Using Self-Regulation Theory to Inform Technology-Based Behavior Change Interventions

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Abstract
Research geared toward technology use to promote health-related behaviors has been rapidly expanding, yet evidence regarding the effectiveness of the proposed interventions is inconclusive. The proposed study builds on self-regulation theory, persuasive system design model, and task-technology fit model to propose design guidelines essential for translating intentions to engage in a desired health-related behavior into actual behavior. The current study proposes that mobile applications will have stronger potential to support their users in executing users’ intended health-related behaviors if the applications are designed to (i) monitor and provide feedback to users about the discrepancy between their current and desired levels of behavior, (ii) encourage users to change their behavior, and facilitate the selection of strategies needed to execute the targeted changes, and (iii) ease the execution of selected strategies. The potential implications of the proposed guidelines for practice and research will be discussed.

1. Introduction

The need for an effective consumer-centric health-care system, where patients take active control of their health and well-being, has been emphasized by practitioners and scholars [2]. However, it is not possible for any health care system to support every individual in need of changing his/her health behaviors [17]. Thus, research projects geared toward the utilization of various technologies (e.g. internet, web- and mobile-based systems and applications) to support individuals’ healthy behavior deserve more attention. Anecdotal evidence and research findings show that various interventions have potential to change health-related behavior, yet, “… roughly half have failed in their attempts to change patient behavior” [3, p.570]. The pressing question is how to design technology-based interventions to be effective in aiding people change their behavior? [42].

Whereas increasing attempts have been made to provide design guidelines for technology-based interventions for behavior change [e.g. 4,5,6,7,11], there is a fertile opportunity to enrich existing efforts by utilizing a broader theoretical perspective as a base for designing interventions [52]. A commonality of available interventions is mainly their aim to use persuasive strategies to alter attitudes toward the target behavior as a precursor to behavior change. While theories of attitude enriched our understanding about intentions to behave in a specific way, they left the mechanisms through which intentions are translated into actions unexplored [4].

The proposed study offers in the context of consumer-centric health information technology (CHIT) guidelines for designing technology-based interventions. The proposed study integrates self-regulation theory from social psychology, and the persuasive system design model of human-computer interaction into the well-established theory of task technology fit from information systems (IS) domain. More specifically, the proposed study aims to explore the potential influence of the degree of “fit” among tasks required to change health related behavior, and the available functionalities in the used technology on health-related behavior. Furthermore, given the recent advancements in mobile technologies, we focus on mobile applications as potential tools to facilitate health-related behavior change. The current study proposes that interventions have a better chance to support the user in executing his/her intended behaviors when designed with the goals of (i) providing feedback to the user about the discrepancy between his/her current and intended levels of a health-related desired behavior, (ii) facilitating the selection of the strategy needed to achieve the targeted changes, and (iii) facilitating the enactment of the strategy needed to attain the desired level of behavior. By compensating for the attention and motivational failures, CHIT could facilitate the translation of intended behavior into action by allowing for the
maintenance of a crucial bridge, namely, self-regulation.

The proposed study is expected to have potentially significant implications for both practitioners and researchers. While a plethora of research in the domain of IS is anchored to adoption and use of technology, the current study expands that research to investigate the influence of technology use on behavior change. Moreover, the current study expands the literature studying technology-based behavior changes by moving beyond theories of attitude, and instead focusing on self-regulation theory for designing interventions. By integrating the self-regulation theory into the domain of technology-based behavior change research, the proposed study is paving the way for other researchers to add a new portfolio of interventions revolving around self-regulatory mechanisms.

In the remaining sections of this article we examine our theoretical rationale, followed by development of our model, followed by descriptions of our proposed study design methodology. We end with a discussion of the potential contribution of the study, and further research ideas.

2. Research background

In the following section we summarize the relevant literature and highlight the gap in the literature.

2.1 Persuasive technology

“Persuasive technology” [19], “persuasive systems” [39], and “behavior change support systems” (BCSS) [40], are different terms that have been used to describe technology that aims to change people’s attitudes and/or behaviors through persuasion. Briñol and Petty have described how persuasion typically takes place: “… a person or a group of people (i.e., the recipient) receives an intervention (e.g., a persuasive message) from another individual or group (i.e., the source) in a particular setting (i.e., the context)” [3, p.71]. Persuasion is successful when the recipient changes his/her attitude toward the behavior about which the persuasive message was received. Changes in attitude are assumed to be succeeded by a change in behavior.

Persuasive systems design model (PSDM) represents the state-of-the-art conceptualization for designing and developing persuasive systems [33]. The PSDM is built on Fogg’s [19] general principles for designing persuasive technology, and the model provides design principles organized into four distinct categories: i) primary task support, ii) dialogue support, iii) system credibility, and iv) social support. The design principles related to primary task support category focus on supporting the persuasive systems’ users in carrying out their primary tasks. Design principles related to computer-human dialogue support facilitate interaction between the user and the system. The system credibility design principles relate to how to design a system so that it is more believable and thereby more persuasive. The design principles in the social support category describe how to design the system so that it motivates users by leveraging social influence [39].

Persuasive technologies are applied in a multitude of domains, such as: education [20], safety [14], and health [13]. In the health domain, persuasive systems have shown promising results across different areas of behavior change, such as physical activity [15], weight management [34], and substance abuse [9]. Although there is evidence on the effectiveness of persuasive technology, researchers have been cautioned about the generalizability of the results [see for review 13]. Nelville and others [38], argue that there is uncertainty about whether the observed changes in behavior could be maintained over the long run. Moreover, sample sizes were relatively small, and problem of significant participant attrition exists [8]. Furthermore, the magnitude of behavioral change in some studies is significantly lower than the magnitude achieved through traditional manual based approaches [56]. Finally, a recent review of 85 web-based interventions for substance abuse indicated that the effect size of the interventions was small [55]. To summarize, while persuasive technologies provide some potentially useful directions, more research is needed to identify theories, strategies, and delivery modes of interventions that improve the magnitude and sustainability of desired behavior change.

2.2 Behavior change theories

The design of interventions should, ideally, start with a specific target outcome; identify possible mechanisms that are known to be associated with the desired outcome; and then work backwards to design interventions. In general, reviews of studies aiming to change an array of health behaviors have indicated that theory-based interventions are more effective than those not using theory [22,55]. But which behavior change theory should be used for designing interventions is not an easy question to answer. Theories of behavior change are heterogeneous, they cover different facets of behavior change, they range from explaining (i) how people become inclined to change behavior (e.g. form an intention), to (ii) how they translate this inclination into actual behavior change, to (iii) how they maintain newly adopted behaviors. For example, when does someone decide to
lose weight, quit smoking, or start exercising? How does someone translate this good intention into actual behavior? How does someone maintain long-term commitment? Therefore, the strongest interventions should be built from multiple theories [22] or, likewise, from a single general theory of behavior change that can subsume the insights gained from other theories.

Theories of attitude (e.g., protection motivation theory (PMT) [45], the health belief model (HBM) [30], elaboration likelihood model (ELM) [41], and theory of planned behavior (TPB) [3]), have been vastly used to predict behavioral changes [53]. The essence of attitude theories is that a set of modifiable beliefs shapes people’s intentions to behave in specific ways. Intentions in turn are considered to determine behavior directly. In general, variations among the different models might pertain to the examined set of beliefs or the paths that might influence behavior directly or, both. As a result, building on PMT, HBM, and TPB, interventions should target threat and coping appraisals, perceived threats and perceived effectiveness of targeted behavior against these threats, and behavioral intentions and perceived behavioral control respectively. ELM, although focused on changing attitude as a mean to change behavior, yet it places more emphasis on the characteristics of the persuasive communication bringing the change [41]. ELM delineates two routes (central and peripheral) through which attitude change can result from receiving a persuasive message. The central route to persuasion involves careful scrutiny of the arguments in the message by its recipient, which require the recipient to be motivated and able to process the message. When the recipient’s levels of motivation or ability are low, persuasion will take place through a peripheral route based on simple heuristics such as the credibility of the message source. Thus, interventions built on ELM will target variables that might influence a person’s motivation or ability, or both to process a persuasive message [31].

While theories of attitude have informed the literature of behavior change, yet they have a common limitation that might influence their appropriateness for designing interventions. Attitude theories make the critical assumption that developing an intention to behave in a specific way will automatically lead to the intended behavior [4]. However, when the intention-behavior link has been closely examined, results have shown that a medium-to-large change in intention leads to a small-to-medium change in behavior [see for review 26]. Furthermore, attitude theories have left the mechanism through which formed intentions are transformed into performed behavior unexplored. To summarize, in order to design effective interventions to fill the gap between intentions to change health-related behaviors, and actual behavior there is a need to go beyond existing theories of attitude. Compared to theories of attitude, we believe that self-regulation theory has the potential to serve as a blueprint for designing interventions targeted at behavior change [4].

2.3 Self-regulation

Many writers use the terms self-control and self-regulation interchangeably, but those who make a distinction typically consider self-control to be the deliberate and conscious subset of self-regulation [43], which can take place both consciously and unconsciously [36]. Self-regulation entails processes that translate beliefs into intentions, and intentions into actions leading to goal attainment [4,36]. At the center of most theories of self-regulation is the idea that people set goals and compare their progress against the goals. If there is a discrepancy between a goal and the current state, they make modifications to their behaviors, cognitions, emotions, or goals. These processes and their interrelationships comprise the negative feedback loop, which consists of an input function, target goals, a comparator to assess the discrepancy between observed behavior and target goals, and an output function [11]. Tying self-regulation theories back to theories of attitude, it appears that theories of attitude are focusing only on the determinants of goals development (e.g., losing weight, or exercising regularly, or quitting smoking) and overlooks how goals are going to be achieved. To sum up, self-regulation theory has the potential to explain the essential mechanisms to translate intentions into actions.

Depending on what part of the self-regulation processes is under study, research streams investigating self-regulation could be categorized around three broad research questions: How goals guide behavior [11], why people fail in maintaining the pursuit of their goals [6], and how people might increase the likelihood of acting upon their good intention, and achieve their goals [23]. Carver and Scheier [11] approach self-regulation as a set of goal-performance discrepancy-reducing feedback processes entailing behavior and affect monitoring, appraisal, and coping. Their approach highlighted the processes underlying self-regulation yet didn’t explain how the self-regulatory processes are implemented [43]. Baumeister and colleagues [6] anchored the success of self-regulation attempts entirely on the availability of self-regulatory resources. In that framework, inhibiting emotions, urges, or desires causes depletion of what is thought to be a limited self-regulatory resource and therefore makes continued exhibition of self-regulation, even in unrelated domains, less likely. Research has been equivocal about the nature of self-regulatory resources
[21], but more recently research suggested that failure of subsequent self-regulatory attempts occurs due to temporary shifts in both motivation to exert control and attention to cues signaling need for control that take place after self-regulation efforts are exhibited [29]. Despite its relevance for understanding self-regulation failure, the resource approach has some trouble in explaining how people may achieve successful self-regulation. A number of theories have been proposed that have in common the assumption that the process of successful goal striving can be best described as passing through a number of distinct stages, and that suggest factors that might influence the transition from one stage to another (e.g. model of action Phases [28], and theory of implementation intentions [24]).

3. Model development

The current study aims to propose theoretically based guidelines for designing IT interventions by integrating some of the useful directions from the work of Fogg [19], and Oinas-Kukkonen and Harjumaa [39] with the well-established theory of self-regulation [5]. The main theoretical rationale for integration will be adopted from Goodhue and Thompson [26] model of task-technology fit (TTF). In contrast with models predicting acceptance and use (e.g. TAM [16], UTAUT [51], and TAM3 [49]), TTF attempts to explain the performance of IS users. The original design of TTF was specifically directed toward managerial decision-making, and measures task-technology fit along multiple dimensions [26]. The main premise of TTF is that an individual’s performance can be enhanced when the functionality provided by the technology fits the task on hand (i.e. assists an individual in performing his or her portfolio of tasks) [26].

In the context of the CHIT, TTF would reflect the extent to which technology assists its user in performing his or her portfolio of self-regulatory tasks essential for achieving the desired level of health-related behavior. As the gap between the requirements of a task and functionalities of a technology widens, TTF is reduced. Consequently, to design an effective technology-based intervention that is characterized by a high degree of “fit” with present tasks, it is essential to understand the required self-regulatory tasks as well as how functionalities in a targeted technology could serve them.

3.1 Self-regulation tasks

Tasks are broadly defined as actions carried out by individuals in turning input into output [26]. More specifically, a task could be defined as behavior requirements to the extent that each task is categorized by its objective; in other words a task specifies the activities that someone is supposed to do [57]. In our proposed study a task is defined as the behavioral requirements for accomplishing desired health-related goals, via some process, using given information. From that perspective self-regulatory tasks can be classified into three related tasks i) identifying a need to regulate, ii) deciding whether, and how to regulate, and iii) enacting a regulation strategy [54].

3.1.1. Identifying a need to regulate behavior.

Monitoring and obtaining feedback on goal progress are central to the task of identifying the need to adjust a behavior toward a desired goal. Monitoring involves periodically noting one’s current state and comparing these perceptions with salient reference values [12]. The need to regulate behavior arises when there is a discrepancy between people’s current state and their desired state as defined by their standards. Thus, the need to regulate behavior will be difficult to identify when the person (i) does not have appropriate standards against which to compare the current state, (ii) does not monitor the relation between the current and desired state, or (iii) does not construe the discrepancy as requiring action [12].

3.1.2. Deciding whether and how to regulate.

Once people have identified that they need to regulate their behavior, they must decide what to do about it. Individuals are more likely to undertake behaviors they believe will result in valued outcomes relative to other behavior. Moreover, peoples’ beliefs about their ability to perform a particular behavior will influence the choices they make, their persistence and magnitude of effort they will exert in the course of performing those behaviors [5]. Having decided to regulate, the next step is deciding how to do so. Most goals can be achieved in a variety of ways (e.g., the goal to lose weight can be achieved by exercising, regulating food intake, or both), and effective goal pursuit requires that the person select an appropriate means to attain the goal [1]. However, choosing an effective regulatory strategy is a cumbersome task. A strategy that is effective in one situation may not be effective in other situations [27], and when multiple conflicting goals exist the regulation is even more difficult [18].

3.1.3. Enacting a regulation strategy.

The final task in the self-regulatory process is to enact the intended response. Identifying and seizing opportunities to regulate can be difficult as the opportunity may only be available for a short period of time, or the person lacks sufficient regulatory resources to seize the opportunity [54]. There may be a limited window of opportunity for which regulation efforts are likely to be most effective, and effective regulation requires that the person quickly identify and seize that window. In addition to missing the regulation opportunity, lacking
resources needed to enact self-regulation will lead to not implementing the chosen self-regulation strategy. The strength model of self-control [7] suggests that the availability of regulatory resources influences the effectiveness of regulation efforts. To summarize, the fulfillment of self-regulatory tasks might be hindered by a person’s inability to set goals, monitor and compare behavior to desired goals. In addition, carrying out self-regulatory tasks might be obscured by a person’s lack of willingness or ability to develop, select, and implement the needed strategies.

3.2 Mobile technology

Technologies are viewed as tools used by individuals in carrying out their tasks [26]. Mobile devices like smartphones are believed to offer unique opportunities for facilitating changes in users’ behavior [19]. The exponential growth of adoption of smartphones, as well as the enhancements in their capabilities is reflective of their grand potential to foster healthier lifestyles for users. Among other features, portability, convenience of use (anytime, and any place), continuous data streaming, and advanced computing power give smartphones an edge over other forms of communication technologies. Furthermore, smartphones provide social support that is needed for a varying array of activities. As a result, we focus in our proposed study on the functionalities of mobile applications defined in this study as software developed to run particularly on smartphones and mobile computing devices. We believe that in the context of CHIT mobile applications are capable of supporting the self-regulatory tasks required for successfully achieving behavioral change.

3.2.1 Supporting the identification of the need to regulate behavior. Mobile application might facilitate monitoring and feedback provision sub-tasks through a number of functionalities such as self-monitoring, social comparison, and simulation [15,19,45]. The availability of self-monitoring functionalities provides users with the means to track their performance or status toward goal achievement. A mobile application could potentially support the monitoring task by eliminating the tedium of keeping track of one’s own performance or status. For example, a mobile application could keep track of users’ physical activity, and compare it with their desired level of activity over a given time period [15]. Ideally, self-monitoring functionality should provide users with a real-time data feed that reflects the progress toward their goal. Providing users with feedback will keep them motivated toward achieving their goal [32]. Also, the availability of social comparison functionality will enable users to compare their performance to the performance of others, especially others who are similar to them. For example, mobile application enables users to easily exchange information related to their wellness and health-related behaviors [47]. As performance of others could be used as a benchmark or reality check, social comparison could facilitate realistic goal setting, and evaluation of progress. Moreover, the availability of behavior simulation features enables users to observe immediately the link between cause and effect of their behavior. Simulations can fast-forward through time and show users the possible ramifications of their present activities, which can help illustrate the need for taking an action in the present to alter future outcomes [19,39]. For example, eating one cookie while on a diet might not be construed as requiring action, but the effects aren’t apparent immediately in a real world [19]. Simulation features in a mobile application can help calculate the potential increase in weight because of that cookie, and provide feedback to the user in the present time.

3.2.2. Supporting the decisions related to whether and how to regulate.

Mobile applications could potentially improve the users’ perceptions of their ability to change their current behavior toward a desired level of health-related behavior, and lighten the burden of choosing a regulation strategy through offering a number of functionalities such as praise, behavioral modeling, and personalization [15,19,46].

Self-efficacy belief toward changing a health-related behavior can be enhanced through receiving encouragement from others, as well as through seeing others engage in the desired behavior. A mobile application that offers positive feedback in the form of praise to its users improves their self-efficacy to enact a change. For example, praises received through automated text messages in mobile phone applications could be employed to promote users to engage in physical exercises [48]. Moreover, the availability of behavioral modeling functionality in a mobile application enables users to observe others who are performing their target behaviors and to see the outcomes of their behavior. For example, a shared fitness journal in a mobile application will allow users to see how others are behaving [15], which in turn allow users to deem the targeted behavioral change possible. Through this vicarious learning, users will improve their self-efficacy.

While taking the decision to adjust behavior to achieve a desired goal could be supported by praising and modeling functionalities, choosing a regulatory strategy could be facilitated by the availability of personalization functionality that provides information tailored specifically to mobile application users. The burden of choice is reduced when users choose among a limited set of strategies tailored to their preferences,
instead of sifting through copious generic information and numerous strategies.

3.2.3. Supporting the enactment of a regulation strategy. Mobile application could facilitate the task of enacting the intended strategy through multiple functionalities such as recommendations and navigation [19]. Providing suggestions and reminders at the right moment delegates the identification of the window of opportunity to the mobile application. For example, the application can signal when it is the best time for the users to exercise by making recommendations based on their schedules, preferences, and location. All of the previous data could be automatically captured by the mobile application. Moreover, a mobile application can facilitate the enactment of the strategy of choice through the availability of tunneling functionality, where the user is automatically led through a sequence of events, step by step, once the desired strategy is determined [19]. Thus, the availability of tunneling functionalities reduces the need for self-regulatory resources required for effortful self-regulation.

In conclusion, TTF model predicts the greater the degree of fit between the technology and the task it supports the greater the impact on performance will be [26]. Following that logic we identified the unique self-regulatory tasks required to achieve behavior change as well as the possible mobile functionalities needed to serve the self-regulatory tasks. The following list summarizes the propositions made:

**Proposition 1:** The greater the perceived ability of mobile application to support the task of identifying the need to regulate, the higher the user evaluation of task technology fit will be.

**Proposition 2:** The greater the perceived ability of a mobile application to support the task of deciding to regulate behavior, and the task of choosing a regulation strategy, the higher the user evaluation of task technology fit will be.

**Proposition 3:** The greater the perceived ability of mobile application to support the task of enacting a regulation strategy, the higher the user's evaluation of task technology fit will be.

4. Study design

The study will be executed over two phases. In phase one a mobile application that reflects the proposed functionalities will be designed. The mobile application will be aimed toward increasing physical exercise. A pilot study will be conducted to ensure that the designed features are identifiable by the users. The mobile application will record data regarding physical exercise in terms of the number of steps walked by the user. Another application will be designed that has none of the proposed functionalities except for the ability to record data regarding physical exercise in terms of the number of steps walked by the user.

In phase two an experimental design will be conducted. A sample size of 400 employees at a major university in the Midwestern United States will be selected. Full-time employees often do not have a chance to exercise as much as they should, and many work indoors at least 40 hours/week. The study is intended to investigate whether the developed intervention can change the employees' actual physical exercise. Participants will be randomly assigned to a treatment group where they will receive a mobile phone with the designed application loaded. The control group will receive the same mobile model with the other application. After eight weeks, the participants will return the mobile phones to the researcher.

Before the participants are assigned to the treatment and the control groups they will complete a questionnaire assessing their level of self-regulation skills [37]. Moreover, the history of the participants’ physical exercises will be captured. Once the study is conducted a number of measures will be collected. For example, TTF will be captured using measures adapted from Goodhue [25], actual performance will be assessed using the total number of steps walked by the user during the experiment, and the use of mobile application will be measured through capturing the frequency, duration, and intensity of use [50].

The study will use ANOVA and multiple regressions to analyze the data. ANOVA will assess whether there are any differences between the treatment and the control groups in the study. This will determine if there is variation in the user evaluation of degree of task-technology fit. The dataset will be subjected to multiple regression analysis to test the proposed relationship.

The study design aims to address possible threats to the validity of the inferences generated from the study [46]. For example, the utilized experimental research design will reduce concerns related to a number of internal validity threats such as group differences in maturational rates, in the experience of historical events, and in regression artifacts [46]. Moreover, random assignment of subjects to treatment and control groups will eliminate the threat of selection bias. Threats regarding differential rates of attrition among study participants will be minimized through providing participants with sufficient incentives to compensate for their participation in the study [46]. Also, differential rates of attrition will be evaluated, and accounted for if exist [46]. Furthermore, statistical
conclusions’ validity threats are taken into consideration and are addressed through multiple techniques [46]. For example to increase statistical power large sample size is selected and equal sizes of control and treatment groups, and measures with high reliability will be used [46]. Finally, external validity threats will be reduced by using purposive sampling of study participants [46].

5. Potential contribution

The proposed study is expected to contribute to the literature by offering novel viewpoints, both theoretical and practical, in designing and developing health behavior change interventions.

The proposed study attempted to resolve some of the challenges in designing health behavior change interventions. The most challenging issue is the lack of unified theory upon which interventions could be designed [52]. To add, available models that are used to understand health related behaviors and develop interventions, suggest that intention is the immediate antecedent of behavior. Recent studies clearly illustrated that while the formation of behavioral intention is necessary, yet, by itself it is not sufficient to produce behavior [44, 55]. Also, recent studies in the domain of health related physical activities [44] emphasized the need to move toward interventions that focus on the translation of formed intention into behavior. In the proposed study, self-regulation theory is offered as a unified theory that can subsume a number of theories used in the domain of health related behavior change. By moving beyond theories of attitude and focusing on how intentions could be transformed into actions the current study is expected to increase the effectiveness of designed interventions.

Furthermore, the proposed study aims to enrich empirical findings about the influence of technology-based interventions on health-related behavior change. To elaborate, the proposed study illustrated the self-regulation tasks as interdependent tasks. As a result, focusing only on a subset of self-regulatory tasks may not be sufficient to yield a desirable result. Thus, the proposed study is offering insights into the limited success of available interventions.

Finally, the proposed study attempts to integrate research efforts across three disciplines, thus enhancing and bridging interdisciplinary awareness and communication.

10. References


