to employ the same influence strategy to encourage that user to continue performing the target behaviour. Otherwise, an alternative approach will be employed to build persuasive messages and to persuade the user.

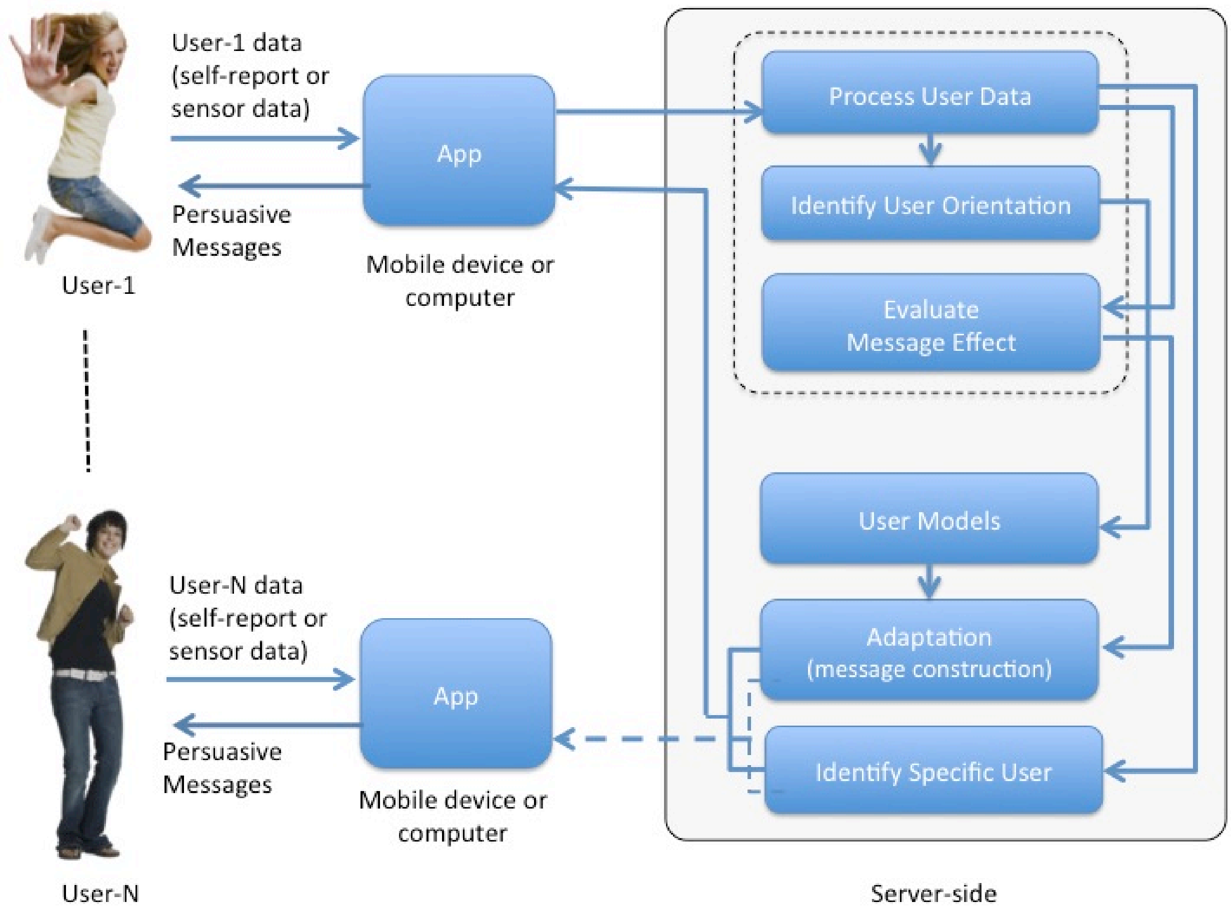

Figure 2. Diagram of the proposed adaptive persuasive system

Because the central system is processing the data coming from N number of users, and because it should generate user-specific persuasive message, it is important that it has the ability to identify uniquely each user and the associated data.

5.5 First Proposed Study

To study the effectiveness of message tailoring when it is based on regulatory fit theory, I propose an experiment in which the influence of persuasive messages on individuals' attitudes and behaviours will be examined.

In this experiment, participants with a sedentary life style will be encouraged—through persuasive health messages—to become more physically active and to take a 20-minute brisk-walk every day. They will receive daily messages framed based on two different persuasion strategies, which may match or not match their regulatory focus.

A statistically significant difference in the outcome behaviour between the match and non-match (commonly known as fit and non-fit) conditions will prove the first hypotheses, which is:

Tailoring health messages according to individuals' regulatory focus increases the chance of user adoption of target behaviour.

The independent variables in this experiment are:

- Individuals' regulatory focus (promotion-/prevention-focused)
- Message structure (prevention-/promotion)

And the dependent variables are:

- Behaviour (level of physical activity)
- Behavioural intention

Study population. For the purpose of this experiment, university students will be recruited. Such selection is in accordance with many prior studies, where regulatory focus theory was used for tailoring health messages (Kees, 2011).

Recruitment criteria. Potential participants should meet the following criteria:

1) Only those individuals who have a sedentary life style will be qualified to participate. To impose this requirement, students should complete the International Physical Activity

Questionnaire[17] (IPAQ) (Booth, 2003) to identify their level of physical activity, and only those with a low level of activity will be admitted.

2) Potential participants are required to complete Higgins' "Regulatory Focus Questionnaire" (Higgins et al., 2001), to make their chronic regulatory focus known. Identifying their regulatory focus a head of time and in the recruiting phase is necessary to ensure that the study population will consist of equal number of prevention- and promotion-focused individuals.

3) Additionally, participants should consent to install a mobile application[18]—specifically designed for the purpose of this study—on their phones, which will provide them with the persuasive messages and will also record and analyze the data related to their behaviour.

Sample size. In previous studies where Higgins' approach was used to promote physical activity (Latimar et al., 2008b; Kees, 2010; Kees, 2011; Gallagher, 2011; Jin, 2012; Martinez, 2012; Pfeffer, 2013), the average number of participants was 129.7. Moreover, in a systematic review conducted by Ludolph and Schulz (2015), which aimed to investigate the effectiveness of employing regulatory fit theory in health communication, the reported effect sizes of the analyzed studies were between r = 0.3 and 0.62. Such an effect size is considered to be medium to large, and therefore, in order to have a statistical power of 0.95, a sample size of 150 seems reasonable. This number will also ensure the required sample size specified by

[17] This is a common scale that measures individuals level of physical activity over the previous seven days, and has been used in many studies, including that by Latimar and colleagues (2008b).

[18] Mobile app will be developed in Android and iOS.

O'Keefe and Nan (2012), as they warned that a smaller sample size may lead to observing an inaccurate and possibly an exaggerated effect size.

Outcome measures. Two types of outcomes will be measured.

1) Participants' level of physical activity. The number of daily steps taken by participants during the 20-minute brisk-walk will be collected by a mobile app[19].
2) Participants' behavioural intentions. By means of a questionnaire, individuals' intention to perform physical activity can be measured. This type of assessment has been used in similar contexts (such as in the works of Jin (2010b), (Kees, 2010), (Kees, 2011), (Martinez, 2013), and Pfeffer (2013)) to measure the effect of a persuasive message on people. Unlike those studies, in which Likerts scales with ordinal values (strongly disagree to strongly agree) were used, in this study, participants will be asked to indicate the probability that they would perform their daily brisk-walk. Thus, the normality assumption for conducting suitable statistical analyses after the experiment will be satisfied. An example of such a questionnaire item is:

I predict that there is a ____ chance that I will go for a 20-min. walk today.

10% 2) 30% 3) 50% 4) 70% 5) 90%

Procedure. At the beginning of the study, there will be a baseline period of one week. During this period the average physical activity of participants will be measured. Every morning they

[19] Case and colleagues (2015) conducted an experiment wherein they examined the accuracy of mobile phone applications and wearable devices in measuring individuals' physical activity. Based on their findings, some of the existing mobile applications can function as accurately as common wearable devices on the market. One of the tested apps was Health Mate, which I will be using in my proposed experiment.

will receive a reminder through their mobile app to go for a daily brisk-walk. After receiving the reminder, they should immediately answer the behavioural intention questionnaire. Then during the day, once they start their daily walk, they should activate a step counter on their mobile phone app, and once they finish their walk, they have to terminate that step counter by pushing a virtual button on their phone, which will actually record the sensor data associated with the step counts.

Prior studies showed that just receiving messages (regardless of their content and structure) will increase participants' level of physical activity; therefore, it is important that in this baseline period, reminders are sent to ensure that the factor influencing the outcome variable is the *structure* of a message and not *receipt* of that.

After the baseline period, a two-week intervention period starts. The two-week period is consistent with the length of other studies including those of Muraven (2010a) and Klinger (2013) that investigate self-control (controlling's one behaviour). At the beginning of the intervention period, participants will be randomly divided into two groups: prevention-message recipients (PreMR) and promotion-message recipients (ProMR). Examples of the messages include:

Prevention message: Regular physical activity protects you from chronic heart diseases or chronic back pain (Pfeffer, 2013).

Promotion message: "Regular physical activity makes your body fit and gives you more energy throughout the day" (Pfeffer, 2013, p. 131).

Throughout the intervention period and every day after receiving their persuasive message, as during the baseline period, participants should immediately answer the behavioural intention questionnaire. Additionally, they should activate the step counter on their mobile phone app once they start their daily walk and deactivate it once they finish it.

At the end of this phase, to compensate participants, they will be entered in a draw to win a $200 gift card.

The collected data will be analyzed, and a between-subjects analysis of variance will be conducted. Because the participants will be randomly divided into either PreMR- or ProMR-group (regardless of their regulatory orientation), in each group, both fit and non-fit conditions will exist[20].

After the intervention period, the average increase in the level of physical activity of the fit condition will be compared to that of non-fit condition. Any statistically significant difference in the amount of increased physical activity between the two conditions will prove the first hypothesis.

As an extra safety measure, I will also investigate and analyze the outcome values of the behaviour intentions measure, to see if any statistically significant difference exists between the average of the increased intention to perform physical activity in the fit and non-fit conditions. If a statistically significant different emerges, then this additional analysis will also confirm the proposed hypothesis

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[20] To be more specific, in the PreMR-group, there will be prevention-oriented individuals, as well as promotion-oriented individuals. Therefore, promotion-oriented individuals will experience the fit condition (a match between their orientation and the message orientation), and promotion-oriented individuals will experience the non-fit condition (no match between individual's orientation and the message orientation). Similarly, in the ProMR-group, there will be promotion-oriented participants, as well as prevention-oriented participants, promotion-oriented participants will experience the fit and prevention-oriented participants will experience the non-fit condition.

5.6 Second Proposed Study

In the first experiment, I will study the effect of a static tailoring mechanism. In the second, I will test a proposed adaptive persuasive system that dynamically tailors health messages to individuals', encouraging them to become more physically active. I hypothesize that the proposed system will increase the efficacy of persuasive systems and will decrease user attrition rates.

The design of this study will be similar to that of the first one[21] (recruitment criteria, study population, sample size, etc.). However, during the intervention period, participants will not be divided into PreMR- or ProMR-groups. Instead, in the first day of the 2-week intervention period, each participant will receive a message that fits his/her regulatory focus—identified at the beginning of the study. Then, on the second day, if a participant's response to the delivered message (for example, a promotion-framed message) resulted in performing the target behaviour[22], the system continues to send him/her new promotion-framed messages in the days after, until it detects that the participant's response (number of steps taken that day) to the delivered message is below his/her average steps counts (measured in the baseline period). In that case, the system will send this participant a message formulated according to the alternative persuasion strategy (a prevention-framed message), and if the newly employed strategy is effective (the participant takes steps beyond his/her average step count), the system continuous to employ that strategy until the end of the intervention period or till when the newly tried strategy becomes ineffective.

[21] For the second study, new participants will be recruited to prevent the carryover effect.

[22] If a participant takes the number of steps that is equal or more than her/his average step counts measured in the baseline period.

For a system to be adaptive, it is necessary that it be capable of observing user behaviour and then making decision based on each observation in order to employ the appropriate persuasion strategy. To build such a system, an intelligent agent is necessary, and I would employ a self-learning mechanism similar to the one used by Kaptein (2012) to build this intelligent entity.

At the end of the second study, the performance of the participants of the first and second experiments will be compared and results will be statistically analyzed to investigate whether the rate of user attrition in the adaptive persuasive system becomes lower than the attrition rate of the static one, tested in the first study. If the adaptive persuasive system results in a lower attrition rate, my second hypothesis will be proved.

6. Timeline

- Fall 2012: Taking first graduate course, starting literature review, collaborating on a research with Oculys Health Informatics
- Winter 2013: Taking second graduate course, continuing literature review, collaborating on a research with Medtronic Inc.
- Spring 2013: Taking third graduate course, continuing literature review, collaborating on a research with Medtronic Inc., holding a TA position
- Fall 2013: Literature review, collaborating on a research with Medtronic Inc.,
- Winter 2014: Literature review, conduction the first exploratory research study and analyzing the results, holding a TA position, publishing two conference papers, presenting at 2014 Human Factors and Ergonomics Symposium in Chicago, collaborating on a research with the School of Public Health
- Spring 2014: Participating in the IBM's Extreme Blue internship program
- Fall 2014: Completing the literature review
- Winter 2015: Designing the first experiment, finalizing the proposal
- Spring 2015: Comprehensive exam, development of the mobile app for the first study, getting approval from office of research ethics, recruiting participants
- Fall 2015: Running the first experiment, analyzing data, writing a journal paper
- Winter 2016: Finalizing the experimental design for the second study, getting approval from office of research ethics, recruiting participants, developing the adaptive system
- Spring 2016: Finalizing the adaptive system, running the second experiment, analyzing study data
- Fall 2016: Writing thesis, defending thesis, writing second journal paper

7. Conclusion

In this proposal, the lack of empirical guidelines on how to develop persuasive systems in general, and the absence of design rules for developing tailored persuasive communication, in particular, was mentioned as the main motivation for my research.

Many examples demonstrating the potential benefits of tailoring were presented, and different approaches to find the best method of tailoring were reviewed. Some of the problems with the existing strategies such as lack of consistent results in the findings of behavioural scientists and communication scholars were highlighted.

Consequently, a potentially effective approach for the design of adaptive persuasive systems, in which persuasion is founded on a relatively novel behavioural theory, is proposed. Experiments will be conducted to examine the suggested approach.

The findings of this research will potentially be of high value, especially as they will result in a set of design guidelines for developing adaptive persuasive systems. It is important to note that since Higgins' behavioral model is domain independent, the proposed method will be applicable for designing persuasive systems in any domain.

Moreover, and at a higher level, the produced results will not only contribute to human factors engineering, but also to behavioural psychology and health communication.

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9. Appendix: Published Papers

Using Cognitive Work Analysis and a Persuasive Design Approach to Create Effective Blood Pressure Management Systems

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Abstract. When developing patient self-management applications, designs must motivate patients to engage with the intervention so as to increase their medical adherence. This paper hypothesizes that for the analysis and design of these technologies, a Cognitive Work Analysis (CWA) approach would benefit from the additional insight provided by a Persuasive Design (PD) framework. The results of this combined approach are shown to be valuable in informing an Ecological Interface Design (EID) of self-management systems. Benefits come in two ways: First, by improving patients' understanding of their disease and how to manage it, and second by increasing their motivation to self-monitor. The next step of this research will be to devise a set of design guidelines that can be used to create effective patient self-management systems.

INTRODUCTION AND MOTIVATION

Every year, about 9.4 million people die worldwide due to the complications of hypertension (World Health Organization, 2013). The United States alone spends more than $ 47.5 billion annually on patients with high blood pressure (Heidenreich et al., 2011). This condition, a factor associated with congestive heart failure, requires patients to monitor their blood pressure (BP) on regularly (World Health Organization, 2013). However, research shows less than 25% of patients maintain their BP under a good control (Wolf-Maier et al., 2004). Although there is increasing evidence that BP tele-monitoring interventions improve overall BP control (Paré, Moqadem, Pineau, & St-Hilaire, 2010; Agarwal, Bills, Hecht, & Light, 2011; Logan et al., 2012), adherence to these technologies is low, and some of the barriers to their use include (Huff et al., 2011):

- Lack of knowledge
- Lack of motivation
- Forgetting
- Not having time

These findings challenge the notion of what is an effective human factors design for these new patient centered environments. As human factors practitioners, we regularly employ techniques that can help reveal decision-making requirements and improve user knowledge. However, we often work with employed users, who are driven to engage with decision-making technologies as an obligation of work. The patient user is often an unwilling volunteer in the process, who may not have the motivation, time or skills to take on their new role as operator in their work domain. For this reason, we have proposed exploring the use of two different approaches, Cognitive Work Analysis (CWA) with Ecological Interface Design (EID), and Motivational Theory with Persuasive Design (PD), to develop solutions that may help to bridge this gap.

We have proposed that CWA could provide design guidance for BP management, given that managing BP is a complex control problem with similarities to other domains where CWA has been applied successfully (Hajdukiewicz, Vicente, Doyle, Milgram, & Burns, 2001; Thompson, Hickson & Burns, 2003; Miller, 2004). CWA, with its emphasis on understanding the work domain, should reveal some of the knowledge-based requirements for successful BP control. However, we also propose that designs for patients must encourage their motivation to engage with the application, in order to be successful. There is little guidance on this matter in the CWA approach, so we have chosen to explore a PD approach. We have proposed that our CWA approach would benefit from the additional insight provided by a PD approach. PD focuses on how to design for user engagement and behavior change. We hypothesize that this approach will help in the design of patient-centered health monitoring systems, in which patients' willingness to improve their well-being can act as a potent leverage to improve system effectiveness. This research is an effort toward that goal.

THEORETICAL FRAMEWORKS

Cognitive Work Analysis

CWA is a framework that assists designers to analyze complex socio-technical systems and derive a set of design implications for developing such systems. By means of this framework, designers can design for unanticipated events by constraining and narrowing down the actors' options and thus shaping their behavior and making the process of decision-making simpler at the time of unpredicted events (Vicente, 1999). In particular, CWA has shown past success in the design of healthcare systems. For example, Wu, Cafazzo, and Burns (2012) conducted a WDA for designing an interface for radiotherapy monitoring systems, and based on their analysis, they made interface design recommendations in order to improve patient safety. Another example is the work of Georges, Burns, Morita, and Ansermino (2013), who performed CWA to elicit the design requirements of a patient monitoring system interface, aimed to assist clinicians in intensive care units. However, as can be seen in these two cases, and also many other research studies discussed in the work of Jiancaro, Jamieson, & Mihailidis (2013), in almost all of the applications, the design was for clinician support.

Persuasive Design

Persuasive Design is a set of techniques that system engineers employ in building Behavior Change Support Systems to help individuals adopt new behavior, or adapt their current behavior (Oinas-Kukkonen, 2010). Fogg, a behavioral psychologist, defines persuasive technology as technologies designed to change individuals' attitudes or behaviors (Fogg, 2002). Persuasive technology itself is built upon a broad combination of psychological theories, including: The Self Determination theory (Ryan and Deci, 2000), Theory of Reasoned Action (Fishbein, 1979), Hierarchy of Needs (Maslow & Herzeberg, 1954), as examples.

In the past decade, considerable attention has been paid to behavior change in a variety of domains, particularly well-being and health. Numerous studies indicate that behavior change interventions can assists users' performance with respect to their health. 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 users with appropriate feedback and inform them of consequences of their health behavior (Cugelman, Thelwall, & Dawes, 2011).

Many benefits are attributed to this approach. Lehto and Oinas-Kukkonen (2011) describe some of those benefits as reduction of the cost and inconvenience attributed to visiting the healthcare team in multiple trips, reduction of healthcare service costs due to the preventive nature of persuasive technology, and so forth. These advantages come through the following characteristics of persuasive systems:

- Being interactive
- Being persistent
- Offering anonymity
- Using many modalities to influence
- Capability of scaling easily
- Capability of going where humans cannot go or may not be welcome
- Capability of managing huge volumes of data

Fogg's Behavioral Change Model

Fogg developed a behavioral change model. According to his model (2009, p. 1), "Three elements must converge at the same moment for behavior to occur: motivation, ability, and trigger." He explains that if behavior does not occur, at least one of these three elements is missing. Also according to his model, it is important that the trigger occurs in a space where users have sufficient motivation and ability to perform tasks related to behavior change. For example, if a user is highly motivated to do a task, but not capable of doing it—even if a trigger is provided (e.g., a reminder)—this will not lead to any action. Fogg's model can be used to identify obstacles that inhibit people from performing a specific behavior. Examples of successful cases where persuasive features were employed include the work of Logan et al. (2011), in which the authors provided high-BP patients with tailored self-care messages via the patients' mobile phones. Their results showed that this intervention caused a decrease in patients' BP. Another example is the work of Cafazzo, Seto, and Jadad (2012), who developed a mobile application for individuals with type 1 diabetes. In their study, patients received incentives based on the frequency of their blood glucose measurements. Their results showed the persuasive system was effective, and the measurement frequency increased by 50% per day.

Persuasive System Design Model

Based on several behavioral change models including Fogg's, Oinas-Kukkonen and Harjumaa (2009) built a framework for designing and evaluating persuasive systems, known as the Persuasive Systems Design (PSD) model. Their model presents a set of PD features, and moreover, identifies the intent, the event and the strategies that can be used to persuade. They categorized design features into the following four categories:

- Primary task support: features that support users in performing their primary task
- Dialogue support: features that support users while interacting with the system
- Credibility support: features that make systems more credible and, therefore, more persuasive
- Social support: features that motivate users by increasing social influence through the system

A combination of features from these four categories can be used to make BP management interventions more engaging and therefore improve patient adherence. Many of those features are associated with the usability of the system and will increase patient's ability to adapt the desire behavior. Many others are those related to patients' cognition, motivation and regulatory focus.

OUR APPROACH

In this paper, we discuss a BP management system as an example of a typical remote health monitoring intervention. In remote BP monitoring systems the inputs include medicine, nutrition, physical activity, and emotional stimuli. These inputs affect patients' BP, and BP fluctuations will be conveyed to a home monitoring device and from there to be transmitted to the clinic servers. Based on patients' current and past data, clinicians will make necessary decisions regarding changes in medications or medication dosages, and new instructions will be sent back to the patients' monitoring device to inform them of the necessary changes. Figure 1 shows a visual representation of the system.

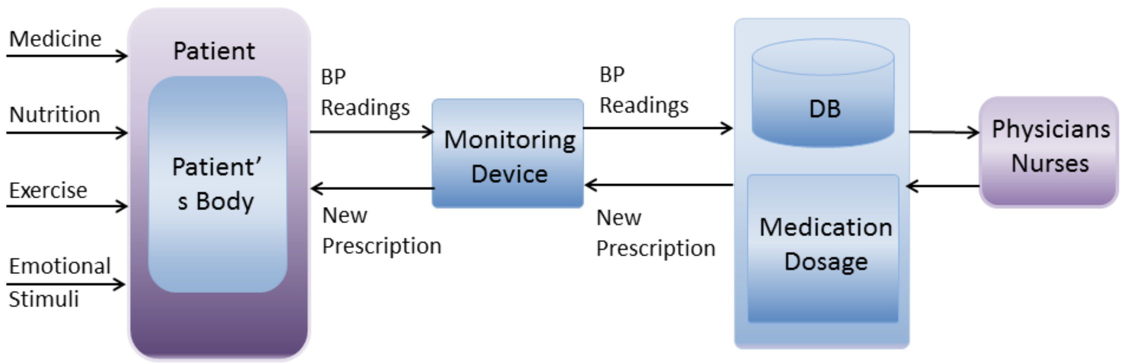

Figure 1. Diagram of a Typical Blood Pressure Monitoring System

BLOOD PRESSURE SYSTEM CHARACTERISTICS

Jiancaro, Jamieson, and Mihailidis (2013) highlighted that applying CWA techniques would be most beneficial when used for complex socio-technical systems. For that reason, we first describe the characteristics of a BP management system based on Vicente's factors of complexity (1999).

Large problem space

A BP management system has a diverse range of variables, due to the variability of

- Medications intake by patient
- Patient's BP values
- Patient's food intake
- Patient's level of physical activity
- Frequency of patients check-ups by clinicians
- Frequency of a newly prescribed medication
- Frequency of BP reading

Also, there are environmental factors such as stress that cannot be properly modeled and therefore should be considered as noise to the system.

In addition to the above-mentioned variables, other sets of variables that play a crucial role on BP management systems exist. Those variables affect patients' motivation to adhere, the level of their cognitive and physical ability to follow their medical regimen, and so forth.

Social

A variety of operators interact with the patient to manage his/her BP, such as physicians, clinicians, and caregivers.

Heterogeneous perspective

Each operator has a different perspective toward the system. However, the goal of all operators is the same: maintaining patient's BP in the normal range.

Distributed

System (patient) and other actors are not necessarily co-located.

Dynamic

A delay exists within the system, from the time when the patient follows a new prescription to when the medications affect the patient's body.

Potentially highly hazardous

If any operator of the system (including the patient) does not follow the defined rules, that can put the patient's health at risk.

Many coupled systems

Within the whole system, many subsystems interact with one another, each designed to attain a certain sub-goal. For example, blood circulatory system, nervous system are subsystems that interact.

Uncertainty of data

Due to the nature of human body, a highly complicated system, unpredictable situations are probable and as a result, uncertainty of data.

Mediated via computer interaction

A computerized system is necessary in order to present operators with the state of system variables (e.g., BP values), as they are not detectable and recognizable by the human sensory system alone.

Disturbance

Failure in any part of the system can cause disruption and, as result, affect the default functionality of the system (e.g., failure in patient's body because of taking wrong medication).

Work Domain Analysis of Blood Pressure Management

Work domain analysis (WDA) is the first phase of CWA and serves as a tool to identify environmental constraints and the functional structure of the domain (Vicente, 1999). Thus far, WDA has been used in a variety of applications and domains, including health and medical applications. For example, Burns, Enomoto, & Momtahan (2008) explored utilizing CWA to develop a decision-support tool for cardiac-care triage nurses, and Hajdukiewicz, Vicente, Doyle, Milgram, and Burns (2001) applied WDA in modeling medical environments and handling unanticipated events in operating rooms.

The work of Miller (2004) is of particular interest, as she included patients and their physiological mechanisms in the work domain. This study was an effort to show the embedded control loops inherent in the physiology of the human body and to address the lack of a framework for representation of patient information to the clinicians, when the latter need to make informed decision regarding the patient health.

Similar to the work Miller (2004), in our analysis, the patient is described as an entity, who is part of the work domain, and also who can play multiple roles according to different perspectives. Either as part of the system, and requiring to be monitored and acted upon, or as an actor, who makes decisions and acts upon those decisions in each single moment according to his/her current state of health.

To conduct a WDA for BP management, first the boundary of the system needs be determined. In our analysis we placed the system boundary about the patient, and conducted a systematic analysis of the problem domain to attain a deep understanding of it. WDA is an effective method that can assist designers to perform this analysis and to develop a thorough representation of the application domain

Our model contained five levels of abstraction and two levels of decomposition (Table 1). The abstraction levels were: 1) Purpose, 2) Principles, Priorities and Balances, 3) Processes (physiological, psychological), 4) Physical Function, and 5) Physical Form. The decomposition levels were the Whole system (patient), and Subsystem (body systems). The subsystems not only included the patient's biological subsystems, such as circulatory, nervous, and endocrine system, but also psychological ones such as the human cognition system.

A key difference between this analysis and previous works applying WDA in healthcare (e.g., Hajdukiewicz et al., 2001; Wu, Cafazzo, & Burns, 2012) is that, in the patient-centered situation, the patient is both the work domain and the actor. In particular, the ability of the actor to act is tightly coupled with his/her health and motivational state and part of the process of self-regulation. In this situation, we propose that it is useful to include the patient's psychological processes in the WDA. As mentioned earlier, this approach is analogous in some ways to the work of Miller (2004), who argued convincingly that when the work domain contains a patient, there are situations of embedded control that need to be carefully understood. The case of patient self-management of BP contains both embedded physical control systems, as well as psychological self-regulation that we claim also influences the control of the system.

Purposes

In our model, maintaining patients' BP with normal range was the main goal of the whole system. In abstraction decomposition modeling, the lower level explains how the goal expressed in the higher level can be achieved. In our case, maintaining patient's BP within the normal range can be achieved by underlying principles of human body, as well as patients' attitude toward their health and their health behavior.

Principles, Priorities and Balances

The underlying physiological laws of human physiology related to BP regulation, and psychological principles related to human behavior are described in this level. Psychological principles were included as they are important for the patient to self regulate. This is an immediate consequence of representing a work domain where the patient is both the work domain but also the actor. We also included patients' belief and value system with respect to their health, but at a higher level of decomposition.

Processes

How patients function with respect to the disease, as well as their knowledge and perception of it, has a crucial role in their BP management. By taking medications as prescribed, and following physician instructions regarding diet or physical activity, patients move toward the main purpose of the system.

When looking at the lower levels of decomposition, to keep the body's BP balanced, both physiological and psychological processes play important roles.

Physiological Processes. Physiological processes in a patient's body are modeled at this level. BP is regulated by a variety of subsystems, such the circulatory system, nervous system, endocrine system.

Psychological Processes. In contrast to previous examples of CWA, we deliberately chose to include the psychological processes of the patient in the WDA. This was done to reflect the fact that patients' psychological processes are involved in their self-regulation.

	Whole system (Patient)	Subsystem (Body Systems)
System Purpose	Maintain blood pressure in normal range	Maintain blood pressure in normal range
Principles, Priorities and Balances	Underlying laws and principles of: Human body for regulating blood pressure Valuing healthy life	Underlying laws and principles of patient's: • Circulatory system, • Nervous system, • Endocrine system, • Cognitive system, • Self-regulatory system
Processes (Physiological and Non-Physiological Processes)	Taking medications according to the new prescription, Following physicians' instruction regarding diet or physical activity	Physiological processes in patient's body (Regulated by circulatory system, nervous system, endocrine system) Psychological processes (Cognitive processes determining person's behavior and choices at each moment) Pharmacological processes of the prescribed drug (Diuretic, beta-blocker, ACE inhibitor, etc.) Metabolism of food and processes associated with food nutrients
Physical Function	Patient body Medication Food	Circulatory system (Heart, blood, blood vessels) Endocrine system Nervous system Active Ingredients of Medication Active Ingredients of Food
Physical Form (patient and equipment)	Age, Weight, Gender, Race of the patient Patient's regulatory focus and mood Medication type and dose Food type and amount	Blood pressure level, Heart rate and condition Blood vessel condition, Psychological status Medication type and dose Food type and amount

Table 1. Abstraction Decomposition Hierarchy of Blood Pressure management

Other Processes. Other system processes also contribute to keeping BP within the normal range; including

- Understanding the updated prescription
- Taking medications according to the new prescription
- Following the physician's' instruction regarding diet or physical activity

Physical Function

This level describes the state of each component in the system and its capabilities. Physical components of the system include the patient, medication, food.

In the lower decomposition level: the state of a patient's circulatory system (heart, blood, blood vessels), endocrine system, and nervous system are described. Also, the state of a patient's cognitive system (although non-physical) is described in this level.

Physical Form

This is the lowest level of abstraction, where the physical appearance, condition, and anatomical configuration of the components are described. These attributes play an important role in BP management as they represent the system's status to its actors (patient, clinician, and caregiver).

CONTROL TASK ANALYSIS

The next step of CWA is to conduct an analysis of control tasks, which helps to identify system requirements, associated with the operators' actions. The decision ladder is a modeling technique that is used to represent the information-processing steps within the system.

Analyzing the control tasks of a BP management from a PD perspective will influence the patient's path through the decision ladder and will be beneficial to patients while they take action to manage their disease. Rasmussen's taxonomy of human performance (1983), which describes the human cognitive model, can help readers to understand better how this influence occurs.

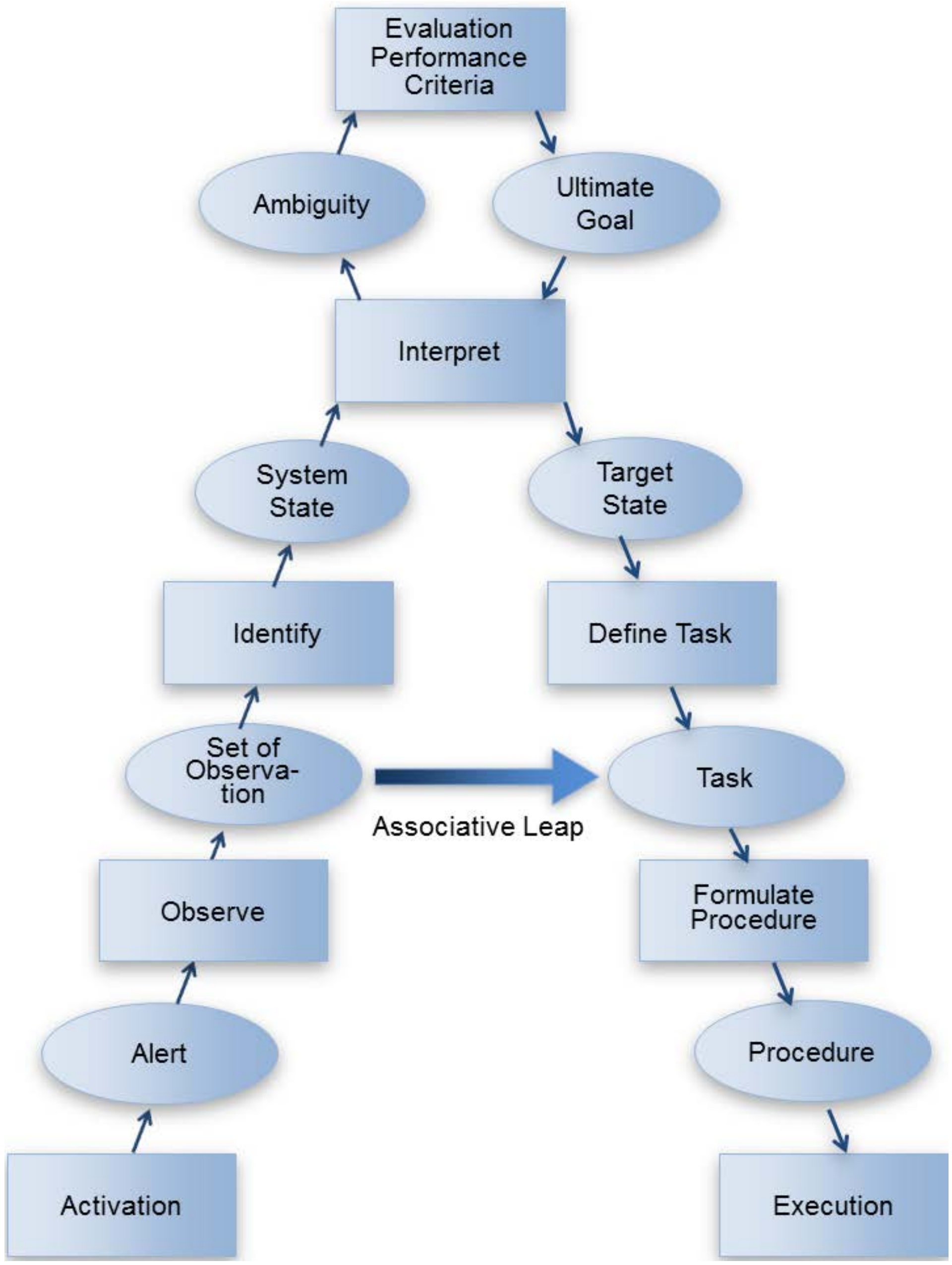

Figure 2. Decision ladder for the patient (adapted form Burns, Enomoto, & Momtahan, 2009)

First, fulfilling PD requirements with respect to improving the usability of the interface will facilitate the patient's movement along the activation-observation-task-execution loop (indicated with the associative leap in Figure 2). This facilitated movement occurs because, according to Rasmussen's taxonomy of human behavior, an individual's performance at this level is guided by a set of if-then rules. Thus each rule in the system maps a particular plan of action; therefore by employing a persuasive approach in the design of the interface, where the current status of the system and the necessary associated action is salient, the possibility that the patient will perform the necessary task increases.

Second, by designing the system's interface in a way that increases patients' knowledge with respect to their condition and how to manage it, the chance that patients will become motivated and take appropriate goal-oriented actions increases. For that reason the interface should educate patients about the importance of adherence to their medications, as well as of paying attention to their diet and their lifestyle.

CONCLUSION AND FUTURE WORK

The objective of this research was to explore how using a CWA and PD approach can inform the design of BP monitoring systems. Our study showed that a combination of these two approaches can be beneficial by improving the patient's understanding of their disease and how to manage it, while simultaneously increasing their motivation to self-monitor. We have proposed that CWA can reveal the relationships between the different system entities that patients need to understand in order to effectively engage in their disease management. We also proposed that applying PD principles to the ecological design of the monitoring system will result in 1) an increase in the patient's motivation driven by gamification techniques and a reward system, and 2) an increase in the patient's ability to take action facilitated by primary task support and dialogue support features. The long term objective of this research is to utilize the CWA framework and PD methodology to devise a set of design guidelines that can be used to develop effective remote health-management systems.

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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.

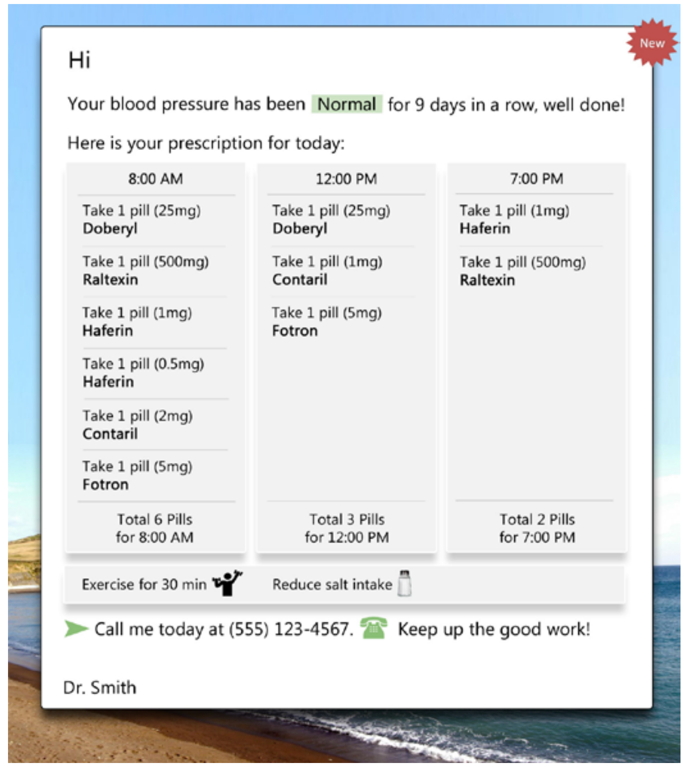

Figure 1. Screenshot of the monitoring application (daily prescription page) in the ED condition

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."

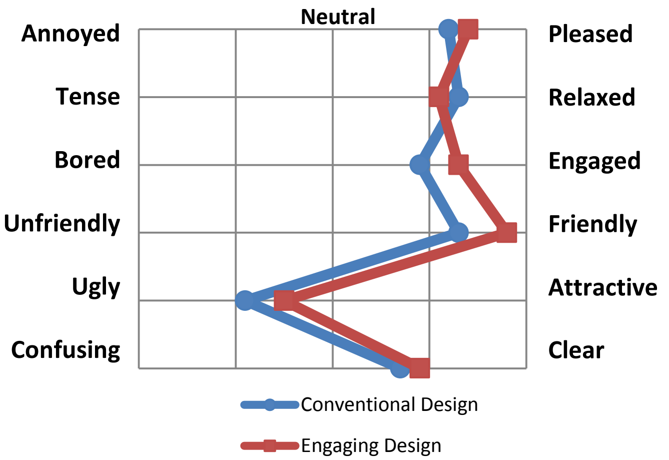

Figure 3. Comparison of the mean values of the semantic differential pairs, based on participants' responses to the CD and ED applications

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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