Discovering Personal Behavioral Rules in a Health Management System

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Abstract— **Designing interactive systems that support health management among chronic care patients has become a research interest in the HCI community. These systems are meant to allow patients to act as normal people, without letting illnesses affect their everyday lives. In particular, various diary and logging applications have been developed to allow people to record, monitor and visualize their daily behaviors and the progress of their disease. One critical aspect of personal health management that such systems do not yet sufficiently support is the diversity of health behaviors among individuals. As previous research indicates, individuals vary greatly in how they manage their health and what "works for them" [1–3]. Discovering personal behavioral rules is critical for wellness and for health maintenance. Technologies that encourage and promote personal rule discovery are thus needed. In this paper, we present our ongoing research on developing such a system, and discuss preliminary findings from an initial user study.**

Keywords- health maintenance; self-management; diet; exercise; discovery; personal rules; self-reflection

I. INTRODUCTION

Self-management of health becomes increasingly important, both for the healthy and for people with chronic diseases. While healthy people aim at maintaining their well-being and preventing the onset of ailments [4], chronic care patients strive to minimize the impacts of existing conditions on their personal and professional lives [5–7]. To do so, patients have to control and manage their symptoms. How to manage health conditions becomes a critical issue to address in the design of chronic care management systems.

Many current systems for health management, such as 20/20 BeWell, CareLogger or SiDiary[1], ask users to describe their health-related behaviors in fixed fine-grained categories. These systems also often require very specific quantified information. Entering all this data imposes a great burden on users since it is difficult and tedious to specify behaviors in a detailed itemized manner [9], such as listing all the ingredients in a home-made meal and their exact quantities [1]. In addition, the impacts of health-related behaviors vary greatly between individuals. Studies have shown that what triggers a chronic headache in some people may not impact others at all [2], and that food intake and exercises exert different effects on diabetes patients [1]. In such cases, standardizing treatments and behaviors may not yield an optimal impact. Instead, health management has to consider personal differences in the management of chronic diseases and the response to health problems. We therefore need to design systems that facilitate the *discovery of personal behavioral rules* whose observance prevents disease symptoms from occurring [1], [3], [7]. Such rules may be quite general ("have a snack before going to bed" [7]), very specific (e.g., only eating home-made rather than regular noodles since those raise the blood sugar level more slowly [1]), or even idiosyncratic (e.g., putting the TV on the cartoon channel to fall asleep more easily [10]).

Discovering personal rules is not an easy task [7]. These rules are disguised and embedded in people's everyday activities and can hardly be noticed without carefully reviewing and reflecting the association between one's daily activities and health conditions. Chen [1] found that it may take a few years for people to fully understand how daily behaviors affect their glucose fluctuations, and suggests to design health management systems that facilitate and encourage the personal rule discovery process.

II. HEALTHWATCH

We designed HealthWatch, a system prototype that allows people to manage their health and to discover behavioral rules that "work for them". This system is designed to serve two proposes. Users can enter and track their behaviors and, through reflection on the data entered over time, are enabled to discover their own rules for managing their diseases: what works for them and what does not. In contrast to other chronic care management systems that often require users to enter highly detailed quantified behaviors, e.g. ingredients of meals and their exact quantities, HealthWatch is designed to allow users to enter behavioral data based on their own personal perception, terminology and preference, and thus to reflect more easily on their personal rules that may only work for themselves.

Figure 1 shows the main web interface of the system, deployed specifically to the application domain of diabetes management. The interface supports two main functions:

[1] www.2020bewell.com, www.carelogger.com, http://www.sidiary.org/. Milewski [8] provides an overview of current health maintenance and wellness systems.

PervasiveHealth 2012, May 21-24, San Diego, United States

DOI 10.4108/icst.pervasivehealth.2012.248695

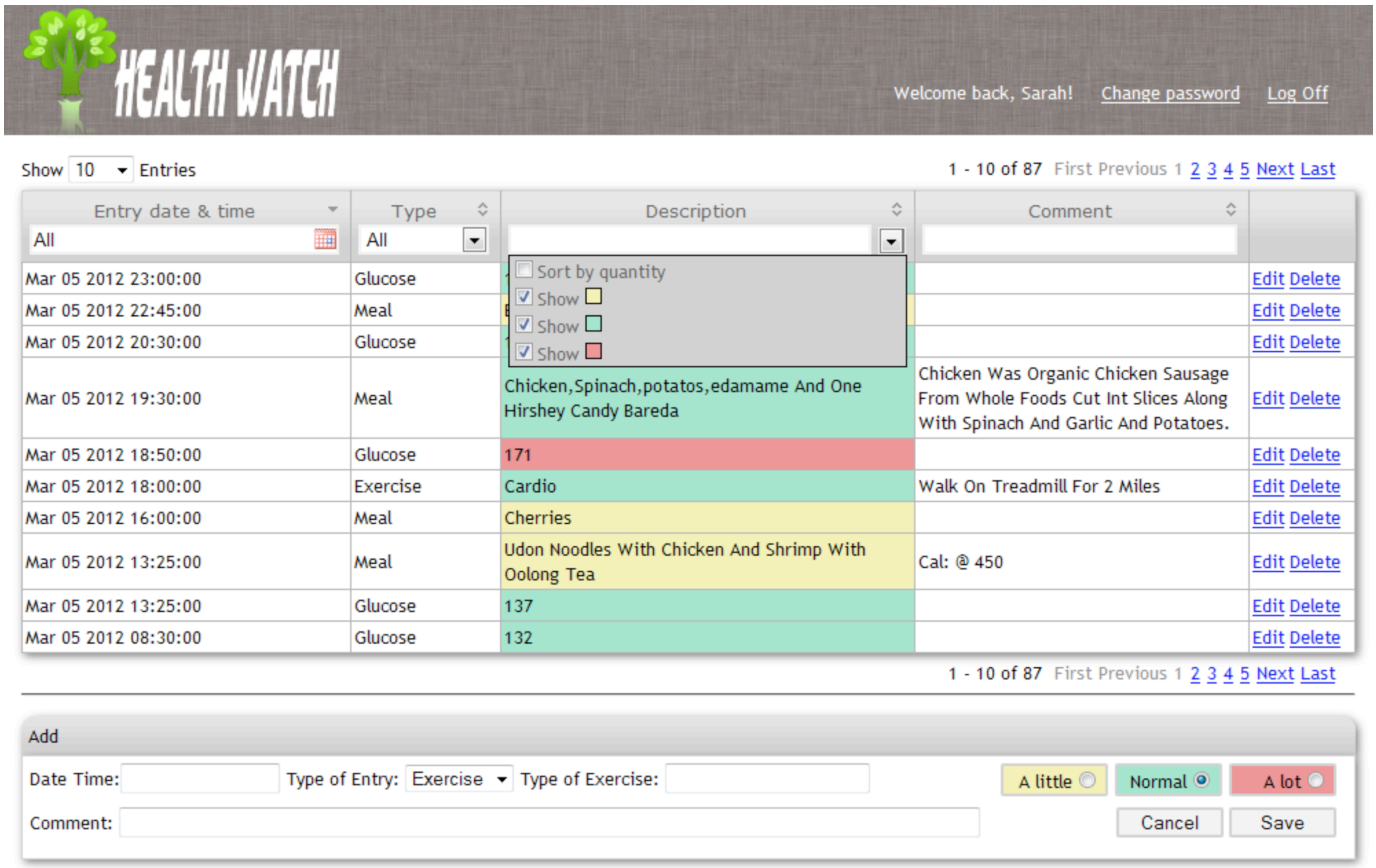

Figure 1. User Interface of HealthWatch

A. *Entry of Health-Related Events*

The lower part of Figure 1 (entitled "Add") shows an entry pane that can be opened or minimized with a mouse click. Users are being asked to report three types of health-related events to the system, preferably right after they occur.

1) Meals: Users are being asked to enter a description of the meals and snacks they had. They are allowed to enter any text into the description field. To nudge them to use a consistent terminology in their entries and to benefit from existing collections of food terms, entry suggestions are being offered from which users may pick one through a mouse click if they wish.[2] The suggestions appear once the user entered 3 characters, and are updated as needed with every subsequent character entry. The following types of suggestions are being offered:

a) Previous entries: The system includes the user's previous entries that textually match the current input best.

b) Entries from USDA Nutrient Database: The system includes entries that were adapted from the USDA National Nutrient Database for Standard Reference [12], containing nutrient information for approximately 8,000 different foods.

Users are also being asked to indicate how much roughly they ate ("a little"; "normal", which is the default; or "a lot"). These notions are associated with the color codes yellow, green and red, respectively. Finally, users can also add comments to their meal entries.

2) Exercises: Users are being asked to record all their physical exercises. They can provide a free textual description, but are again being nudged to use consistent terminology by means of easily-selectable entry suggestions, namely those previously entered exercise descriptions that match their current input best. Users can also indicate whether they exercised "a little" (color-coded in yellow), "normal" (default; green color) or "a lot" (red), and leave a free comment.

3) Glucose level: Users are being asked to measure and enter their glucose levels, e.g. after each meal and exercise. Different from the previous two types, users do not explictly assign a quantity description. However, user measurements are compared with a targeted glucose level range to derive a quantity label and associated color code (yellow, green or red).

Each of the three event entry types is supposed to be accompanied by an indication of the day and time when the event took place. A graphical calendar day picker facilitates this task.

[2] The suggestions are shown below the entry field and are similar in appearance as, e.g., the autocomplete suggestions in Google Search. See [11] for a similar separation of a master database and a personal database for foods.

B. Discovery of Personal Behavioral Rules

The central part of Figure 1 shows the interface that allows users to explore their past entries, to sort them and search in them, and to discover regularities in the entries that give rise to personal behavioral rules. The data in the columns show the dates of the events, their type (meal, exercise or glucose measurement), a description, and optional comments. The event descriptions are color-coded based on the original user input, indicating a normal amount (green), less than normal (yellow) and more than normal (red).

A double triangle indicates that the column is sortable, by clicking on its header. The sorted column would then display an upward or a downward solid triangle, depending on the sorting direction. Users can also restrict the display to certain time periods, types of events, text strings in event descriptions and comments, and amounts (green, yellow and/or red). They can also edit or delete any entry. A more detailed description of HealthWatch and its functionality can be found in [13].

One unique feature of HealthWatch is its support of the discovery of personal behavioral rules. As stated earlier, users are not required to specify the exact details of their meals and exercises. Rather, they are encouraged to use the three categories "a little", "normal" and "a lot", to indicate whether their behaviors are within or beyond their own normal ranges. One of our expectations was that users will reflect on the meaning of "normal" in relation to their health conditions. For example, will one's normal portion of a meal lead to low or high glucose levels? Or will one's normal amount of exercise be sufficient in controlling glucose levels? Doing so allows users to reflect on what works for them, and encourages them to adjust their behaviors to ensure that their "normal" food and exercise amounts are in line with their "normal" glucose levels.

III. Initial Usability Evaluation

We performed an early user evaluation of HealthWatch to gauge the basic usability of the system in a concrete usage scenario, in order to eliminate design and usability flaws. A test with real target users would then follow suit. Early input on usability has been known for long to be a crucial factor in the successful design of software systems [14], and test subjects that are representative for the target user population with respect to the usability questions at hand can provide such input [15].

73 students participated in the study over a period of 10 days. They were asked to regularly record their food intake and their exercises in HealthWatch, and also their pulse rate after each such event (we replaced glucose level tracking by pulse rate measurements since doing the former was not feasible for our healthy population). Participants entered well over 4,300 events into HealthWatch, with a daily average of 2.6 meals, 1.1 exercises, and 2.2 pulse measurements. We removed all entries that were made more than two days after the event, fearing that participants may not recall those events accurately, and also performed some other minor data and participant cleaning. We ended up with 3022 total entries for the analysis. Our test participants exploited the full system functionality for data entry. Among the meal and exercise entries, 19.84% got flagged as "a little", and 12.21% as "a lot" (pointedly, "a little" was predominantly used for food intake, while "a lot" was over-proportionally used for exercising). 26% of entries received a (mostly short) comment.

Participants were asked to complete the System Usability Scale (SUS) [16], a frequently administered and highly reliable 10-item Likert scale gauging participants' satisfaction with system usability. The overall score for HealthWatch was 71, which compares well with the "industry average" of 70.1 reported in [17].

Participants also answered other quantitative and open-ended usability questions. More than 70% prefer to use free text entry rather than selecting from a list. Their stated rationale is often that everyone's meal or exercise is different; therefore a list of general items will not help users record their own meals or exercises accurately. Participants were of two minds on the vague quantity terms *"a little", "normal" and "a lot"*. Half of them thought that the subjectivity associated with these labels was a bad thing. As the interpretation for these terms varies among users, it would create trouble when other users, or health professionals, tried to understand them. The other half felt though that vagueness was good for self-management. They argued that each person is different; therefore it should be left to users to define for themselves what each term means to them.

Our participants replaced glucose measurement by pulse reading and used the system for ten days only, which reduced its effectiveness in detecting non-trivial health changes. Nevertheless, virtually everyone reported various patterns they observed, such as lower pulse in the early morning or slight increase after the consumption of food high in fat or sugar. Most claimed being confident about the correctness of their rules, and half even tried them out. Many participants described detailed reflection processes. For instance, one person noticed that her pulse readings were always much higher after meals even though they were normal at other times. By reflecting on her records, she figured out that the elevated pulse was the result of multitasking while eating, i.e. running to the next class while having a quick lunch. Overall, our study participants were seemingly quite engaged in the experimental task, which heightens their representativeness for the target user population and the external validity of their usability reports.

We received a large number of minor recommendations on how the usability of the system could be improved. The most negative critique from participants was that using a web application is not all that convenient. Many recommended a smartphone version that allows online and offline interaction.

IV. Discussion

The pilot usability evaluation indicated two promising yet challenging directions with regard to the discovery of personal behavioral rules.

First, a majority of our study participants believed that it is easier to track data using our free-text and routine-driven design than entering detailed quantified data. This finding coincides with prior results that documenting one's health-related behaviors is very difficult [5], [7], since these behaviors are embedded in one's everyday routines and can hardly be

measured quantitatively. Forcing users to quantify and standardize the entries is considered challenging when behaviors themselves are personal and thus non-standard. This finding points to the need for the design of less quantitative, but more personal, health management systems.

Second, the concept of designing for self was only partially understood by many study participants, as quite a few mentioned that vague quantity terms that work for themselves might not be understood by others in the same way. It seems that participants are so accustomed to system usage that is standardized across users that they become concerned that their own personal routines may affect others who may need to read their data. This finding suggests that promoting the discovery of "what works for oneself" may conflict with standard health management approaches that have "standard health theory" built in. This new concept and the rationale behind it should therefore be better articulated to users, so that they can best assess the goals and benefits of such designs.

V. Conclusion and Future Work

The initial usability tests of HealthWatch supplied a wealth of information that we currently utilize to improve and enhance the system. The next step will be longer-term studies with diabetes patients, in collaboration with UCI's Center for Diabetes Research and Treatment. Particular emphasis will be put on analyzing the continued usage of HealthWatch over an extended period of time, and the utility of the system in discovering beneficial personal behavioral rules.

In future technical development, we plan to build a smartphone app so that users can conveniently enter events on the go, and to enable them to post behavioral rules that "worked for them" to social networks of patients, so that others can try them out [3]. We also consider a deployment to other health conditions besides diabetes.

Acknowledgment

We would like to thank Sun Young Park and Soyoung Lee for their help in preparing the usability study.

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