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A Framework for Designing Healthy Lifestyle Management Information System

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ABSTRACT
Healthcare costs in the United States continue to rise and are projected to increase to 18.7% of the GDP in the next ten years. Preventing diseases by helping people adhere to healthier lifestyles is one of the weapons against the rising cost of healthcare. This paper introduces a framework for the design and development of an information technology based artifact to help people obtain and maintain healthy lifestyles. An example is provided to illustrate the use of the framework in the context of obesity and weight-loss management. The paper also discusses the challenges and issues that are likely to be faced in the development and implementation of such a system.

Keywords (Required)
Lifestyle management, ubiquitous healthcare, behavior change, context awareness, personalization.

INTRODUCTION
The healthcare industry in the United States is facing major challenges in terms of financial and human resources. In 2003, United States spent 15.3% of its Gross Domestic Product (GDP) on healthcare, more than healthcare spending of any other developed country. The healthcare cost is projected to increase to 18.7% of the GDP in the next ten years in the United States. One of the major factors is the overall rising population of the country, especially the older population (Walkner, 2004). The older population suffers from chronic diseases and requires frequent health care. Besides, there is a shortage of physicians and nurses all over the nation. Preventing diseases can curtail the rising costs and help minimize chronic diseases. Preventing diseases requires people to adopt healthy lifestyles. People need to avoid unhealthy habits, which range from smoking to unhealthy eating. The question is how to make people adhere to healthy lifestyles. Integrating evidence-based principles of psychology and harnessing IT is a promising area to help people achieve healthy lives. In this paper, we explore such possibilities and propose a framework that is based on human psychology and can be used to develop an effective information system to help people live healthy lives. The system utilizes advanced mobile telecommunications, ubiquitous computing technologies and agent-based systems to help people maintain healthy lifestyle.

The rest of the paper is structured as follows: In the theoretical background section, we discuss the theoretical underpinnings that we later use to build our IT system. The subsequent section presents the framework and explains what it does. Later we discuss several issues and challenges in the key challenges section, followed by the conclusion section.

THEORETICAL BACKGROUND
In the past, there has been limited success in human behavior change programs, in part, due to the failure to fully understand the determinants of the behaviors and the failure to properly apply health behavior theories to the development and
implementation of effective interventions (Gielen and Sleet, 2003). Theories are important not simply because they help us understand causes of problems but because they also allow us to identify mechanisms of change, determine why programs succeed or fail, and perhaps most importantly, guide us to better prevention programs.

In 1998, the Centers for Disease Control and Prevention (CDC) and the American Psychological Association (APA) cosponsored a national conference on integrating behavioral and social science in the area of public health and consequently published a book on the topic (Schneiderman, Speers and Silva, 2001). The major finding from this conference was the notion of an ecologic model in understanding and intervening in contemporary public health problems. The ecologic model states that health is affected by a dynamic interaction among biology, behavior, and the environment, and this interaction changes over the life course (Schneiderman, et al., 2001). There are clear individual-level as well as community-level factors in shaping health and health-related behaviors.

The term “applied behavioral analysis” is a specific sub field within psychology that uses the technology of behavior modification and operant conditioning to facilitate change. “Behavior is viewed as learned, and principles of stimulus control, feedback, reinforcement, and punishment shape the acquisition, maintenance and extinction of behavior” (Gielen and Sleet, 2003). However, the literature related to this is vast. That is why in 1991, NIH had assembled theorists to develop a unifying framework for applying behavioral theory to the prevention of HIV infection (Fishbein, Bandura, Triandis et al, 1991). That discussion led to five major theories that have since been utilized in attempts to understand and change a wide variety of human behaviors: the health belief model, the social cognitive theory, the theory of reasoned action, the theory of self regulation and self-control, and the theory of subjective culture and interpersonal relations. When all five theories and their variables are combined, consensus was reached on eight factors that are key: 1) intentions, 2) environmental barriers, 3) skills, 4) outcome expectancies (or attitude), 5) social norms, 6) self-standards, 7) emotional reactions, and 8) self-efficacy.

An additional theory that we think is relevant and applicable is the Transtheoretical model (Prochaska and DiClemente, 1983). Most patients (or humans) are not equally ready to embark on any behavior-change prescription given by providers. Rather, there are stages of change and according to this theory, an individual moves through the following stages: precontemplation (benefits of lifestyle change are not being considered); contemplation (starting to consider change but not yet begun to act on this intention); preparation (ready to change the behavior and preparing to act); action (making the initial steps towards behavior change); and maintenance (maintaining behavior change while often experiencing relapses).

In order to provide the above-mentioned factors, it is apparent that one gets continuously motivated and advised. Several lifestyle factors can distract a person from healthy living. There needs to be a personal advisor who assists a person to focus on the goals of behavior change without any distractions. A personal advisor encourages a person to live a healthy life, sets achievable goal for the person, guides to deal with undesirable circumstances, praises him for achieving milestones in the behavior change process and justifies perceived benefits of the behavior change. Many individuals hire such personal advisors; for example, Oprah Winfrey has a personal trainer Bob Greene who helped her take control over her weight. Also, in order to live healthy life, this personal advisor should be a permanent advisor, in other words we can call him a life coach. The concept of having a life coach is great, however, it is infeasible to implement as not everyone can afford or would like to have a life coach follow them around the clock. A ubiquitous IS can fulfill this requirement by enabling a digital avatar that acts as a life coach. The framework explained in this paper provides guidelines to create a personalized ubiquitous IS designed to help people adhere to healthy lifestyles.

SIMILAR OR LIKE SYSTEMS FROM LITERATURE

Healthy lifestyle includes domains such as smoking cessation, obesity prevention and chronic disease control. Significant amount of work has been done in such domains through Internet interventions and other techniques. Some of them are commercially available. To our knowledge, these approaches lack the holistic view that incorporates principles from human psychology as well as technology and so they are no effective in long term. In this section, we briefly describe such systems that are related to our framework.

Motorola has come up with seamless health record concept that is family oriented and focuses on preventing illness by bringing personal health record at one place (Local, 2005). They propose to use a mobile device as their focal point and aims to reap the benefits of the growing power and sophistication of mobile computing and communication devices. It is certainly important to have personal health record anywhere, any time. However, merely providing personal health record to a person is not sufficient to prevent illness. Incorporating human psychology to change human health behavior is essential.

Han et al. (Han, Park and Kurkuri, 2006) propose a platform and framework to develop mobile e-health services. The essential components of the framework include bio-data catching, bio-data gathering and management, knowledge extraction and decision support, and e-health service platform. Our approach in creating the framework is different as we emphasize on personalization, use of existing technology and context awareness.
Stephen Intille and his team at MIT (Intille, 2003) are investigating perception for “just-in-time” information presentation and learning to motivate behavior change. A few commercial web sites also promote similar ideas. Some existing well-known websites for promotion of healthy lifestyles, such as Ediets, Calorie King and The Biggest Loser Club have a few commonalities to our framework as can be seen in Table 1. None of the programs mentioned in Table 1 is based on contextual information and there no clear indication that shows that they are based on psychological principles.

Table 1: Comparison of similar commercial systems (*denotes tools such as Body Mass Index Calculators, Calorie Counters etc)

<table>
<thead>
<tr>
<th>Name</th>
<th>Correspondence</th>
<th>Services</th>
<th>Domain Knowledge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calorie King</td>
<td>email</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Ediets X</td>
<td>email, chat, forum</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>FoodFit</td>
<td>email, forum</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>South Beach Diet X</td>
<td>forum</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>The Biggest Loser Club X</td>
<td>forum</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

A NEW FRAMEWORK FOR LIFESTYLE MANAGEMENT

Our framework is depicted in Figure 1. We explain each component of the framework below:

**Domain Knowledge**

The HLMIS can be applied to different areas of healthy lifestyle ranging from obesity prevention, smoking cessation to diabetes control. A system should be based on the specific domain knowledge.
Consumer Health Data Acquisition

The first step in developing an HLMIS is the acquisition of consumer health related data. This can be through existing health records, electronic or otherwise, biosensors, or through a questionnaire provided through a health website. The characteristics of the health data acquired depend upon the application domain. The data can include demographic information as well as health and lifestyle information. Any information about chronic conditions also needs to be captured.

Consumer Health Data Repository Creation

The second step in the HLMIS development is the creation of a data repository for storing the acquired consumer information. The repository needs to be able to store a large volume of data for every individual consumer and respond to queries as well. The HLMIS repository could either be built from scratch, or could also be connected to an existing repository.

Personalization

Personalization is building a meaningful one-to-one relationship with a consumer by understanding his or her needs in a given context and using personal preferences and contextual information to help him or her reach a desired goal within that context. “User context is any information that can be used to characterize the situation of an entity, for example time of day, location, user activity, nearby devices and people” (Dey and Abowd, 1999). The data in the repository as well as domain knowledge is used to create a personal profile of the consumer. This can be accomplished through techniques such as data mining in order to discover the personalized needs of the consumer within specific context. Agent-based technologies can be used to create a personalized digital avatar.

Message Creation

An important component of HLMIS is message creation. These messages should be considered as notifications or alerts that are sent to the consumer via various modalities. These alerts are reminders carefully designed to aid the person to do something essential to live healthy lifestyle. They could also serve as information feedback to the central server to collect data such as calorie intake. Messages are personalized and relevant to each domain.

Interactive Communication With Consumer

In order to deliver the personalized messages created in the previous step, an application-programming interface (API) is needed. The messages are delivered via a web portal, as emails or on Personal Digital Assistant (PDA) and cell phones. HLMIS is also an interactive system that takes user response as well as contextual information at the response time into account to update the user profile through the use of datamining techniques. This will allow the system to adapt to an participant’s needs and context continuously.

Evaluation

The HLMIS can be evaluated just as any other health program. The feedback from the evaluation is used to update the system.

An EXAMPLE OF AN HLMIS

The use of the framework is illustrated by providing an example of an HLMIS currently being developed at our Network Convergence Lab for consumers who wish to achieve and maintain a healthy weight through diet and exercise. The HLMIS consists of five steps. The first step is the data acquisition. The HLMIS can achieve this step through a web portal that has questionnaires that the consumers fill in. The questionnaire is based on domain knowledge that requires consumer data including physical data such as age, weight and height; demographic data such as gender and race. Additionally lifestyle information such as eating and physical activity habits and working hours are covered by the questionnaire. In the next step, this information can be stored in a relational SQL database. Domain knowledge recommends the consumer to follow a five step plan to achieve and maintain a healthy weight: Eat sensibly, exercise daily, reshape eating behavior, keep a food and exercise diary and arrange moral support (Allan, 2005). The data repository can be used to personalize the five steps for the consumer. This can be achieved through a data mining and heuristic engine working in conjunction with the data repository. The outcome is personalized messages that can be in the form of email, newsletter, Short Message Service (SMS), Multi-media Message Service (MMS) or automated phone call. ActiveXpert SMS messaging server facilitates sending, receiving and processing such SMS and e-mail messages (ActiveXperts, 2005). An interface between the system and the consumer is a web portal, PDA or phone. Web portal has personalized space for the consumer that can be accessed through a username and a password. A web portal also provides social support through chat rooms and forums. The context-aware application can also receive input from sensors such as an accelerometer and a heart rate sensor. The accelerometer is a device for measuring acceleration in relation to gravity. A heart rate sensor detects the subject’s (heart) beats per minute. Either or both can be
used to determine the current state of a subject e.g. sitting, standing, walking etc. (Kern, Junker, Lukowicz and Troster, 2003; Siewiorek, Smailagic, Furukawa, Krause, Moraveji, Reiger, Shaffer and Wong, 2003; Tapia, Intille, Lopez and Larson, 2006). This data can be combined with environmental data such as time, location and weather to give a richer picture of the context of the subject’s actions.

Based on the context and communication preferences, the messages are sent to the consumers. The HLMIS allows interactive communication with the participant by allowing the user to change their preferences, respond to messages and even periodically receive contextual information about the participant. An example could be of a consumer frequently attending conferences. Most conferences tend to have a variety of food including rich food. Based on schedule and contextual information such as time and location, the HLMIS sends out a message to a person to recommend certain food choices. Another example could be of a consumer who is very busy in his daily life and hardly finds time to exercise. The role of the HLMIS here is to maximize the use of the free time slots in his schedule to make him physically active. When the consumer is about to reach to his office, there would be a message on his cell phone asking him to park his car far from the office building and walk to the office building. He may also receive an email during his office hours suggesting him some exercises that can be done while sitting on a chair. The HLMIS also incorporates tools for participants that allow users to meet their goals. In our example exercise such tools are an active calorie and that sends messages based on contextual information to remind people to keep track of their food intake and fitness activities.

PRELIMINARY EVALUATION

For a preliminary evaluation, we conducted a pilot study in which we acquired participants’ health data and schedule information and sent them messages during the different times of the day to motivate them to be physically active and calorie conscious. For example, one of the participants was lacking regular physical activity and also required to keep check on her calorie intake. This participant had to work from 9:30 AM to 8:30 PM. We sent her an SMS at around 9:00 AM asking her to park her car little far from her office building. At noon, we emailed her to provide information about the food taken by her so far during the day. Around 2 PM, we sent her an email suggesting some exercises that can be done in an office environment. We received positive feedback from the participants. According to them, the system was effective and made them focus on their health. Some of the messages made them think about different ways to be physically active.

KEY CHALLENGES

We now identify the key challenges and issues in building such a system.

Retention

Maintaining healthy lifestyle or changing behavior is a continuous procedure and it requires people to adopt and use the system continuously. Past preliminary Health Information System (HIS) has resulted in large user churn. The system should be very easy to use and consumers must see the benefits and value. Participant retention is key.

Data Acquisition

Designing an optimal questionnaire to gather required data from the consumer is also challenging. It is sometimes hard to acquire all the required information from the user using a questionnaire. Some of the indicators, such as level of physical activity, social support are hard to measure merely by asking questions. The same amount of social support can mean high social support to one person and low social support to another person. This has recently been pointed out by National Institute of Health (NIH) to be quite challenging (NIH, 2005).

Message Design

Designing messages to be delivered to the consumers is perhaps the most challenging area. For an effective system, it is essential that the content, timing and frequency of the messages are reasonable. The messages need to be motivating rather than annoying and there is a very thin line between them. A large volume of messaging can make participants ignore them because of repetition and a feeling of being nagged by the system. It highly depends on the psyche and personality traits as well as patience level present in an individual. Thus, it is very challenging to understand every individual and create optimal messages for them. The messages should be carefully designed using behavior change theories such as social-cognitive theory, transtheoretical model and relapse prevention model. Another challenge is to design messages such that the length and format of the message is optimized for the communication media, for example small screen size of a cellular phone and the billing options limits the length and frequency of the messages.
Technology

For context aware messaging to work, the participant requires a Global Positioning System (GPS) enabled device to be carried around with them for the duration of the study. Many cellular phones today have the capability to report GPS data to a server such as the HLMIS server. This allows the HLMIS to know the coordinates for a participant at a given time, enabling context aware messaging to take place. Unfortunately, GPS can be inaccurate, up to 10 meters. This is because cellular phones need to have a clear line-of-sight to at least three GPS satellites to report a location accurately. This may not be possible all the time because sometimes the participant can have the phone indoors or in a location that makes it difficult for signals to be received such as a back pocket.

Personalization for each consumer requires detailed datamining and it may also require certain degree of artificial intelligence. This can lead to a very complex system. Emerging technologies such as intelligent agents should be considered to handle such complex systems.

Privacy

An HLMIS is based on the concepts of context awareness and personalization that requires tracking a participant’s location and as well his/her habits. For example, suppose an HLMIS has been developed for smoking cessation and it can track consumer’s smoking behavior with the use of a nicotine sensor and a GPS phone. In this case, there are chances that the data acquired by the system gets compromised somehow and the insurance companies come to know about the consumer’s smoking behavior. A privacy engine that allows or blocks personal, contextual and even schedule information based on certain parameters should be incorporated into the HLMIS.

Evaluation

Understanding the impact of HLMIS on lifestyle is demanding in terms of time and sample size. Change of behavior is a long-term process and hence the evaluation needs to be longitudinal study. Also, because of wide differences of health characteristics among individuals, it is required that the study is done on a very large number of populations. One of the other evaluation challenges is to operationalize the required measurement variables. For example, it is hard to operationalize changes in eating habits. There are other environmental factors that affect on lifestyle such as social influences, which can obscure the measurement process.

CONCLUSION

A healthy lifestyle is a key to disease prevention. The framework presented in this paper describes the steps required to develop a Healthy Lifestyle Management Information System. A digital avatar like a personal life coach that supports a consumer in maintaining his or her health and fitness goals in a cost effective and privacy sensitive way can be created through HLMIS. Further work is required to overcome the challenges associated with the development of an HLMIS.

REFERENCES


