Opportunities for Computing to Support Healthy Sleep Behavior

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Abstract
Getting the right amount of quality sleep is one of the key aspects of good health, along with a healthy diet and regular exercise. We conducted a literature review and formative study aimed at uncovering the opportunities for technology to support healthy sleep behaviors. We present the results of interviews with sleep experts, a large survey, and interviews with potential users that indicate what people would find practical and useful for sleep. We identified a number of functional and non-functional requirements for technology for sleep. We explored three possible technology ideas for healthy sleep behaviors: a sleep tracking tool, game to promote sleep, and sleep condition assessment tool.

Keywords
Sleep, health, technology, qualitative study, design

ACM Classification Keywords
H5.m. Information interfaces and presentation (*e.g.*, HCI): Miscellaneous.

General Terms
Design

Introduction

Eating a nutritious diet, exercising regularly, and getting the right amount of sleep are the three major activities people can do to ensure a healthy lifestyle. The first two activities have recently become the focus of many new computing technologies designed to promote good health. These technologies encourage good habits, help users track progress over time, and help users set and meet their health goals. Despite the numerous benefits of a good night's sleep, however, the HCI community has spent considerably less attention on ways that computing can support sleep.

Designing for the promotion of healthy sleep behaviors is both a worthwhile goal for many reasons. The health-related benefits of the right amount of sleep include reduced fatigue and stress, and a decrease in the risk of a number of diseases. When people regularly get less than 6 or 7 hours of sleep or more than 9, there is an increased risk for a number of diseases, including diabetes [4] and heart disease [2].

Similarly to how others have used technology to improve other aspects of health, we believe there is an opportunity for technology designers to make an impact in creating healthier lifestyles surrounding sleep. Tracking regular sleep habits can help bring awareness to the problem, as can persuasive technologies designed to motivate good behavior. There are also a number of sleep disorders, such as sleep apnea, insomnia, or delayed sleep phase syndrome, which often go undiagnosed, and which technology could help sleep doctors detect and diagnose.

In this work, we aimed to explore the opportunities for computing technologies to assist individuals with obtaining and maintaining good sleep habits and reducing bad sleep habits. We conducted interviews with domain experts, a large-scale survey of individuals on their attitudes toward technology for sleep, and individual interviews with potential users to uncover design guidelines and help define a space for technology in this domain. Based on the findings from these works, we discuss design ideas which would meet the needs of users hoping to improve their sleep habits, including an improved sleep tracking tool, a role-playing game to promote sleep, and a sleep condition assessment tool.

The remainder of this paper is organized as follows. First, we present a number of existing research projects and commercial products relating to sleep. Next, we describe the methods used for data gathering, followed by results. We then provide a discussion with design requirements and three ideas for technologies, and conclude with plans for future work.

Related Work

We conducted a survey of existing research projects and commercial products that used technologies to support sleep. We identified three main categories of technologies. The first category includes technologies designed for the purpose of tracking aspects of sleep. An actigraphy device designed in wristwatch type is broadly used in the clinical settings to evaluate basic sleep patterns, such as the amount of hours in sleep, sleep quality, and number of awakenings [1]. Some other sleep tracking products require a wearable sensor on a headband [11] while others involve manual input through mobile phones [8] or online journals [5]. The second category of sleep technologies we discovered is technologies that help a person either wake up in the

morning or go to sleep at night. This category includes daylight simulators [3] used for the bright light therapy and white noise machines [10] that play soothing sounds as well as the most common tool—various types of an alarm clock. Lastly, many research-based applications focus on social aspects of sleep, including sharing sleep status within a social network [6,9].

Despite a number of existing applications, however, we noticed several key technologies that seemed to be missing. One was a fully automated way of sensing sleep behaviors in a simple, non-wearable, and unobtrusive manner. Second, we did not come across persuasive technologies designed to support good sleep habits. Finally, there were not many comprehensive studies in the literature that fully evaluated the use of the different technologies we reviewed for their overall usability and effectiveness.

Recommendations for Good Sleep Hygiene
• Do not go to bed until you feel sleepy • Do not use your bed for anything other than sleep or sexual activity (e.g., reading, watching television) • Do not eat or exercise within three hours of going to bed • Do not drink caffeinated beverages after 2 p.m. • Exercise during the day, preferably in the morning hours • Do not nap • If you do not fall asleep within 30 minutes of going to bed, get out of bed and engage in a quiet activity (e.g., reading, watching TV, etc.) • Ensure that the conditions in your room are optimal for sleep: dark, quiet, and slightly cool

Table 1. Recommendations for Good Sleep Hygiene for how people can ensure the best sleep possible. Gathered from the interviews with sleep experts at a university-affiliated sleep disorder center.

Study Design

We used a mixed-method approach to data gathering alongside a user-centered design process. Our first step was to interview domain experts at the sleep disorders center affiliated with our university. During the contextual interview, we asked questions about recommendations for good sleep hygiene (Table 1), different sleep disorders, treatments for common sleep problems, and technology currently in use.

Based on our literature review and interviews with sleep domain experts, we developed an online survey that would help to define the requirements for technology to support sleep focused on the acceptability of different types of sleep technology. The data gathering consisted of an online survey of 230 participants (Male = 41.7%, Female = 51.8%). In order to obtain a deeper understanding of the potential user group, we conducted semi-structured interviews with 16 individuals whom we selected from the survey participants based on the diversity of demographics, and experience with different sleep disorders. Interviews were conducted either in person or over the phone and all were audio recorded and transcribed. Each interview participant was compensated with a $15 Amazon.com gift card. We focused on identifying participants' sleep routines, what helps and prevents them from sleeping, attitudes toward technology for sleep, and if applicable, any experience with a sleep problem or disorder.

Results

In this section, we report the results we organized in the themes which emerged from the interviews and survey data analysis.

User Goals with Regard to Sleep

Many participants had goals of maintaining the recommendations for good sleep hygiene listed above on a regular basis, or a desire to be educated on good sleep habits. This included improving the consistency of the hours they went to sleep by going to bed and waking up at the same time every day, or becoming a "morning person" to synchronize with others around them. Other participants were interested in breaking bad habits with regard to sleep, such as a dependence on sleep medications, or letting work or homework interfere with their sleep habits. People who did not have any particular problems to address were just interested in better understanding their behaviors and reflecting upon their habits as an overall measure of their health. Some were interested in tracking the content and quality of their dreams.

Reasons why Maintaining Good Sleep Habits is Difficult
Although many participants had goals with regard to improving their sleep habits, they had numerous responses on why it is difficult to achieve them. Some reasons were beyond their control, such as those dealing with a medical condition or sleep disorder. Some participants struggled to maintain good habits due to lifestyles or family situations. Reasons for staying up late includes too much work, school stresses, family members or pets keeping them up or preventing restful sleep. A number of study participants noted that environmental conditions such as light, noise, or room temperature often prevented them from a restful sleep. The final reasons we uncovered were psychological. Some people were kept from a restful sleep by worries, fears, or bad dreams.

Technology Feature	Not at all likely (%)	Minimally likely (%)	Moderately likely (%)	Very likely (%)	Extremely likely (%)
Record data automatically without my help	4.3	10.1	17.3	29.5	38.8
Report the quality of sleep obtained	4.3	10.6	27.7	29.1	28.4
Recommend optimal conditions for	4.9	12.7	27.5	28.9	26.1
Track and review sleep data over	7.1	12.1	22.9	29.3	28.6
Track dreams	6.5	13.7	25.2	23.7	30.9
Display basic sleep data over time	8.6	15.7	24.3	25.7	25.7
Shares data with another device	12.9	15.0	23.6	29.3	19.3
Portable or mobile	10.6	17.7	23.4	24.8	23.4
Record sleep durations and	15.7	15.7	29.3	22.1	17.1
Record time to fall asleep or get out	12.8	18.4	34.0	19.1	15.6
Record data based on my regular	14.2	24.1	29.8	17.7	14.2
Record frequency of snooze button	26.8	19.0	16.2	21.1	16.9
Share sleep data with select people	29.1	26.2	17.0	12.1	15.6

Interested in Using Technology?	
Yes	20.1%
Maybe	41.5%
No	38.5%

Current Technology	
SleepPhase [7]	3
Social Networking	2
Phone-based App	1
Web-based App	2
Sleep Apnea Tool	7
White-noise	22
Other Technology	35
No Technologies	188

Table 2. Technology interest and current use. Left table shows the percentage of participants who were likely to use a technology with different features who responded "Yes" or "Maybe" on the "Interested in Using Technology" question. Top right shows the percentage of people who are interested in using a technology for sleep. Bottom right shows technologies currently being used by study participants (by number of participants).

Attitudes toward Technology for Sleep
We asked survey and interview participants about their attitudes toward existing technologies for sleep and what features they might like to see. Nearly two thirds of our study participants answered "Yes" or "Maybe" to the question on whether they would be interested in using a new technology to help their sleep (Table 2, top right). Of those who responded "Yes" or "Maybe," we asked them how likely they would be to use a number of features, such as tracking sleep over time, automatic recording, etc. (Table 2, left). The most popular features were displaying basic sleep data over time, recording data automatically, and tracking the frequency, quality, and content of dreams. Not many people in our study actually used a technology to help with sleep, other than an alarm clock or cell phone alarm clock (Table 2, bottom right). When asked about their attitudes toward some of the different commercially available projects, participants had mixed reactions. Many like the idea of the SleepPhase [7] system, but were resistant to the thought of having to wear a special device every night. A number of interview participants like the idea of something that could be integrated into an alarm clock or cell phone, so they would not have to buy a separate device.

Discussion
In this section, we outline design requirements and present three ideas for new technology designs that would support healthy sleep behavior.

Functional Requirements
• Customizable alarm sounds and volume • "Snooze" button capability • Dawn simulation • Tracking of sleep duration and times • Audio screening of sleep or snoring • Detection of sleep phases • White noise generation • Record content of dreams • Make suggestions for good sleep schedules • Make suggestions and track progress toward goals • Support sleep expert recommendations
Non-Functional Requirements
• Customizable appearance • Cannot be too bright • Works with existing technology (e.g., cell phone) • Cost effective • Cannot take too much time • Is not uncomfortable nor disrupts sleep • Automatically record sleep without user input • Simple and unobtrusive

Table 3. Functional and non-functional requirements determined based on our study

Design Requirements

Using the data from our study, we determined a number of design requirements for designers working in this space (Table 3). This primarily came from the survey data on the acceptability of different sleep features and attitudes toward sleep technologies. Many participants stressed that devices needed to be as simple, unobtrusive, and automated as possible due to tiredness at sleep and wake times making them less willing to deal with poorly designed user interfaces. Several recounted discarding poorly designed alarm clocks out of frustration. There were also a number of features that users wanted to see implemented into a well designed technology, including tracking sleep or dreams over time, screening for snoring, daylight simulation, coaching, and setting regular routines.

Technology Design Ideas

Based on the results from our data gathering and the requirements outlined above, we conducted a design session where researchers brainstormed different technology ideas that would support healthy sleep behaviors. In a subsequent meeting, researchers as a group critiqued each design for its feasibility, originality, and potential for meeting the needs of the users we studied. The more promising ideas were refined and are presented below.

UNOBTRUSIVE, AUTOMATIC SLEEP MONITORING CLOCK

One of the key features requested by both the domain experts and individuals with sleep problems was the ability to unobtrusively estimate behaviors over time and make recommendations for improvement. Most commercial products we reviewed relied on wearable sensors or continuous manual input which many of our study participants stated was an undesirable feature. In addition, the experts we talked to stated that precise sleep measurements were not necessarily needed to have an accurate picture of sleep behaviors. Thus, we propose a technology that could use a simple weight sensor to unobtrusively estimate how much time was spent in bed each night and give recommendations on the ideal bedtimes and how far the user is from that goal (Figure1, left). Though a weight sensor is not perfect, it could represent a compromise between accuracy and unobtrusiveness.

ROLE-PLAYING GAME TO PROMOTE SLEEP

Games have recently been a form of persuasive technology to encourage healthy behaviors. A number of adventure games use the metaphor of sleeping within the game that we could take advantage of in design. For example, role playing games, such as Final Fantasy series or Dungeons and Dragons, use the notion of resting for healing the character's wounds between battles. In many of these games, this involves staying at an inn or a campsite. We propose a game that could be linked to a real-life sleep sensor, and the player's character in the game only heals when the player actually sleeps himself (Figure1, middle). Because resting is essential to making progress in the game, and many of these games have compelling stories, we believe this may encourage players—especially children and younger adults—to get regular sleep more often. New stories and adventures could be created to help keep the game interesting and sustain behavior over a longer period of time. Because of potential "cheating," thresholds may be needed to limit the amount of sleep to a reasonable amount.

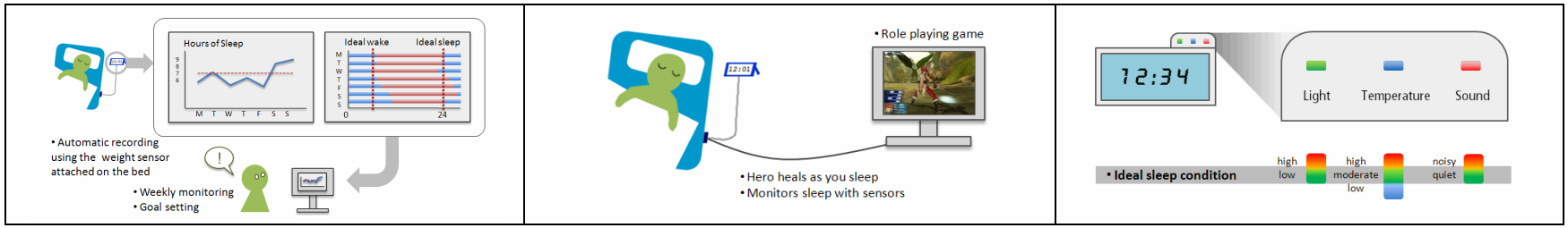

Figure 1. Technology design ideas: (Left) Unobtrusive sleep monitoring tool uses a weight sensor under the bed to estimate sleep times and wake times. (Middle) Role playing game where the player's character only heals when the player actually rests in real life. (Right) To help support a good sleep environment, this tool uses sensors to measure the room temperature, light, and sound and changes light colors as a simple indication if one or more conditions is not ideal.

Sleep Condition Assessment Tool

From our interviews with the sleep experts and our review of the literature, there are a number of recommendations for how to make a room suitable for sleep. Three of these recommendations are things that can be sensed with simple sensors: sound, light, and temperature. We propose a tool that has a light sensor, microphone, and temperature sensor, which can be placed nearby the bed that measures and indicates the suitability of the room for sleep (Figure1, right). Green indicates that conditions are optimal, whereas red or blue indicates that adjustments should be made.

Conclusion and Future Work

The research presented in this paper sought to uncover the ways that technology can help people set and maintain healthy sleep behaviors. We are currently building prototypes of the first design idea we described in the discussion section and planning to deploy them with real users to determine their effectiveness. We will first compare the prototype with an actigraphy device to determine the reliability of the system and then will add persuasive coaching functions to support healthy sleep habits. In closing, we believe that there is much potential for future technology designers to affect this relatively underexplored area that can have a big impact on the lives of a large number of people.

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