Using Behavior Modification Theory to Understand and Guide Technological Interventions
by Tammy Toscos and Kay Connelly
Indiana University

1 Introduction

Interactive behavior change technology (IBCT) has shown great promise for people with diabetes as a supplemental resource that will support them as they take health actions to manage their disease and work to prevent long term complications. IBCT may include the use of pervasive devices (such as mobile phones, personal digital assistants and sensing devices), as well as pc based and internet based applications. A study of existing IBCT for diabetes revealed “only one third of the studies had incorporated behavioral theories or models into the interventions.” [61] We believe that interactive technologies designed with the intent of changing health behavior will be more effective if they are grounded in the relevant theory. The purpose of this chapter is to introduce three of the most widely used behavior modification theories, demonstrating how they may be used to evaluate and assist in the design of IBCT.

Numerous theories have been proposed in the study of health behavior modification, each trying to explain why people take, or fail to take, health-related action. Reviews of theory-based health interventions show that the most popular theories include the Social Cognitive Theory, the Transtheoretical Model and the Health Belief Model [25, 2]. In this chapter, we will use these prominent theories to reflect on existing IBCT developed to help diabetic patients, both Type I and Type II. We write from the perspective of technologists, providing a brief description of the three health behavior modification theories, utilizing the terminology and presentation from “Health Behavior and Health Education: Theory Research, and Practice” by Karen Glanz, Barbara Rimer and Frances Marcus Lewis [25]. Other prominent theories, which we do not have the space to discuss here, include the theory of planned behavior, community organization, social marketing, patient provider communication, social support and social networks. We refer the interested reader to “Health Behavior and Health Education: Theory Research, and Practice” [25] for more detailed information.
Application Domains

Throughout this chapter, we will refer to three different types of technologies used for diabetes self-management. While the applications do not capture every possible type of intervention, they are fairly representative of the types of interventions currently in existence or that have garnered a great deal of recent attention in the research community.

1.1 Interactive health web sites

One of the most popular approaches to applying technology to behavior modification is through interactive health web sites. In the beginning, health web sites were essentially clearinghouses of medical information which patients could search to find out more about their medical condition and treatment options. Several have evolved to tailor the information based on a specific health condition, or even geographic region or health provider.

In more recent years, many health web sites have become more sophisticated, providing tools to manage specific health conditions. For diabetics, this may take the form of uploading blood glucose, dietary intake and physical activity levels as a means of tracking the information and the relationship of each to blood glucose control. The monitoring of blood glucose levels over time, coupled with journaling lifestyle choices (e.g. diet, amount of exercise or stress) offers a reflective mechanism for diabetics to identify situations that may result in a critical health event, such as a hypoglycemic episode (low blood glucose). The tools may also show data over time, allowing trends to appear which may otherwise go unnoticed (e.g. linking a particular food item with hyperglycemia). The online environment offers an advantage over paper and pencil log books because it allows for useful visualizations of the information and data sharing with healthcare providers and other care givers.

Web sites may also incorporate skill development components intended to help patients learn and practice the skills they need to manage their particular disease. These can be as simple as providing lists of things people need to remember to do, or worksheets or online tools to assist in diabetes management (e.g. calculating body mass index or meal time insulin bolus). More complex activities and games are emerging in order to assist in skill development, such as role-playing games for newly diagnosed diabetics to assist them in identifying common situations they may encounter in their own disease management.

Finally, incorporating online coaching, either automatic or with a person behind it, is a promising area in interactive health web sites. Coaching combines some level of health tracking and skill development with
personalized feedback, management plans and encouragement. **Tailored feedback** is often generated in response to a questionnaire or some other form of survey that asks the user what information they need or would like to be given. Electronic coaching may be delivered at the web site, via email or mobile device.

### 2.2 Virtual community-based intervention

Virtual communities use the internet to bring together people with similar interests. There are a plethora of virtual communities for people with diabetes, such as TuDiabetes, DiabetesTalkFest, DiabetesDaily, and DiabetesSisters. Online communities provide a vehicle for individuals with diabetes and their caregivers to **share information**. Participants contribute personal stories and experiences that provide learning experiences for other participants who may be contending with a similar problem. Observing the disease management techniques of others provides **role modeling** for individuals and a means of evaluating their own behavior. Some online communities are moderated by health care professionals who can offer **expert advice** via message board posts or synchronous chat sessions.

Online communities **extend the social network** of individuals creating a unique form of empathetic **social support** that only others who are suffering from the same condition can provide [19, 21, 46]. It is not simply information sharing but more importantly **experience sharing** – via story telling – that creates deep personal ties between people whom will likely never meet in a face-to-face situation. This technological outreach has empowered many people with diabetes to help others with the same condition. Within a single online community one may find several sub-groups dedicated to specific issues such as diabetics who have a disability or those who are vegetarian. This medium allows individuals with diabetes a way to reach out to others who may be experiencing some **unusual problems**, people with whom they would not commonly come into contact.

### 2.3 Ubiquitous computing

Ubiquitous computing technologies offer great potential to impact the small, routine decision making from which health behaviors emerge. One of the challenges in changing behavior is heightening awareness of how the small changes can build overtime to create a different health outcome. For example, the effort to create a 500 calorie deficit each day to produce a modest one pound per week weight loss can be accomplished by making relatively small changes in activity level or dietary intake. Recognizing the impact of these small changes often requires extensive journaling to track a particular behavior for later reflection. Ubiquitous computing can be leveraged to facilitate this arduous process.

People with diabetes have a heavy **data tracking** burden. This information can provide critical insights about disease management upon reflection [36, 36]. They test the blood glucose levels before meals,
when they feel hyper- or hypoglycemic, after they exercise, and many other situations. This data coupled with information regarding insulin administration, dietary intake, and physical activity levels can present a personalized view of overall blood glucose management that affords a certain amount of trouble shooting. There are other factors that may impact blood glucose that can also be recorded to provide a more comprehensive perspective, such as illness, stress levels, medications, etc. The integration of all this information along with professional and personal responsibilities is a common problem for individuals suffering with a chronic disease [45] and it is an issue for which ubiquitous computing seems particularly well suited. It is well known that paper and pencil journaling has a low rate of adherence over long periods of time. Ubiquitous computing technologies that can facilitate or automate journaling may extend an individuals natural tracking and trending efforts, leading to improved blood glucose management. **Automatic journaling** may produce a more realistic picture of diabetes management and identify more unanticipated trends than paper and pencil journaling.

Ubiquitous computing can also be leveraged as a means to provide context aware cues for health action. Example of such just-in-time support include encouraging people to take the stairs instead of the elevator in order to increase physical activity levels [29], or using text messages on a mobile phone to remind someone to measure their blood glucose. Employing specific strategies to deliver cues that effectively persuade individuals to perform health behaviors is another promising area in ubiquitous computing [6].

Estimating the carbohydrate content of meals is another challenging aspect of living with insulin dependent diabetes. For these individuals, miscalculating the carbohydrate content can lead to dangerously low or high blood glucose values. Mobile phones and PDAs can used to store the carbohydrate content of numerous foods to improve carbohydrate content guessing. There are also services that offer guidance with guessing the nutritional content of foods that have been photographed and sent to a dietitian via mobile phone. These mobile devices are useful because they can provide such real-time information at the very moment and location it is needed most.

Ubiquitous computing technologies can also be connected to a larger support system. Data transmitted in real time facilitates remote monitoring, thereby assisting caregivers of children with chronic conditions or special needs [34]. This can be particularly important to parents of children with type 1 diabetes. There are devices on the market currently which allow glucometer readings to be automatically transmitted to a caregiver’s mobile phone and email. Remote monitoring is also important for individuals living in rural areas that cannot readily meet with their health care team. It is also valuable to children caring for their aging parents.
2 Social Cognitive Theory

*Social Cognitive Theory* (SCT) is one of the most commonly used theories in the behavior modification research and has undergone tremendous evolution since it was introduced by Albert Bandura in the 1960’s and was called *Social Learning Through Imitation* [25]. In its current form, SCT proposes a dynamic model of behavior where personal factors (e.g. cognitions, perceptions) and environment factors (social and physical) are continuously interacting and influencing each other. It represents a departure from preceding learning theories, which suggested human behavior is purely a product of environmental stimuli, by emphasizing the importance of human cognition in behavioral choices. The constant interaction of a person’s characteristics, a person’s behavior, and the environment in which the behavior takes place is a foundational concept of SCT called *reciprocal determinism* (Figure 1). This concept reflects the complexity of human behavior by revealing that a change in one of these factors will result in a change to each of the others.

![Figure 1 – Reciprocal Determinism](image)

2.1 Overview of Constructs

One of the central constructs in SCT is *self-efficacy*, the confidence a person has in their ability to overcome barriers and perform a particular behavior. According to SCT, self-efficacy is predictive of an individual’s intention to perform a behavior and as such is the most important determinant of behavior change. Self-efficacy is a powerful theory in itself that has been added to other behavior modification theories. Self-efficacy can be increased by providing individuals seeking a particular behavior change with a series of small steps that break down the complexity of achieving the final goal. Each step should be constructed in a manner that ensures success. A simple example would be the provision of an exercise regimen that incrementally builds towards a final fitness goal. A related concept in SCT is *self-control*, which is the self-regulation of behavior related to a goal. Self-control, or self-regulation, has sub-functions including monitoring one’s own behavior, comparing behavior to self-set goals, and self-
reward. Self-efficacy is important for building an individual’s self-confidence in their ability to self-regulate. The practical implications of this concept for behavior change include offering methods for people to set goals, track their behavior, solve related problems and reward themselves for goal achievement.

Intense emotions can interfere with the performance of particular health-related actions. For example, stressful life events can make it difficult to adhere to diabetes management goals such as routine physical activity or remembering to take medication. SCT recognizes the importance of providing individual effective strategies for emotional coping. Providing problem solving and stress management training is an important implication relating to effective coping that will contribute to self-control and enhanced self-efficacy.

Another important concept of SCT is behavioral capability, which suggests that individuals must possess both knowledge of the behavior and the skill to perform the behavior. Simply gaining an understanding of the behavior does not guarantee the ability to perform the behavior, thus it is important to distinguish learning and skill as a separate step towards behavioral capability. For example, a person may know that low fat meals protect against heart disease, but lack the skills to prepare low fat food items. Specific
health behaviors can be targeted and skills training provided in an effort to address this component of behavior modification.

Outcome *expectations* and *expectancies* are also important determinants of behavior according to SCT. *Expectations* are a person’s anticipated outcomes of a particular behavior. Expectations can be learned from experience, observation, hearsay, or physiological arousal related to the behavior. *Expectancies* are the values an individual places on a particular expectation. Behaviors can have both positive and negative outcome expectancies. People are more likely to take health-related actions that lead to positive outcomes. For example, a person may have previously achieved a weight loss goal by taking 10,000 steps a day (positive reinforcement) and now has expectations that resuming that prior level of activity will render a similar weight loss (expectations). However, the positive expectancy of weight loss related to the walking behavior does not outweigh the negative expectancy of the reduction in time to devote to writing a chapter for a book.

SCT also incorporates the concept that if a particular behavior is followed with *reinforcement*, performance of that behavior will increase. Reinforcement can be both extrinsic (i.e. external reward) and intrinsic (i.e. internal reward) and is either directly experienced, vicariously experienced, or self provided. For example, an individual with diabetes may observe a diabetic friend reduce their HgbA1C level after following a walking program routinely for 3 months. This may vicariously reinforce the individual’s decision to walk more. Similarly, if the individual experiences a reduction in HgbA1C after instituting their own walking program, it will offer reinforcement by direct experience. Vicarious forms of reinforcement evolve from another concept in SCT, *observational learning*. Observational learning happens when an individual watches the behavior of another person and observes the resultant reinforcement they receive. An individual’s health-related actions may therefore be influenced by the behavior by others in their environment, as in the concept of reciprocal determinism.

*Environment* can be described as things external to a person that may affect their behavior. This includes social environment, such as friends and family, and physical environment. *Situation* refers to an individual’s perception of their environment. This could be the real or distorted view of time, physical features, participants, and his or her role in the situation. Together, environment and the situation create a force for health behaviors. For example, a diabetic child’s food preferences and exercise habits are in part a result of their home environment, including the behavior of their family and the access to specific foods and exercise opportunities. The child’s situation is predicated by their age and dependency on their parent. Therefore, interventions must move beyond the person with diabetes and work more broadly with their social support system that is a critical part of constructing health behavior norms.
While SCT is broadly used as the framework for many health interventions, there are recognized limitations. First, there are so many constructs that it is often unclear how several constructs may act together to influence behavior. Therefore it is important to specify which of the constructs are being addressed with a particular intervention. There are also suggested issues with the reliability of measurement of some of the constructs. As with most theories, more research is called for in order to establish the relationship between the various constructs and health-related behaviors. [25]

2.2 Application of SCT in IBCT design and evaluation

Technology is particularly suited to supporting many of the SCT constructs. Indeed, there exists some very promising theory-driven research in this area [1, 3, 23, 26]. Table 1 outlines some of the many possible design implications for IBCTs, grounded on the SCT constructs. Next, we examine how the three selected application domains match up with the concepts of SCT.

<table>
<thead>
<tr>
<th>SCT Concept</th>
<th>Implication for Interactive Behavior Change Technology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Self-efficacy</td>
<td>Construct interventions that facilitate the decomposition of specific health behavior into <strong>small, achievable steps</strong>; The systems should construct steps that are <strong>tailored</strong> for a particular user via interaction with system.</td>
</tr>
<tr>
<td>Self-control</td>
<td>Allow user to <strong>track progress</strong> and measure against established goals; Leverage ubiquitous computing to embed tracking into daily activities of living; Build in <strong>self-reward</strong> mechanisms; Offer <strong>cues</strong> for problem solving</td>
</tr>
<tr>
<td>Behavioral capacity</td>
<td>Provision of <strong>education and training</strong> to develop specific skills aimed at a particular health behavior; Leverage benefits of interactive capabilities of computing systems for learning; Utilize video capability for skills training</td>
</tr>
<tr>
<td>Emotional coping</td>
<td>Provide <strong>problem solving training</strong> for stress management. Offer features that <strong>enhance social networks</strong> for support during difficult times from others who have had similar experiences.</td>
</tr>
<tr>
<td>Expectations</td>
<td>Provide <strong>real-time feedback</strong> in response to desired health action in a manner that reinforces healthy and realistic expectations. Offer opportunities for user to interact with others who are experiencing similar problems in order to provide <strong>role modeling</strong></td>
</tr>
<tr>
<td>Expectancies</td>
<td><strong>Tailor feedback</strong> so it is personalized to an individual’s values or incentive for a particular outcome. Use interactive learning to <strong>correct health misperceptions</strong> and construct healthy behavioral norms.</td>
</tr>
<tr>
<td>Reinforcement</td>
<td>Provide <strong>rewards for goal achievement</strong>. Reward construction can be done by the user, healthcare provider or system.</td>
</tr>
<tr>
<td>Environment &amp; Situation</td>
<td>Provide information and education to the individual’s social support system</td>
</tr>
<tr>
<td>Observational learning</td>
<td>Use interactive media to <strong>model desired health behavior</strong></td>
</tr>
</tbody>
</table>

Table 1 – Some implications for the IBCT design based on SCT Concepts
2.3 Interactive health web sites

Interactive health web sites support several of the constructs in SCT. Web sites offer an inexpensive means of providing patients with a medium where they can build self-control by allowing patients to more easily track goals that may have been established with a health care provider or perhaps even a professional coach affiliated with the web site. These sites also offer more accountability than paper and pencil method because the data can be more easily shared with others. Accountability to others for a particular health action can facilitate self-control.

Health web sites can also provide important information that is presented in an interactive format so that the user can more readily learn skills that contribute to problem solving. Online tools, such as an interactive game that provides common problem solving experiences such as estimating the carbohydrate content of foods, offer additional mechanisms for learning to occur. When done well, this feature of interactive health websites can enhance behavioral capability. The learning that occurs during the interaction with these components may also correct commonly held misconceptions about diabetes, e.g. one cannot consume fruit because it is too high in sugar. Observational learning can occur in various ways, for example the website may offer video examples of individuals performing specific procedures such as proper infusion set insertion for insulin pumps.

Web sites that offer personalized emails with information targeted at a particular individual, can also act to support emotional coping by providing strategies and tactics for disease management during stressful or emotionally charged life events. Emotional coping is also enhanced by social network features of many health web sites such as provision of options to have a live chat with a health care provider. Tracking data electronically also allows for virtual rewards or reinforcement to be created automatically when individuals achieve particular goals. One common example is devices that track physical activity such as walking and running. Data is uploaded from the device to an interactive website and virtual or actual rewards are given based on activity level.

Information solicited from users to generate tailored messages may include querying about perceived barriers to a particular health behavior and/or the expectations for overcoming barriers (e.g. questions that may expose specific issues with regular blood glucose testing). This type of querying can lead to a better understanding of the value associated with a particular health action thereby affording insight into expectancies for health behavior. Expectancies may be a critical element of motivational, tailored feedback because it can reveal how a specific health behavior may or may not be integrated into self-identity.
The information gathered from users can also be used to construct an action plan that provides small, achievable steps towards a diabetes related goal. For example, a diabetes educator may use the data gathered by the system to help their patient focus on tackling one problem at a time by providing a series of goal related actions via email. In this way technology can be used to enhance self-efficacy by empowering the patient to take small gradual steps that are more likely to be successful.

2.4 Virtual Communities

SCT stresses the importance of effective emotional coping strategies for successful behavior change. This may entail the continued compliance with medical treatment during difficult periods, e.g. maintaining dietary goals during a stressful life event. Virtual communities have been established as useful resources for social support for those suffering with a chronic illness and recovering from surgery or injury. Preece et al. investigated the empathetic qualities of posts on a message board support group for individuals with knee injuries [46], and Farnham et al. looked at the impact of social support offered via the internet on the quality of life of cancer patients and their caregivers [19]. The shared information within online communities has a different impact than written materials or advice from a health care provider because it is the authentic experience described by a person who has gone or is going through similar circumstances. In addition, there may be very unusual or rare problems that a person with diabetes is experiencing and this medium is unique in its ability to extend one’s social network beyond proximal interactions, increasing the likelihood that relevant information can be obtained.

Various community members are at different stages with their disease, ranging from newly diagnosed to a virtual lifetime of diabetes. The real-life coping strategies that are shared within these communities provide role model behavior for others who may learn vicariously though the experience of others the benefits (expectations) of a certain health action, e.g. lower HgA1C value after implementing a walking program. Observational learning takes place when we can examine the behavior of others in the storytelling mode of communication that occurs in online communities. Parts of the story may resonate deeply with an individual and serve to be a powerful persuasive message beyond that delivered by a health care provider. In these circumstances behavioral capacity is improved as successful strategies are adopted by the individual. Virtual communities that allow easy entrée for new members are likely to lead to most effective interventions as it improves the likelihood that this type of interaction can occur for those who may need it the most. Also, the concern that only positive health behaviors are modeled may be supported by the inclusion of rating system for member contributed posts similar to those used in other virtual communities (e.g. Slashdot).
2.5 Ubiquitous Computing

Ubiquitous tools offer a unique advantage for leveraging SCT constructs when compared to web based applications because they move about with people during their everyday activities, offering real-time support for behavioral management. The mechanisms by which ubiquitous computing can fulfill the constructs in SCT are similar to interactive health web sites. The ability to track progress and measure against goals will work to improve self-control which can ultimately lead to improved self-efficacy for disease management. However, ubiquitous computing tools may allow for easier data collection which increases the likelihood that sufficient data can be collected to provide meaningful reflection and comparison against diabetes related goals. For example, mobile phones can be used to capture data from on the body sensors and detect opportunities for health action cues that enhance self-control in real-time. For example, a text message can be generated by synthesizing information from a continuous glucose monitor and a device that detects physical activity.

Automating the collection of data with ubiquitous computing devices may also increase the volume of data available for analysis. Tracking data in this way allows for better and faster trending information to be presented to the individual which may foster a change in expectancies associated with a particular health behavior. The impact of emotional stress or impact of a particular meal on blood glucose levels may be more evident. In this regard, a person with diabetes may be able to dispel misconceptions about diabetes that have been passed along by well meaning friends and family, e.g. foods that are considered “bad” for people with diabetes. Real-time reinforcement for goal related health behaviors may be more effective at strengthening expectations and outcome.

Real-time data collection can also provide a means for connecting people with their support system at the very instant they are in need, thereby providing a scaffolding for emotional coping. Strategies for coping with various challenges in everyday diabetes management can also be delivered to the support system surrounding the person with diabetes (e.g. the parents of a diabetic child). This would serve to improve diabetic’s environment by improving both the skills and awareness of those involved with their care. One example is using text messages for communicating blood glucose values [22, 58, 20] or simply appointment reminders. Ubiquitous tools also offer a unique method of enhancing skills related to diabetes management since they are integrated into the daily activities of living, moving with the user to provide just-in-time information. Behavioral capacity can therefore be affected by the provision of on-demand advice (e.g. estimation of carbohydrate content of foods).
3 The Transtheoretical Model

The Transtheoretical Model (TTM) offers an alternative approach to understanding health behaviors brought about by a convergence of the principle behavioral theories [48]. The central construct of the TTM posits that a person’s readiness for a behavioral change is a temporal one that progresses through a series of six stages. The TTM is sometimes called the stages of change model due to the importance of the stage construct. This model was first used to understand the behavior change process of individuals trying to quit smoking in the early 1980’s, but has since been used to understand a variety of health and mental health behaviors [25].

3.1 Overview of Constructs

The Stages of Change construct is comprised of six separate stages that describe the process an individual progresses through as they change a particular behavior (Figure 3). People who are not planning to take action for health behavior change in the next six months are in the first stage of change, precontemplation. People in this stage are deemed inappropriate candidates for health interventions because they are resisting change or unmotivated. These individuals may be in this stage either because they are not aware of the health risks of their behavior or they have had a bad past experience trying to change the behavior. People who are planning to take action in the next six months are in the second stage of change, contemplation. Individuals in this stage are in a persistent state of balancing the pros and cons of changing their behavior. They are not considered for typical interventions which assume people will take immediate action. People in the third stage of change, preparation, are characterized as those intending to change a behavior within 30 days and may have already taken some action within the last year. Individuals in this stage are ideal candidates for traditional intervention programs. People who have recently changed a behavior are in the action stage and those who have done so for more than six months are in the maintenance stage of change. The final stage, termination, is when people are no longer tempted to resume their old behavior and have complete self-efficacy. It has been suggested that this stage may be an unrealistic goal for most people and thus has not been addressed in intervention studies [25]. The TTM describes the process of moving through these stages as cyclical. Moving back and forth between stages or completely backsliding is considered a natural process [49].

Two of the major determinants of whether or not a person will progress along the stages are decisional balance and self-efficacy. The decisional balance construct describes decision making as striking the benefits of the health-action (pros of a particular behavior change) against the associated costs (cons of a particular behavior change). The concept of self-efficacy as described in Social Cognitive Theory was...
added as a construct of the TTM to describe the confidence an individual has in their ability to deal with specific high temptation circumstances that may contribute to a relapse in behavior. An example would be the ability to fend off cravings that may cause a return to a previous undesired health behavior.

Processes of change are the actual activity people undergo to move through the stages of change. This construct offers guidance for developing health-related interventions that will promote behavioral change. Several processes have been identified that assist people in making and maintaining changes; with different processes being more effective at different stages (Figure 3). Some of the ones we’ll discuss are:

- **Consciousness raising**: learning new facts, ideas and tips about health condition, and effect of desired behavior on health.

- **Self-reevaluation**: realizing the behavior change is part of one’s identity. Understanding the impact of current and desired behavior on one’s image.

- **Self-liberation**: believing that one can change their behavior and obtaining a commitment to doing so.

- **Helping relationships**: seeking out and using social support in support of desired behavior change.

- **Reinforcement management**: getting rewards for desired behavior and removing rewards for undesirable behavior.

- **Stimulus control**: adding reminders or cues for the desired behavior, and removing reminders and cues for the undesirable behavior.

- **Social liberation**: increasing opportunities to achieve behavior change, often for disadvantaged people.
The last process of change, social liberation, is a special case in that it can have an impact at all of the stages. Technology offers great potential to helping people adopt healthy behaviors. Low income and rural groups could benefit greatly, as inexpensive technology can assist in delivering health services to those who have difficulty accessing such services due to lack of funds or inconvenient geography. Minority groups could benefit by the social networking aspects of technology, allowing them to participate in virtual communities where they are no longer the minority. With the digital divide, we are at risk of using the technology to assist only those who already have access to resources. Numerous government and private agencies, however, are putting resources into narrowing the digital divide. If
successful, improving health outcomes for disadvantaged people by increasing their opportunities to receive health interventions has the potential to have a major impact on our society.

3.2 Application of the TTM on IBCT design and evaluation

Many researchers designing and evaluating IBCT’s, especially technologists unfamiliar with the behavior modification theory, do not take into account the particular stage in which a person may be. When gathering participants for evaluating an intervention, they often neglect to differentiate between the stages, thus confounding their results. An intervention may be highly effective for an individual in the preparation stage but irrelevant for a person in the precontemplative stage. By grouping everyone together in a user study, researchers may achieve disappointing results, instead of identifying a true success. Stage of change screening tools have successfully been used by Consolvo et al. to recruit user study participants who are most likely to benefit from the technological intervention [12, 13]

In this section, we examine how IBCTs address the change processes by facilitating movement from one stage to another, or maintenance of an existing stage. Many of the constructs are closely aligned with those discussed for social cognitive theory, such as self-efficacy, stimulus control (a form of self control and cues) and reinforcement. We will not repeat ourselves by going into depth about how the technology addresses these constructs. Instead, we will focus on how technology may assist with moving a person along the stages of change, emphasizing the particular stage the intervention is likely to be most effective.

3.3 Interactive health web sites

An interactive health web site can tailor its content based on the current stage of the patient. Researchers have developed instruments suitable for online use [15, 16], allowing a site to periodically administer a questionnaire to its members to determine their current stage.

For people in the precontemplative stage, the website may focus on consciousness-raising related to the decision balance for behavior change, e.g. tipping the balance between pros and cons. The main difficulty, however, is getting people in the precontemplative stage to even visit the web site, as changing their behavior is not something they are considering. However, many people who are newly diagnosed with a medical condition such as diabetes are in the precontemplation stage for changing their behavior, but are eager to seek out information about their disease or condition. Web sites providing basic information for newly diagnosed patients should try not to overwhelm the individual in this stage, but instead tailor the information they provide in such a way as to assist in the transition to the contemplative stage.
For those in the contemplative stage, a web site might focus on *self-reevaluation*, helping a person see what their life might look like, and how it might improve, if they were to make the behavior change. This could involve some level of tracking to understand the current health state, and role-playing or storytelling to glimpse how their health might improve.

In the preparation stage, the web site could facilitate *self-liberation* through both role models, and providing tools and skills that would be seen as necessary to implement the behavior change. This is what many interactive web sites provide by default, but an individual may not be ready for this type of skill requirement until they reach the preparation stage.

Finally, both the action and maintenance stages could be supported through a combination of online coaching (a form of *helping relationships*), tracking (enabling *reinforcement management*) and cues (to assist with *stimulus control*). Given the expense of online coaching, it makes sense to target individuals in the action or maintenance stages for this resource-intensive intervention since it is likely to have the largest impact for people in those stages. Likewise, tracking through a web-site is time-consuming for an individual and not sustainable over the long-term. Thus, it is important to encourage tracking at the appropriate stage in order to maximize its impact.

Most interactive web sites have not demonstrated long-term use by their target population. Using TTM to target specific stages with different features has the potential to be a more successful approach. ProChange is an example of such an interactive web site that is tailored to an individual’s current stage; it has obtained positive results in the areas of stress management, medication adherence, weight management and smoking cessation [47].

### 3.4 Virtual communities

The main change process addressed by virtual communities is the presence of numerous *helping relationships* that may not be present in one’s physical social network. In fact, the interaction with people who have the same condition can have an impact on other processes of change as well. As mentioned in the SCT section, contact with individuals who are further along in the stages helps to serve as role-models, and can impact both *consciousness-raising* and *self-reevaluation* by being exposed to authentic and personal experiences of people who have struggled with similar behavior changes. On the other side, people who are taking or maintaining action can share their stories with the community, thereby helping to solidify the behavior change as part of their personal identity. Community acknowledgement of one’s success can in itself be a powerful *reinforcement*. 


3.5 Ubiquitous computing

Ubiquitous computing offers many of the same features as interactive health website and virtual communities, but does so in real-time throughout a person’s day. While still in the early stages, the hope is that by integrating the technology into a person’s everyday life, and automating common tasks, individuals will be more likely to adopt the technology over the long term. For health interventions, this level of adoption could have a powerful impact.

In terms of consciousness-raising, a newly diagnosed diabetic may obtain a service which allows them to use their cell phone to take pictures of barcodes of the food items they are about to purchase at the grocery store and receive immediate feedback about how that food impacts their health. The service could even offer suggestions for a healthier alternative. The information and tips provided on their phone is grounded in their actual experience, as opposed to being pre-prepared literature for a large audience.

Similarly, a system can address self-reevaluation more authentically by embedding a role playing game in the context of one’s life. As an example, an activity sensor could track a person’s current level of activity and relay that to their mobile phone. An application running on the phone could convey how different increases in activity levels over time might impact their health. The application is more authentic than the online role-playing games because it gives a much better idea of what would be involved in helping a particular individual reach a particular goal.

The mobile nature of ubiquitous computing is particularly suitable for addressing self-liberation, as mobile tools can be used to assist in achieving the behavior change. For example, a cell phone can help offer assistance with estimating the carbohydrate content of food in virtually any context the person may need the information. Finally, ubiquitous computing can perform detailed and automatic tracking to enhance reinforcement management, utilize context to provide relevant cues for stimulus control, and provide instant access to one’s social network and helping relationships.

The key is to provide the different types of interventions at the appropriate stages. The power of technology enables one system to address the needs of people at multiple stages. It may be possible for the technology itself to utilize context to covertly determine the stage of an individual. For example, an activity monitor can detect an increase in activity levels, indicating a change to the action stage, or a decrease in activity levels indicating a possible slide backwards. It can use that information to further support the action (e.g., by providing positive reinforcement), or to help the individual get back on track (e.g., encourage their social network to help, or provide tips for returning to their previous behavior).
4 Health Belief Model

The Health Belief Model (HBM) is one of the most commonly used frameworks to describe individual choice regarding health behavior. For over fifty years the HBM has been used to describe the motivation behind choosing to, or not choosing to, change certain health behaviors that will prevent disease. The HBM suggests that health behavior is a result of a person’s desire to stay healthy or get well and their belief that a certain health action will reduce the threat to their health or help them get well.

**Figure 4 – Health Belief Model**

4.1 Overview of Constructs

The key concepts of this model include perceived susceptibility, perceived severity, perceived benefits, perceived barriers, cues to action and self-efficacy. The *perceived susceptibility* construct is defined as a person’s subjective belief that they are likely to become ill. *Perceived severity* is a person’s subjective belief about the seriousness of the condition and what medical or social consequences may result if action is not taken. Together, perceived susceptibility and severity create perceived threat which provokes people to change health behaviors. If the perceived severity or the perceived susceptibility is low, the threat to one’s health is likely to be minimal so the motivation to change is low. For example, a person in
their twenties may perceive that their chances of having a heart attack are low so motivation to eat a heart healthy, low fat, high fiber diet is low. Similarly, the severity of a common cold may not be threatening enough to persuade an individual to wash hands frequently.

Perceived benefits are a person’s subjective assessment of the effectiveness and feasibility of the health action suggested to reduce the risk of illness. If the individual does not believe the action will be effective they will not change their behavior regardless of how great the perceived threat. The perceived barriers, ranging from discomfort to danger, also mitigate the perceived benefits. An individual will conduct an informal cost-benefit analysis of the recommended health action to determine if the benefits outweigh the barriers. “The combined levels of susceptibility and severity [provide] the energy or force to act and the perception of the benefits (less barriers) provide the preferred path of action” [52].

Early definitions of the HBM included the construct of cues to action which suggests that some form of external (e.g. environmental events) or internal triggers (e.g. changes in the body due to aging) are necessary to initiate action regardless of the level of perceived threat and benefits of that action. The role of cues in health actions has not been well studied as they are difficult to evaluate because they may be so minor that they pass by conscious recognition [25]. The original formulation of the HBM was modified to include concept of self-efficacy in the 1980’s [53]. In addition to feeling threatened by an illness, believing that a specific health action has a low cost and will help reduce the threat, people must have confidence they have the ability to overcome perceived barriers and executes the health action.

4.2 Application of The Health Belief Model in IBCT design

HBM has many overlapping constructs with SCT and TTM. In particular, we have already discussed self-efficacy and cues to action in the other sections. The combination of perceived benefits and perceived barriers is conceptually the same as decision balance in TTM. Therefore, we will focus our discussion in this section on ways to leverage the idea of perceived threat. Unlike the other models, HBM lends itself to a discussion of preventative health through its perceived susceptibility construct, which focuses on the level of concern that an individual may have about becoming ill.

In order to make the decision to change one’s behavior, one must have a sense that there is an existing threat. If a person already has diabetes, then their awareness is such that they can seek out existing tools to measure their level of susceptibility for the progression of their disease. Similarly, the threat may be that there are close family members who have diabetes, making the individual more susceptible to developing diabetes as well. In many cases, having a condition “run in the family” is the simple case in terms of raising awareness about risk. Health web sites can administer questionnaires to assess a person’s
risk, such as Kaiser Permanente’s Diabetes Personal Health Decisions tool, which allows members to enter information to determine if they are at risk for diabetes. However, if the risk is due to lifestyle factors, a person may not even be aware of the risk possibility, and thus don’t think to take the questionnaire.

Ubiquitous computing offers the ability to detect risk factors automatically, thereby allowing a system to inform the user about the possibility of risk. The system could either administer an existing risk assessment tools in real-time, or encourage the user to take one at a later point. For example, if a person’s mobile phone utilizes location technology to detect that they spend a lot of time in fast food restaurants, they may encourage the individual to take a questionnaire to assess their risk of heart disease and obesity.

An interesting avenue of research is to develop risk predictors based on observable behaviors as opposed to questionnaires. With the push towards personal medical records, such systems could even combine observed behaviors with family medical history to make the assessment. As the technology becomes more ubiquitous, there will be rich data from which to draw. Example of useful information include:

- **Physical activity levels**: detected from sensors embedded in mobile phones and/or clothing
- **Location information**: from which a variety of behaviors can be inferred, such as types of food consumed based on restaurants visited
- **Nutrition information**: gathered from grocery receipts [38] or rfid readers in the kitchen
- **Stress levels**: gathered from 1) interaction patterns with the environment, such as gate monitors in the flooring of one’s home, or posture detection through video analysis; or 2) physiological sensors embedded in clothing or the environment, to measure heart rate or skin conductance
- **Emotional health**: detected from emotion recognition systems that analyze video [11, 55] and/or social interaction levels.

If a particular technology is believed to provide valuable data for risk assessment but is not yet ubiquitous, researchers may consider borrowing from public-health publicity campaigns. Massive publicity campaigns such as “5 a day” (referring to the number of fruits and vegetable people should consume each day) and “10000 steps a day” (which gave away pedometers and encouraged people to walk more) have demonstrated positive results. National health campaigns that challenge people to utilize inexpensive technology that can assess their health risks are a promising future direction.
Once a person is aware of their risk, perceived severity can be influenced through a variety of means, such as basic education, role-playing games, and simulation software. Similar to the discussion under TTM, role playing games can be enhanced through ubiquitous computing by utilizing an individual’s baseline data gathered automatically with technology, and by playing the game in real time, over time, to more realistically portray the possible negative outcomes if the individual were to retain their current health behaviors. Such simulation software is also useful to clarify the perceived benefits of particular health actions such as the positive impact of walking 30 minutes daily. This may work to enhance a person’s perception of the efficacy of small changes in routine.

5 Tools for assessing theory-based interventions

In the development of health behavior interventions it is recommended that designers 1) decide upon a specific behavioral outcome, 2) decide upon the particular SCT construct(s) that is most likely to make an impact on the selected behavior, and 3) decide upon a method to assess the impact of the intervention on the target behavior [25].

5.1 Social Cognitive Theory

There many tools that have been used to measure the impact of diabetes management interventions based on SCT constructs. Some of these have been criticized for their lack of reliability [25] but some of the constructs have been successfully measured and have shown to be influential.

In a review of literature published between 1985 and 2002, Nancy Allen found evidence that SCT was effective for interventions that targeted the uptake of physical activity in people the diabetes. She found that “self-efficacy was predictive of exercise initiation and maintenance over time.” [1] In the studies she analyzed, she found a variety of tools were used to measure SCT constructs including: McCaul and colleagues self-efficacy instrument [39]; Crabtree’s instrument [14]; Hurley and Shey’s instrument [27]; Grossman and colleagues instrument [26]; Boykin’s instrument [8]; and others [42, 33, 54].

Silje Wangberg recently published the findings of an internet-based diabetes intervention aimed at improved self-care behavior and designed using SCT constructs [59]. The intervention included monitoring and graphical feedback; information in the form of articles and user contributed materials; videos of peers modeling behaviors and lectures by health professionals; and various interactive tools (e.g. quizzes) to facilitate learning. The Summary of Diabetes Self-Care Activities [56] used to measure the impact of the technological intervention.
5.2 The Transtheoretical Model

Assessing the impact of an intervention designed with TTM constructs in mind requires an examination of how well it serves the purpose of moving individuals to the next stage. Criteria for evaluating the impact of an intervention are therefore dictated by the target behavior. Jones et al. [31] used TTM to create an intervention aimed at diabetes self-care behaviors. They used “stage-matched personalized assessment reports, self-help manuals, newsletters, and individual phone counseling designed to improve readiness for self-monitoring of blood glucose (SMBG), healthy eating, and/or smoking cessation.” [31] They evaluated the impact of the intervention by posing questions to study participants that ascertained their intention to change and the state of their current behavior, e.g. actual frequency of blood glucose testing. Similarly, Vallis et al. [57] used a stage-based categorization that characterized an individual with diabetes “readiness to adopt healthy, low-fat eating habits.” They assessed the impact of various factors on stage of change for healthy eating behaviors.

5.3 The Health Belief Model

The HBM has been used to explicitly address issues related to diabetes prevention and compliance with medical therapy [3]. One tool that has been used by many studies is the Diabetes Health Belief Model (DHBM) scale [27]. This scale is an 11-item questionnaire that gauges the individual’s belief in a particular concept about diabetes management, e.g. “My diabetes is not problem to me as long as I feel all right.” [27, 28] High scores, near the maximum of 55, are associated with an increased readiness to take action.

Phan et al. [40] used the DHBM scale along with the Self-Evaluation of Adherence to Diabetic Treatment (SEADT) to evaluate the impact of beliefs about diabetes upon compliance with diabetic routine in type 2 diabetic amputees. The SEADT is an 11-item questionnaire that asks the individual with diabetes to assess their adherence to diet, medication regimen, exercise recommendations, glucose testing and foot care. They found health beliefs are linked, both positively and negatively, to diabetes self-care [40]. Powell et al. [44] used the DHBM scale in conjunction with the Diabetes Knowledge Test (DKT) and a literacy assessment to determine if diabetes-related knowledge is associated with readiness for health behavior action in people with type-2 diabetes. They found low levels of health literacy were associated with worse glycemic control but not related to their readiness for action. Based the HBM, low health literacy individuals “still perceive their illness is severe, believe in the benefit of therapy, and perceive they can overcome barriers to care.”[44]

The HBM model is often used in combination with other theoretical frameworks. Richardson et al. [51] used HBM principles to construct a tailored motivational message algorithm for an interactive health web site designed to encourage individuals with type-2 diabetes to get more physical activity. The message
content was based on individual responses to baseline surveys that the study participants completed. The intervention also included components designed to meet SCT constructs.

5.4 General Tools

There are many instruments and measures that can be used to evaluate target behaviors in general, regardless of the theoretical framework. Table 2 outlines some that have been used in internet based interventions [23, 23]. The RE-AIM framework – an acronym for Reach, Effectiveness/Efficacy, Adoption, Intervention and Maintenance – has been proposed as a technique to evaluate a given health behavior intervention in general but also specifically to diabetes self-care [23]. Its aim is to expose the potential impact to public health by guiding intervention developers to through an evaluation process. **Reach** and **Effectiveness/Efficacy** are assessed at the level of an individual, asking if the population who needs it most will be reached and if the intervention is effective at addressing the target behavior. **Adoption** and **Intervention** are assessed at the organization level, asking if adoption of the intervention will be taken up in real world settings and if it can be consistently delivered in the intended manner. **Maintenance** applies to both the individual and institutional level and addresses the issue of long term viability of the intervention.

Cummins et al. have proposed a set of criteria for the evaluation of health web sites that is grounded in the ‘5As’ model of behavior change. This model of care offers a sequence steps that a health care provider can take to address a variety health related behaviors. The original model, which was intended for counseling tobacco users, was modified and includes the following criteria as detailed in [15].

- **Advise**: e.g. is intended audience clearly identified; are the goals of website stated?
- **Assess**: e.g. is there scientific basis for assessment; what degree of tailoring of feedback is based on assessment; is there disconnect between assessment and feedback?
- **Assist**: e.g. are strategies provided to assist the individual in meeting the recommendations?
- **Anticipatory guidance**: e.g. does the site provide guidance regarding potential relapse?
- **Arrange follow-up**: e.g. are there suggestions and/or reminders for how often to return to the site; is there a dynamic plan for reaching goals?

The authors suggest that a quality health web site will meet 4 of these 5 criteria [15, 16].
### Behavioral Measures

<table>
<thead>
<tr>
<th>Behavioral Measures</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kristal Fat &amp; Fiber Behavior</td>
<td>20-item scale assessing behavior patterns relative to low-fat eating [35]</td>
</tr>
<tr>
<td>Block/NCI Fat Screener</td>
<td>62-item food frequency questionnaire [7]</td>
</tr>
<tr>
<td>7-day dietary recall</td>
<td>Retrospective description of food consumption during the last week</td>
</tr>
<tr>
<td>PASE <em>(Physical Activity Scale for Elderly)</em></td>
<td>Measures frequency of physical activity in past 7 days [60]</td>
</tr>
<tr>
<td>Diabetes care guidelines met</td>
<td>Number of 11 criteria from the American Diabetes Association Provider Recognition Program [32]</td>
</tr>
</tbody>
</table>

### Biological measures

<table>
<thead>
<tr>
<th>Biological measures</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>HbA1C</td>
<td>Hemoglobin A1C is a blood value that reflects blood glucose control over several months</td>
</tr>
<tr>
<td>Lipid Profile</td>
<td>Blood values that reflect risk for cardiovascular disease and are impacted by both dietary and physical activity behavior</td>
</tr>
<tr>
<td>Body Mass Index</td>
<td>An indirect measure of body fat composition calculated based on an individual’s height and weight</td>
</tr>
</tbody>
</table>

### Psycho-social Measures

<table>
<thead>
<tr>
<th>Psycho-social Measures</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>DSS <em>(Diabetes Support Scale)</em></td>
<td>12-item scale that assesses perceived social support [4]</td>
</tr>
<tr>
<td>Diabetes Distress Scale</td>
<td>17-item scale that assesses quality of life [43]</td>
</tr>
<tr>
<td>CES-D <em>(Center for Epidemiologic Studies – Depression Scale)</em></td>
<td>Self-report measure of depressive symptoms [50]</td>
</tr>
</tbody>
</table>

Table 2 – Select assessment tools for various target behaviors

### Conclusion

Developing IBCT based on behavior modification theory is likely to improve effectiveness [9,17, 61] and we believe that informatics professionals should be well grounded in that domain of research before they engage in this type of interdisciplinary research or practice. Similarly, informatics professionals can offer important design considerations based on the theory and practice in their own field, e.g. human computer interaction (HCI). This is particularly important as technology advances to provide ubiquitous computing systems that will help change our everyday health behaviors. HCI researchers are turning to a focus on discretionary use of technology at home and during leisure time vs. non-discretionary use in work settings. The findings from future research into issues that are emerging from new interfaces brought with new technologies – such as small interfaces, tangible interfaces and interfaces that move thus dynamically
change context of use – will be extremely valuable to those trying to develop IBCT that is embedded in our everyday experience.

John Piette has reflected on the current state of IBCT, stating that these technologies may help bridge the gap between increased demand for diabetes care and a shortage of resources [41]. In his article he suggests 7 guiding principles for future development of IBCT for diabetes self-management. Among these suggestions two in particular resonate with the purpose of this chapter. First, he cautions against the lure of “cool apps,” insisting that interventions must have a strong foundation in behavioral theory. The abysmal dropout rates from interactive health web sites, termed the “law of attrition” by Gunter Eysenbach [18], may be addressed by taking a theoretical approach to development. In our opinion HCI researchers may also offer valuable insights by applying the theory and methods from our domain. Second, Peitte states “IBCT is most effective when it supports human contact.” [41] Technology is not the proverbial “silver bullet” and often is not the right choice for treating many people with diabetes. The essential idea from this principle is that as technologists we must work closely with the professionals who understand diabetes and the people who are living with it best. We must carefully examine how the introduction of technology impacts the lives of those it is intended to help, ensuring that it is indeed a useful tool for health care providers who are working with these patients. Interdisciplinary efforts to improve the management of diabetes that involves researchers in health and technology fields poses its own challenges, as described in Chapter X of this book. Understanding the theory behind health interventions is a first step that technologists must take into making those collaborations fruitful.
References


5. Becker, M.H. and Janz, N.K The Health Belief Model Applied to Understanding Diabetes Regimen Compliance The Diabetes Educator 1985; 11; 41


40. Pham, D.T., Fortin, F., Thibaudeau, M.F. The Role of the Health Belief Model in Amputees' Self-Evaluation of Adherence to Diabetes Self-Care Behaviors. The Diabetes Educator 1996; 22; 126


44. Powell, C.K., Hill, E.G. and Clancy, D.E. The Relationship between Health Literacy and Diabetes Knowledge and Readiness to Take Health Action. The Diabetes Educator 2007; 33; 144


47. Pro-Change LifeStyle Program Outcomes Report, August 17, 2007


