Design of Persuasive Technologies for Healthy Sleep Behavior

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ABSTRACT
Getting the sufficient amount of quality sleep is a key aspect of good health along with a healthy diet and regular exercise. Despite its importance, sleep has been considerably underexplored in the area of human-computer interaction. In this proposal, I describe my research in understanding the need to help improve people's sleep habits and creating a persuasive sleep application to help them achieve their sleep-related goals. The persuasive sleep application involves self-monitoring and feedback features to help people be aware of their sleep habits. My dissertation research investigates a design of a self-monitoring system focusing on how information is presented as a persuasive means accounting for user emotions in the context of receiving concerning health news.

Author Keywords Health, wellness, sleep, persuasive technology, self-monitoring, design, information presentation, cognitive dissonance.

ACM Classification Keywords H.5.2 User Interfaces: User-centered design; J.3 Life and Medical Sciences: Medical information systems.

General Terms Design, Human Factors.

INTRODUCTION

Eating a nutritious diet, exercising regularly, and getting adequate sleep are three important activities that people can do to support a healthy lifestyle. The first two have been the focus of many new technologies designed to promote good health. For example, mobile and sensing technologies have been used to encourage healthy eating and exercise habits, track progress over time, and help people set and meet health-related goals [5,11]. However, while sleep has been the subject of rigorous scientific research in the medical community, the human-computer interaction (HCI) and UbiComp communities have placed considerably less attention on ways that technology can support sleep.

Designing technologies to promote healthy sleep behaviors is a worthwhile goal for numerous reasons. Chronic sleep deprivation is common in the developed world, with 28-29% of all young adults reporting only 6.5 hours of sleep each night [2]. Getting the appropriate amount of sleep has been correlated with numerous health benefits, including reduced fatigue and stress. Likewise, when people regularly get less than 6 or 7 or more than 9 hours of sleep per night, there is a correlation with an increase in a number of diseases, including diabetes [9] and heart disease [1]. In addition to one's physical health, there are other important consequences of poor sleep habits. When people do not get enough sleep, their alertness is greatly reduced [2], and they often put themselves at a greater risk of a car accident, with estimates of as many as 36% of all fatal car accidents resulting from driver drowsiness [10]. Finally, a poor night's sleep can affect memory [12,14] and cognitive functioning [6], which can result in poor work performance.

Similar to how technology has been used to improve other aspects of health, there is an interesting research agenda surrounding the exploration of technologies for promoting healthy sleep habits. At the core of technologies for promoting healthy sleep behavior lies sleep tracking, which can bring an individual's awareness to the problem, as can persuasive technologies designed to motivate good behaviors [8]. Sleep monitoring data can be used to help doctors detect a number of sleep disorders, such as insomnia, sleep apnea, or delayed sleep phase syndrome, which often go undiagnosed. At the same time, self-monitoring data out of the normal range may cause anxiety, which is exemplified by a number of panicked users asking for help in health-related message boards. When people encounter information that does not meet their expectation, they are motivated to take action to decrease the psychological discomfort [7]. As Festinger points out in the theory of cognitive dissonance, avoiding discomforting information is easier than changing behavioral or environmental factors that cause the problem [7]. In the context of self-monitoring, this signifies the discontinuation or abandonment of the use of a self-monitoring tool in order to avoid the information. Thus, there is a need to account for emotional aspects when designing a self-monitoring tool focusing on how information is presented to the users in a way not to discourage their self-tracking effort. My dissertation work seeks to help bridge the gap between the need for users' emotional supports when encountering health information and the design of a self-monitoring system for healthy behavior.

In my dissertation work, I intend to design and evaluate technology-based interventions to assist people with obtaining and maintaining healthy sleep habits. The specific research questions I seek to answer include:

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1. How can technologies facilitate long-term self-monitoring of sleep behaviors to improve user awareness?
2. What are the information needs of each group of stakeholders (general public, patients, sleep doctors, sleep researchers) tracking sleep? How do they make sense of and react to the self-monitoring data?
3. How can self-monitoring data be presented as a persuasive means to encourage self-monitoring efforts and healthy sleep behaviors? How might behavior change theories and persuasive strategies be applied in the design of a self-tracking system?
4. Does an increase in awareness of one's sleep habits eventually lead to healthy sleep behavior?

The proposed research agenda presents a balance of user-centered ubiquitous computing research as well as educating and encouraging sustainment of overall healthy sleep habits. The research also has a technology-centered agenda, which seeks ways to build feasible and effective technologies that sense sleep behaviors over a long-term period and integrate sensing solutions into applications for end users, sleep researchers, and clinicians. The research will employ both qualitative and quantitative research methods to evaluate the effectiveness of the different technology approaches over the long-term.

INITIAL FIELD WORK

I, along with other researchers, conducted a literature review and formative studies [4] to uncover opportunities for technologies to support healthy sleep. Interviews with sleep experts (N = 4), a large-scale survey of peoples' attitudes toward sleep-related technologies (N = 230), and interviews with a subset of the survey respondents (N = 16) helped me identify a number of design considerations, challenges, and opportunities for using computing to support healthy sleep behaviors. From this formative study, I learned about *sleep hygiene*, a list of recommendations that helps people maximize their chance of getting a good night's sleep. However, seemingly straightforward recommendations such as "keep a consistent wake time and amount each day, seven days per week" is difficult to follow because sleep hygiene recommendations do not provide concrete and actionable information as to exactly what to do. I also identified that tracking sleep is an important feature for all stakeholder groups. Sleep experts expressed the need to collect sleep data *in situ*; for those with sleep disorders, tracking sleep is helpful for more accurate diagnosis; for those without sleep disorders, tracking sleep may still be helpful to increase their awareness and encourage healthy behavior change. However, most existing products rely on wearable sensing or continuous manual input, which are often uncomfortable and easy to forget, making them unsuitable for long-term sleep tracking. This presents an opportunity to develop unobtrusive solutions that allow users to monitor their sleep schedules without requiring them to wear anything.

PROPOSED RESEARCH

The formative studies led me to devise a multi-phased research plan which includes 1) designing a sensor suite that tracks sleep and evaluating its accuracy, 2) presenting sleep data collected from the sensor suite and creating a feedback loop to increase user awareness, and 3) evaluating the long term effect of in-home sleep monitoring. In the evaluation of complex interventions such as the sleep tracking and coaching tool, having several iterative processes is necessary [3]. During the course of designing the application, focus groups with clinicians and potential user groups will be carried out to receive feedback on the design.

Phase 1: Design & Development of Sleep Tracking Tool

One of the important aspects of this phase is to identify a way to use sensors to reliably create a sleep record. The main criteria for our technology design is to provide an acceptable estimate of a person's sleep schedule over the long term that does not require a wearable device. In addition, the device should not interfere with a person's sleep (e.g., a bright screen, an uncomfortable pillow, *etc.*) and should help users comply with the sleep hygiene recommendations. I propose to experiment with a number of sensors, including pressure sensors, light sensors, microphones, and in-bed accelerometers to find the most appropriate combination that balances accuracy with unobtrusiveness. The automated sleep diary will include timestamps for when the user goes to bed, when the user wakes up, number of awakenings during the night, and the timing and duration of any naps that happen in bed. I have already begun experimenting with different sensing technologies to test the feasibility of this study. The current prototype uses a pressure sensor between the mattress and box springs. The sensor is triggered whenever the user puts at least 100 lbs of pressure on the bed, and when the 100 lbs of pressure is removed, which provides a close approximation for the time the participant is in bed. The pressure sensor downloads the data to a Chumby Insignia Infocast, which can upload the data directly to a central server and function as both an alarm clock and an interface for reviewing sleep data. Using the pressure sensor to approximate sleep hours comes with limitations such as false positive detection when people are doing other activities in bed. However, the sleep experts noted that precise sleep measurements were not necessarily needed to have a meaningful picture of sleep behaviors and trends. For this reason, I believe that a reasonable compromise can be made between accuracy of sleep data and unobtrusiveness of sensing. I will test the accuracy of this prototype by comparing it with an actigraph device—a wrist-worn sensor that is currently considered the gold standard in sleep research, manual sleep diary, and other commercial sleep tracking products such as ZEO.

Phase 2: UI Components

The second technology component is the design and development of the interface for presenting sleep data and helping people set and keep appropriate sleep and wake time goals. User-centered design process and iterative prototyping will be employed to determine the appropriate interface and assess its usability. I plan to consult with our collaborators at the University of Washington Sleep Center to ensure that the device coaches users on sleep hygiene techniques and helps set goals that comply with the sleep medicine community's recommendations.

The Infocast device could show individuals' sleep trend over time and highlight any abnormal behavior patterns to increase people's awareness (consciousness raising) of their own sleep patterns. It is important for people to realize the benefits that they would get if they were to make the behavior change. Showing the benefits of good night's sleep such as an increase in one's subjective feeling (e.g., happiness) or a decrease in the risk of getting diabetes might help people commit to a long-term behavior change. To minimize burden on the user side, these applications should be integrated into a technology that people might already be using such as an alarm clock or a mobile phone. For those who have strong motivation to change their sleep habits, more proactive persuasive strategies such as stimulus control or sleep restriction techniques may be employed. For example, when bedtime nears, ambient reminders (e.g., dimming of the lights) can be sent or the TV might be automatically turned off to help people get ready for sleep.

When presenting sleep data, the system provides summary of feedback to show how far or close the user's current state is to the goal state. This can be done through visualizing user's current sleep data with his/her goals being overlaid. If the user does not make progress in achieving the goal, the system may provide more information on what things can be improved, and how other people in the same population are doing. It is important for the sleep application to track sleep along with other sleep-related factors (e.g., subjective sleep quality) that could have been impacted by the sleep behavior change. Any positive outcomes (e.g., successfully achieving or maintaining the goals, experiencing an increase in subjective sleep quality, etc.) should be highlighted to help users realize the benefits of keeping the healthy sleep behaviors which would lead to higher goal commitment. However, more care should be given when providing less positive outcomes (e.g., not having a quality sleep and therefore having a weary morning), which could make people feel helpless and thus lower their self-efficacy. Medical literature on 'communicating bad news' suggests that it is important for the deliverer (i.e., medical professional) to gauge *how much* information a patient wants to know, and *when* he/she wants to hear in order to effectively communicate the bad news and its implications. Likewise, I believe that a self-monitoring tool can be designed to deliver information in a more effective manner accounting for when and how much information to show so that people can meaningfully reflect on their data. Figuring out the best time to share less positive information (e.g., one did not have a good night's sleep, one's sleep score is below the average, etc.) is an interesting and important question; depending on when and how people receive information, they may use the information to be motivated for healthy behavior change instead of feeling helpless.

Figure 1 shows two interface mockups as examples, but I will need to further iterate on the design.

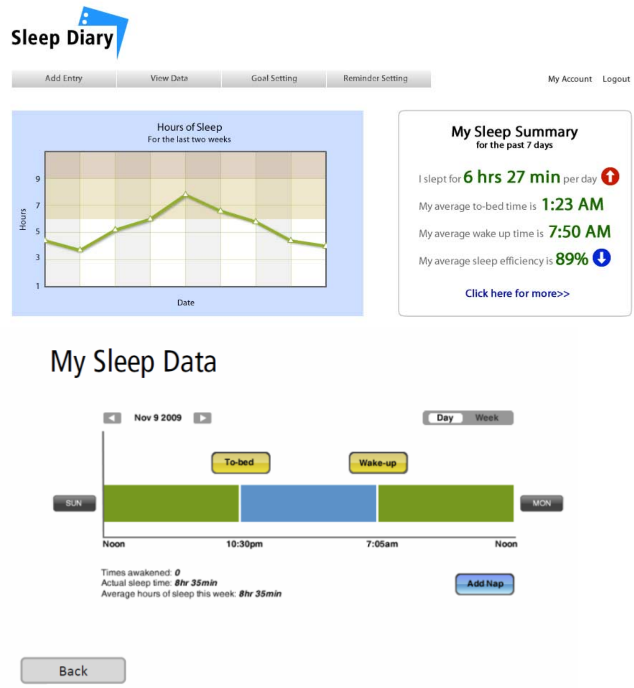

Figure 1: Mockups of potential interface designs for sleep coaching tool showing interfaces for viewing long-term sleep data and editing a day's sleep journal.

Phase 3: Controlled Study and Data Analysis

Once I have designed and developed an acceptable long-term sensing solution, the system needs to be evaluated on its effectiveness in promoting healthy sleep behaviors. Thus, I plan to run a study of the effectiveness of the tool in tracking sleep and encouraging people to meet their goals. The design of our study will be a 10-week, A-B-A study, where the first two weeks consist of participants using the device without the capability of viewing their data or the coaching features enabled, the next six weeks consist of an intervention phase, and then the final two weeks are a return to the original state. The basic protocol for the study will be to have the research team meets participants who volunteer to take part in the study in their homes to install the sensing device, explain the study, and conduct initial interviews.

The device will collect sleep and wake times for the first two weeks, which will serve as a baseline. From the baseline data, the system will help participants set up ideal sleep and wake time goals according to standard Cognitive Behavioral Therapy techniques for insomnia [13]. After the two-week baseline period, viewing sleep data over time and sleep coaching features will be available. Participants will use the system for 6 weeks as an intervention phase. Finally, after the 6-week intervention phase, the sleep device will be returned to its initial pre-intervention state, but still collect data about sleep behaviors. The purpose of this phase is to see whether the sleep device had a lasting impact on their sleep habits, or if the habits go back to normal after the coaching is taken away. The sleep device will log all interactions and button presses throughout the three phases to collect more detailed usage information such as frequency of use and most accessed features.

Throughout the study, I will also conduct a series of interviews and surveys to collect qualitative data and user feedback about the device. Before the start of the study, I will provide participants with a survey that asks about their current sleep habits, have them estimate their typical sleep and wake times, and probe their opinions on the use of technology for healthy sleep behaviors. After each phase, I will conduct a short interview to get interim feedback on the sleep device and their self-reported experiences of changes with their sleep habits. The surveys and interviews will bring us a deeper understanding of study participants' conception of their sleep patterns and how far or close it is to an actual data collected from the sleep tracking device.

For participant recruitment, I will recruit 10 participants who currently sleep alone and have goals of improving their sleep habits. I will aim to recruit 5 males and 5 females with 3–4 people from each of the following age groups: 18-30, 31-45, 45 and older. Our main methods of recruitment will be through publicly posted flyers and electronic postings to classified ads, such as Craigslist.org. I will also use contacts at the University of Washington Sleep Center for assistance with recruiting. Participants will be compensated $10 for each week for their participation, for a total of $100 per participant.

Following the completion of data collection, qualitative data and quantitative data will be analyzed. For the quantitative data, I will compare the consistency of the sleep and wake times each day and the difference in minutes from their target sleep and wake times for the three phases of the study. For the qualitative data, I will transcribe all interviews and conduct a coding of the data to identify themes using affinity analysis. Then I will start to extract common themes from the two and develop a set of design guidelines that other designers can use when creating health-based self-monitoring systems.

CONTRIBUTIONS

The proposed research, if successfully executed, has the potential to enhance the sleep behavior of users of the system, and to help sleep doctors and researchers gather sleep-related measures more effectively *in situ*. My previous formative work with target users and sleep experts has informed design requirements for technologies in this field. This research will bring into focus the domain of sleep as a new area for computing research. The design and evaluation of new ubiquitous computing technologies for sleep will further the knowledge of how technology can be designed for long-term health tracking and behavior change. Findings regarding how to convey concerning health news via a self-tracking system will be applicable to the design of other types of self-tracking tools beyond the sleep domain.

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