

ShutEye: Encouraging Awareness of Healthy Sleep Recommendations with a Mobile, Peripheral Display

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ABSTRACT

Sleep is a basic physiological process essential for good health. However, 40 million people in the U.S. are diagnosed with sleep disorders, with many more undiagnosed. To help address this problem, we developed an application, ShutEye, which provides a peripheral display on the wallpaper of the user's mobile phone to promote awareness about recommended activities that promote good sleep quality. Based on preferences about the user's desired bedtime and activities—for example, consuming caffeine or performing vigorous exercise—ShutEye displays guidance about when engaging in those activities is likely to affect sleep without requiring any explicit interaction from the user. In this paper, we describe ShutEye and results from a four-week field study with 12 participants. Results indicate that a simple, recommendation-based peripheral display can be a very low-effort but still effective method for improving awareness of healthy sleep habits. We also provide recommendations about designing peripheral displays and extend insights for designing health-based mobile applications.

Author Keywords

Peripheral display; sleep; sleep hygiene; mobile phone; health; wellbeing; mindfulness;

ACM Classification Keywords

H5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous;

INTRODUCTION

A sufficient amount of quality sleep is essential for maintaining a healthy lifestyle. Sleep plays a critical role in learning and memory, metabolism and weight control, safety, mood, cardiovascular health, and disease [5]. A growing body of scientific evidence correlates insufficient sleep with

serious health issues, ranging from an increased likelihood of catching the common cold [5] to an increased risk for diabetes [29] and heart disease [3]. Beyond physical effects, sleep disorders are the third factor to overall unhappiness after clinical depression and chronic pain [8]. Despite this evidence, many people still do not get enough quality sleep [15]. In the National Sleep Foundation “Sleep in America Poll” conducted in 2009, Americans report an average of 6.7 hours of sleep per night, with sleep researchers recommending at least eight¹. In addition, according to the National Institutes of Health², at least 40 million people in the U.S. are diagnosed with sleep disorders, with many others not yet diagnosed.

Clinicians often recommend that patients who complain of sleep problems should first work to improve their sleep habits, or *sleep hygiene*. Sleep hygiene is the term sleep experts use to refer to the practices that are believed to promote good quality sleep [30]. Examples of these recommendations include having a regular sleep-wake cycle, avoiding caffeine later in the day, and ensuring that the sleep environment is cool, quiet and dark. Good sleep hygiene is a central part of cognitive-behavioral therapy to treat insomnia [9] and is now often the first method sleep clinicians suggest when patients complain of poor sleep quality [28]. When these suggestions are implemented, people can often address many sleep problems without the use of medication, therapy, or surgery. However, prior research has also shown that even individuals with *knowledge* about good sleep hygiene may actually have poor sleep hygiene *practices* if they fail to remain aware of it [19].

Thus, to help promote awareness about activities that contribute to healthy sleep habits, we developed a mobile phone application called *ShutEye*. ShutEye uses a glanceable peripheral display on the phone's wallpaper to provide real-time sleep hygiene recommendations from the sleep literature about common activities that are known to impact sleep relative to bed and wake times. ShutEye's display reflects when activities such as consuming caffeine or en-

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¹ National Sleep Foundation. www.sleepfoundation.org

² National Institutes of Health.

www.ninds.nih.gov/disorders/brain_basics/understanding_sleep.htm

gaging in vigorous exercise are likely to impact a user's sleep. For example, the user can quickly glance at her phone's screen to determine if it is currently advisable to have a cup of coffee. The recommendations are relevant to her preset sleep and wake time goals. Because the display is on her mobile phone, the user is gently reminded of sleep hygiene recommendations throughout the day.

Prior mobile, peripheral displays, such as the UbiFit Garden display for visualizing physical activity [7] or UbiGreen for reflecting a user's green transit behavior, required the user to wear tracking devices or journal their activities, which places a high burden on the user. ShutEye does not require the user to enter any information or otherwise interact with the system to record data. It simply reflects recommendations relative to the current time and the user's preset sleep and wake goals. This encourages awareness about sleep recommendations without the burden of journaling or the resource-intensiveness of automatic sensing.

To investigate ShutEye's impact on awareness and minimization of user burden, we conducted a 4-week qualitative field study with 12 participants. This work has two primary contributions. First, our application uses a novel recommendation-based peripheral display in a new application space of promoting healthy sleep habits. Second, our results show that ShutEye encouraged awareness of healthy sleep recommendations and emphasized the importance of a consistent sleep schedule without the user burden associated with journaling or the need for complicated activity detection algorithms and sensing. We also provide general considerations for peripheral displays and health technologies.

BACKGROUND AND RELATED WORK

In this section, we discuss the background of sleep hygiene and show how ShutEye draws from and contributes to research in peripheral displays, awareness, and technologies designed for sleep health.

Sleep Hygiene

The term "hygiene" is defined by Merriam-Webster as "conditions or practices conducive to health." Similar to how the practices of dental hygiene, such as brushing and flossing one's teeth, are known to encourage good dental health [1], *sleep hygiene* includes a set of habits and practices that are known to promote healthy sleep. Kleitman first discussed sleep hygiene nearly 50 years ago [18], and since then, it has been used to treat insomnia and excessive sleepiness. Sleep hygiene is influenced by four categories, which we describe next [30].

The *homeostatic drive for sleep* refers to activities that promote the individual's intrinsic physiology to facilitate sleep. These activities include avoiding naps, getting regular exercise, taking hot baths, and having a pre-sleep hot drink. *Entrainment of circadian factors* help create a regular sleep-wake cycle. They include trying to maintain regular sleep and wake times, getting exposure to sunlight during the day, and avoiding bright light in the evening. Circadian factors also include *zeitgebers* [26], which are external cues

that help synchronize one's internal circadian clock, such as the sunset time, meal time, or when work days begin and end. *Drug effects* refer to those with harmful effects on sleep quality. The literature focuses on the effects of alcohol, nicotine, and caffeine. *Arousal in a sleep setting* focuses on ensuring the bedroom is free from disruptions, such as noise, light, temperature, motion, and poor air quality.

Our goal with ShutEye is to improve awareness about common activities that are known to impact sleep depending on *when* individuals engage in them relative to their desired sleep and wake times. Thus, we focused on recommendations for the homeostatic drive for sleep, circadian factors, and drug effects, since the arousal in a sleep setting category did not relate to time-based recommendations they were excluded. These recommendations are represented in ShutEye relative to the user's desired sleep and wake times.

Peripheral Displays and Awareness

According to Matthews et al. Activity Theory definition, peripheral displays are tools that support an activity at the operation level rather than the action level [23]. They further clarify this definition as displays that are not intended to interrupt the user's primary task, such as the case with interruption displays. Because they are used at the operation level, successful peripheral displays require low cognitive effort and therefore must be glanceable allowing quick information processing. Our goal with ShutEye was to provide recommendations that can be regularly referenced with minimal cognitive load or user burden. Thus, the information is there when needed, but easily ignorable when not. Peripheral displays have been used in a wide variety of contexts from viewing large quantities of information peripherally [13,25] to awareness of the environmental implications of a person's actions [10]. The use of peripheral displays to show health information has also been recommended as a strategy for promoting behavior change [7] due to its ability to promote awareness of activities. Our work with ShutEye builds upon previous findings to explore how peripheral displays can promote mindfulness in the domain of sleep recommendations.

Promoting Healthy Sleep through Technology

Some research and commercial applications have been specifically designed to promote sleep. Choe et al. provide a literature review and a framework for understanding the design dimensions of technologies for promoting sleep [4]. Examples include BuddyClock [16], a social application that enables users to share sleeping status within social networks to increase awareness of habits and use social structure to support sleep and the Wellness Diary [24], which allows users to log sleep information as part of overall wellness. Several commercial applications, including FitBit³, SleepCycle⁴, and ZEO⁵, track information on the amount of hours slept and different sleep states. These ap-

³ Fitbit, Inc. <http://www.fitbit.com/>

⁴ Sleep Cycle, <http://mdlabs.se/sleepcycle/index.html>

⁵ Zeo Inc. <http://www.myzeo.com/>

plications focus on tracking sleep information for awareness or preliminary diagnosis of sleep issues. ShutEye also focuses on sleep, but takes a different approach by encouraging the user to be aware of healthy sleep habits without requiring manual tracking or wearable sensors.

Mobile Health and Wellbeing

Mobile systems for health have used manual input from users, automatic input from sensors, or some combination of the two. Many systems that aim to encourage physical activity use sensors such as pedometers [6,20], accelerometers [27], biometric sensors [27], location data [2], or custom sensor platforms [7]. Most of these systems also require or enable the user to augment the sensing system with manual journaling of activities. Others rely entirely on users manually journaling, especially with difficult-to-detect activities such as food intake [12] or general wellbeing [24]. Data capture, either through wearable sensors or manually, can be burdensome on users due to the time and effort involved or through discomfort from wearing sensors.

A number of mobile health applications have explored creative ways of displaying information to help users become more aware of health-related activities. For example, Fish'n'Steps [20] represents users' step count information as a fish in a virtual aquarium. Shakra [2] and Houston [6] display physical activity data as a pictorial representation or a bar chart in comparison to a group of the user's peers and toward a specific goal. Applications that provide just-in-time visualizations to help users change their habits are also closely related to our work. UbiFit uses a pictorial representation of the user's physical activity as a personal peripheral display on her mobile phone [7]. TripleBeat provides a peripheral display of the user's current heart rate compared to their target for their current activity [27]. These applications provide real-time information while users are in a position to change their behavior, such as getting more physical activity, relieving stress, or increasing their workout intensity.

ShutEye differs from these systems in that it is designed to provide many of the benefits of mobile health applications through awareness of activities that impact sleep, but does not rely on data capture, thus minimizing the user's burden of using the application. We believe that for this application space, there is a trade off between a highly accurate but high burden data capture and visualization and a low burden system that provides less customized recommendations. Because others have explored the higher burden, highly accurate side of this trade off in other domains, with ShutEye, we aimed to explore whether a low burden, but reduced accuracy approach could still be effective in improving people's awareness.

DESIGN OF SHUTEYE

ShutEye uses a glanceable peripheral display to communicate sleep recommendations, which runs as the active wallpaper and lock screen image of the user's mobile phone. It shows a 24-hour window with up to nine horizontal bars of different colors resembling a timeline (Figure 1, left). Each bar represents an activity that is known to affect sleep, either positively or negatively: consuming caffeine, napping, exercising, eating heavy meals, consuming alcohol, nicotine use, and relaxing, as well as two custom activities that the user can specify. By default, the display shows caffeine, napping, exercising, meals, alcohol, and relaxing. An icon on each bar at the right of the screen reminds the user of what the bar represents. At any time, the user can change which activities are displayed, create custom activities, or hide the activity icons.

We implemented ShutEye on the Android-based Nexus One phone, although it can run on any Android device. The Nexus One has five background screens: the primary screen, or 'home screen,' plus two screens to the right and two to the left, which are accessed by swiping in either direction. ShutEye's 24-hour timeline is spread across the five screens; the current time is always on the home screen. A

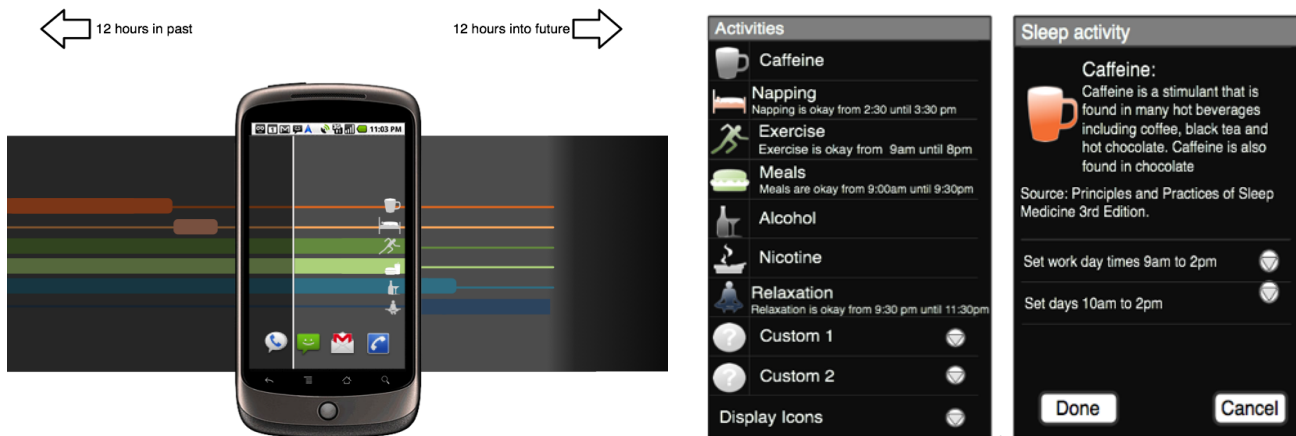


Figure 1: ShutEye's peripheral wallpaper display (left) consists of a timeline with horizontal bars representing activities that impact sleep. Thick bars indicate when an activity is unlikely to negatively affect or likely to improve sleep; thin bars represent when an activity is not recommended. The vertical bar updates automatically and indicates the current time. In the interactive application, colored icons represent activities (center), where users can read about the recommendation and customize its times (right).

vertical line on the home screen cuts through the horizontal bars to identify the current time. The display to the left of that vertical line is darkened to show that it is in the past. At any given time, a colored horizontal bar might be thick or thin. A thick bar means that engaging in the activity is unlikely to disrupt sleep, and in some cases—such as with relaxing—may even help it. Thus, while glancing at the home screen, the user can quickly determine which current activities are likely to affect the user’s upcoming sleep episode. The design therefore, creates a “time-line” of which activities will impact the user’s sleep throughout the day.

Before converging on the timeline design metaphor for the peripheral display, several other designs were considered. This included other metaphors for time, such as a polar clock and an hourglass. We also considered more abstract depictions for the sleep hygiene recommendations, similar to the interfaces in prior work for mobile information displays [6,10]. We conducted informal usability tests to evaluate the competing design and converged on the horizontal timeline design, because it was easiest to quickly interpret.

ShutEye also consists of an interactive application where users can specify preferences and learn more about sleep recommendations. They can manage their desired sleep schedules, browse preferences for which activities to display, adjust the recommendations, and learn about why the activities are likely to affect sleep (Figure 1, center). ShutEye supports two custom schedules: one for “work days” (Monday through Friday by default) and one for “free days” (Saturday and Sunday by default). By allowing users to customize their desired sleep/wake times and work/free days, the recommendations—which are often of the form “end vigorous exercise at least six hours before sleep time”—can be customized (Figure 1, right).

Each standard sleep-related activity in ShutEye (see Table 1) comes with a recommendation from the sleep hygiene

literature as well as an explanation and its source [30]. Because sleep experts have acknowledged that the activities may affect individuals differently, ShutEye allows the user to adjust the recommendations. For example, the sleep literature recommendation for caffeine is to end consumption 8-14 hours before bedtime. However, caffeine affects people differently, and it does not always take 8-14 hours for the effects of caffeine to wear off. Thus, users can change the recommendation to be appropriate based on their own experiences, but can easily return to the defaults.

4-WEEK FIELD STUDY

In this section, we describe the 4-week field study where 12 people used and evaluated ShutEye throughout the course of their normal activities.

Study Method

Our 4-week field study involved three stages: an initial in-lab session, four weeks using ShutEye in the field, and a final in-lab session. This study’s goal was to explore whether ShutEye’s display could promote awareness about sleep recommendations, though the ultimate intention was to prompt changes that would help them get better sleep. We focused on encouraging awareness rather than behavior change because it gave us the opportunity to understand a very sensitive and relatively new domain for HCI. Our approach was based on Klasnja et al.’s recommendations [17] for evaluating novel technologies promoting health behavior change. Klasnja et al. argue that due to the complexity of long-term behavior change, one should not focus on measuring behavior change itself while technology is still exploratory, but instead focus on understanding *why* and *how* technologies might eventually be effective in promoting change. This calls for a study that is mostly qualitative.

Initial in-lab session. After signing a consent form, participants completed a questionnaire on their sleep habits and basic demographics. The questionnaire included the Ep-





	Start time	End time	Recommendation	Explanation
 Napping	8 hours after waking	9 hours after waking	A 10 to 15 minute nap is permitted 8 hours after wake up time.	Humans have a normal dip in their wakefulness about 8 hours after waking time. Napping after that dip in wakefulness increases the likelihood that naps will disturb your sleep cycle
 Meals	Wake time	3 hours before bed	Do not eat or drink a heavy meal 3 hours before bedtime. However, a light snack may help promote sleep	Digestion of food may lead to stomach issues that can disturb sleep. Consuming liquid shortly before sleep may cause a disruption in sleep due to a need to urinate.
 Alcohol	Wake time	2 hours before bed	Humans metabolize about one drink per hour and it is recommended to wait until blood alcohol level has reached zero before sleeping.	In the short term, alcohol promotes sleepiness by aiding the production of various inhibitory neurotransmitters. However, after a few hours these neurotransmitters will be exhausted and your body will become alert again, thereby disturbing your sleep.
 Relaxation	1 hour before bed time	Bed time	Begin sleep-promoting activities 1 hour before bed	It is important to create a break between the events of the day and the process of sleep. To do this, it is useful to engage in activities that promote sleepiness, such as taking a warm bath.

Table 1: Four of the eight sleep-related activity recommendations represented on ShutEye’s peripheral display.

worth sleepiness scale, a clinically validated scale to evaluate subjective sleepiness [14]. After the questionnaire, we conducted a brief interview that lasted about 10-20 minutes. Questions focused on assessing the severity and nature of their sleep concerns. We loaned participants an HTC Nexus One phone running ShutEye to use for four weeks. We put their SIM cards in the study phone so that the study phone served as their primary phone throughout the four weeks. We gave them an in-depth tutorial on how to use the phone, imported their contacts, and provided the phone's user manual. We then helped them customize their schedules in ShutEye so that the peripheral display would reflect their typical sleep/wake schedule and activities that were relevant to them.

4 weeks in the field. During the study, we asked participants to keep ShutEye as their wallpaper, but did not require them to interact with it otherwise. We sent participants a weekly questionnaire via email that they were asked to complete within 24 hours of receipt. The questionnaire repeated the Epworth sleepiness scale and asked about their use of the phone. It also asked if any atypical events had occurred that might impact their sleep, such as sickness, travel, or a change in their work schedule.

Final in-lab session. At the end of the four weeks, participants returned to our lab. During this session, they repeated the Epworth scale. We then conducted an interview about their experiences during the study, their use of ShutEye, and how, if at all, they believed ShutEye impacted their awareness and knowledge of sleep recommendations. Interviews lasted between 30 and 50 minutes. After the interview, we helped participants replace their SIM cards in their original mobile phones, downloaded the log of ShutEye events from the study phone, and then reset the study phone to the original factory settings to remove any of the participants' personal information. Participants received gift cards worth \$65 USD as compensation for their time.

Participants

We recruited 12 adults (see Table 2) from a major US metropolitan area to participate in the 4-week field study of ShutEye. Eight of the participants were female and four were male. The higher number of female participants is likely due to a higher number of women in general reporting difficulties sleeping⁶. However, sleep hygiene recommendations are not gender specific, and thus we did not attempt to recruit an even number of males and females for the study. Participants ranged from 20 to 53 years old (average: 32; median: 31). The highest levels of education achieved by participants were: high school (N=1), certificate (N=3), bachelor's degree (N=4), graduate degree (N=3), and a doctoral degree (N=1). All participants owned and regularly used a mobile phone, with the majority using smart phones. We recruited 8 participants using a profes-

sional recruiting agency and 4 four through word-of-mouth. They were screened to ensure that they had the goal of wanting to improve their sleep habits, but did not have a diagnosed sleep disorder, as ShutEye was not designed to treat serious sleep issues such as sleep apnea or narcolepsy.

RESULTS

The results from the 4-week field study are primarily qualitative in nature, though we also looked at the pre- and post-deployment scores from the Epworth sleepiness scale to assess baseline sleepiness and look for any trends. Epworth scores can range from 1 to 24. Lower scores indicate less subjective sleepiness, with scores at or above 11 indicating pathological sleepiness. These scores are presented in Table 2 to help contextualize the results.

ID	Sex	Age	Occupation	Epworth		
				Pre	Post	Δ
1	F	36	Security / Office Services	6	5	↓
2	F	32	Retail	7	5	↓
3	F	30	Caregiver for AFH	15	15	↔
4	F	31	Banker - Ops Manager	5	5	↔
5	F	53	Home Health Aide	9	7	↓
6	M	28	Bank Teller / Bakery	5	3	↓
7	F	24	Bicycle Mechanic	3	8	↑
8	F	31	Bookkeeper	3	2	↓
9	F	20	Retail	12	4	↓
10	M	21	Prep Chef	7	2	↓
11	F	38	Info. Tech. Librarian	7	3	↓
12	M	40	Ecologist	12	12	↔

Table 2: Participant demographics and Epworth scores before and after using ShutEye. Three of the twelve participants had initial scores that were indicative of excessive sleepiness.

For the qualitative data, we extracted participant quotes from the interview transcripts into 287 unique units of analysis. Two of the researchers used a combination of deductive (bringing in specific themes of interest based on study goals and interview questions) and inductive (allowing additional themes to emerge from the data) coding schemes. Our deductive coding scheme focused on Matthews et al.'s evaluation criteria for peripheral displays, which include: appeal, learnability, awareness, effects of breakdowns, and distraction [23]. The inductive coding resulted in three additional themes: adherence to recommendations, ShutEye as a recommendation tool, and competing issues with sleep. We outline results from each category below.

Appeal

Participants were generally happy with ShutEye and found it understandable and aesthetically pleasing, although a number disliked the Nexus One phone itself. All participants stated that they did not feel that their privacy was invaded nor were they embarrassed if people asked them about their phone's background screen. To the participants, wanting to improve sleep was not a highly sensitive topic, as trying to lose weight might be. Several participants noted that they missed having a background picture on their

⁶ National Sleep Foundation. <http://www.sleepfoundation.org/article/sleep-topics/women-and-sleep>

screen, being able to have that added touch of personalization, or just seeing something new on their phone.

I was just kind of bored with the same background and I would sometimes want to change it – But it wasn't like I wanted to see something else, or have a personal picture on the background or anything like that. It was more just changing it up. {P9}

Another requested feature was the ability to log aspects of sleep, such as sleep duration, quality, or caffeine consumption. This mostly seemed to be because the participants were curious, but they did not think that these should be required to use the application.

I think if it did have a place for me to actually say, when I actually went to bed, or what was the last time I had caffeine, I think that would – I'd probably do it if it was on there. I think it'd be more so that I could see how well I was doing, to the recommendations, to see if I was really doing as well as I thought I was, or if I was breaking the recommendations more than I thought I was...that's what I'd be interested in seeing. {P9}

Learnability

Most of the participants found the interface easy to understand once we explained it to them. However, one participant was a bit confused by it. She did not use her phone very much over the four weeks due to many personal issues, and she said she thought the phone was supposed to “do something” to remind her of what to do. This could have been due to a misunderstanding in our explanation, or not having enough time to get used to the system to understand how it changed.

We allowed for customization of sleep times on a daily basis, but we found that most participants kept the initial settings and did not change their daily times to reflect when they actually woke up or went to bed, but kept them as more of a sleep “goal” or desired sleep and wake time. Because of this, some of the recommendations may not have been as precise for them (e.g., if the ideal time to sleep was 10 P.M. but they did not actually go to sleep until 12 A.M., then the factors for exercise, food, alcohol, etc. were two hours off). Participants expressed a desire for the device to be able to recognize their actual sleep and wake times to provide more accurate recommendations, though they were not entirely clear how they would want this accomplished.

We also allowed participants to specify custom sleep factors they may want to track. This feature was not often used, with the exception of P8, who added *TV* and *Internet*, and P11, who added *Video Games*. When we asked participants if there was anything they wanted to track that was not included in the system, most of them had a response such as TV, computer use, etc. When we further probed to ask why they did not set up a custom feature or change the times of an existing feature, one participant said it was because she trusted the people designing the application and making the recommendations. This underscores the importance of having medically sound backings for the recommendations and setting good defaults.

It seemed that those settings were fine for me, and I figured people that made the app probably knew what they were doing. ... expectations that they understood what is generally best for most people, and I think that what is generally best for most people is generally best for me. {P8}

Effects of Breakdowns

Matthews et al. [23] state that peripheral displays must reveal any breakdowns to users, since they may be reliant on data to do their primary activities. Because the display itself did not rely on risky technology or user input, breakdowns were non-existent. In addition, because ShutEye did not really deal with highly critical data, breakdowns would not be as problematic with this display as they may be for others. However, because the recommendations were time-based, there was some desire from participants to have the application be more proactive, because they would lose track of time and want to be reminded when it was bedtime or the time when caffeine was no longer recommended.

Sometimes people never pay attention to the things that they do throughout the day so if it popped up on my phone daily, it would make me certainly be aware of what I need to be... just well kind of help my daily life flow a little bit easier. {P5}

These types of notifications would change the nature of the peripheral display to a notification display, but having an optional hybrid approach could be a possibility.

Awareness

The primary goal of ShutEye is to help people learn about sleep hygiene and be more aware and thus more mindful of good sleep hygiene practices throughout their day. Nearly all of the participants (N=11) said that it made them think more about sleep, what contributes to quality sleep, and be more cognizant in general of what affects sleep.

I think that this particular app has definitely made me a lot more cognizant of the choices that I'm making. I mean, I'm obviously not going to always follow it to the letter because things happen. So if I'm out with my friends until two o'clock in the morning on a Saturday night, I'm out until two o'clock in the morning. But yes, I mean it definitely made me kind of think twice sometimes when I'd be like, 'I should get a soda. No I shouldn't.' {P8}

I felt like it just made me more cognizant of all my choices throughout the day, so the napping thing and the eating and exercising and things like that. I often go for walks with my sisters and their dogs and so it was like, 'What time is it? Is it still OK for us to for a long walk?' {P2}

I wasn't more hesitant to do it [non-recommended activity], but I did kind of think of how I might sleep. So, just being aware of maybe I'm probably not going to get the best sleep tonight, maybe, or just thinking that if it was going to affect my sleep. So I was just kind of more conscious of – maybe in the morning – of how great my sleep was and trying to tell if that really was affecting it or not. {P9}

Several participants reported that it made them think a little more not just about sleep, but about other aspects of their health and wellness, such as taking care of themselves in general, or getting more exercise.

...just a reminder for myself to myself that I'm trying to take care of myself and trying to behave and try and get the sleep I need. {P1}

So I don't exercise very much, not vigorously, anyways. I'm active, I walk around, but I don't go jogging or anything, but – yeah, so having the little exercising guy of course would make me feel guilty every day, I was like oh yeah, stop exercising, woops, I never started. {P11}

Five of the participants acknowledged that they did not necessarily change their behavior, but they often felt a little guilty when they did not follow the recommendations. They also understood that it was okay to go against the recommendations on occasion.

I mean there's always that tiny bit of like, you know, guilt like I know shouldn't do this but it doesn't really matter. {P10}

Because awareness and mindfulness are difficult to measure, some participants struggled with identifying whether just learning about the recommendation helped in their decision-making, or if it was because of ShutEye's display.

I thought about having coffee later in the day, and then – so is it ShutEye, or is it just me knowing that I shouldn't do it, so it's hard for me separate those out, but having that there probably did make me think, no, don't have coffee now, it's 1 o'clock, or something. {P11}

Participants reported learning more about what contributes to good sleep, even if they did not necessarily adhere to those recommendations all of the time. ShutEye encouraged participants to set up consistent sleep/wake schedules and be mindful of how their activities could impact their sleep.

I didn't know that all of these things affected your sleep within two hours of going to bed. I had no idea. I mean, I was very aware of caffeine, but the rest – oh and naps, of course. If you take a nap too late, everyone kind of figures that. {P4}

Distraction

We chose to put ShutEye's peripheral display on the wallpaper of the user's phone with the intention that it would be seen whenever they used the phone for any reason. Participants confirmed that they noticed the display when they checked the time, sent or received a text message, checked their email, and so on.

Because you're looking at it all the time. And, I mean, every time you pick up your phone to do whatever it is, I mean, there's the bars, there's the time, and you're constantly seeing what you should and should not do in order to help yourself get a better night's sleep. {P7}

Well, every time I would check a text message or something like that, I would see the bars starting to go away. And then I'm like, OK, if I'm going to get coffee, I'd better go get it now. {P1}

The dynamic nature of the display seemed to help draw participants' attention as well, however, most did not find it to be distracting.

...it's not distracting at all. But you notice it, just because it does change. I don't know. If I was bored I'd slide it back and forth, see what I should've done or what I was doing. {P5}

When asked whether they thought they would notice the display as much if it had not been on their phone's background, all participants agreed that they did not think that they would. They liked having it as a part of the background and thought they noticed it more as a result.

I liked that it was on the background of your phone, and just there whenever you...go to check the clock or whatever. {P9}

Because it's the...desktop on the phone, I'm always looking at it every single time I get the phone. {P8}

We also asked about the visibility of the display over time, and whether or not they noticed it less after using the phone for several weeks. Not surprisingly, participants reported specifically looking at the display often toward the beginning of the study. However, as the study progressed, it became a subtler, but persistent reminder.

The first week I was looking at it all of the time because it was new and different but then the following weeks it was kind of like oh. Just kind of keeping it in the back of my mind. {P2}

Adherence to Recommendations

Though our goal with ShutEye was to improve mindfulness, not necessarily to cause behavior change, our results indicate that ShutEye encouraged at least some short-term behavior change. Eight of the 12 participants had improved Epworth scores, which indicates that their overall daytime sleepiness level dropped (see Table 2). We also asked participants about how, if at all, they changed their sleep-related behaviors. Most participants mentioned changing their behavior regarding caffeine consumption.

For the first week [ShutEye] absolutely made me more aware of...keeping the caffeine earlier in the day, if I could. And then for the rest of the month it was...in the back of my mind at least, if not in the forefront of my mind about drinking coffee, like, before three. So it did something. {P6}

Others mentioned that ShutEye helped them adhere to a more consistent sleep schedule or earlier bedtimes.

I was more consistent with my wake times and bed times... Even on my days off I would still go to bed at the time I had went to bed on work days and get up at the same time. {P9}

The recommendation about naps was helpful for some, but frustrating for others because the time period was always during the middle of the day when they had to work. Others heeded the recommendation timing as it made them consider the impact that it might have later that night.

Whereas, I think before, I probably would have just taken a nap whenever I felt like it... I don't think it changed the amount of time that I slept, but it changed ...when I would actually nap because I would look at it and be like, ahhh –if I took a nap now, then I probably wouldn't be able to sleep later. {P3}

One participant particularly appreciated the relaxation recommendation, noting that she read more as a result of her adherence.

I think [relaxation helped], because I have a tendency, when I get into bed, my brain's just going a million miles an hour, usually. And I think that kind of removing some of that visual stimu-

lation at least from the TV or from being online, I think that that kind of helped calm it down a little bit, just let me like read for a while. That's kind of my meditating, is reading. I've read so many books in the last month. It's ridiculous. {P8}

In contrast to these findings, though, several participants mentioned that at times, they knowingly went against ShutEye's recommendations.

Wanting to go out with my friends kind of overrode wanting to sleep. {P3}

However, even in these cases where participants did not adhere to the recommendations, they did so knowing that what they were doing might negatively impact their sleep. That is, ShutEye's primary goal of promoting awareness and helping users make more informed decisions about their behaviors seems to have been achieved.

ShutEye as a Recommendation Tool

For some participants, there seemed to be a tension between ShutEye helping them reflect on how the activities that they do throughout the day might be impacting their goal of improving their sleep and feeling like ShutEye was dictating what they should and should not do.

I felt like there were certain activities that, you know, I wanted to do but remembering, like, no, you can't because you set that schedule for yourself, and you can't watch TV past this time; you shouldn't go to the gym after this time; you, you know, shouldn't be drinking past this time. And I would choose not to do those things because, sort of, mentally I'd realize, like, I have this sort of schedule set for myself that I look at all the time and reminded all the time. {P6}

Another participant who initially experienced this tension felt better about it after she realized that ShutEye was simply providing recommendations, not rules.

Competing Issues with Sleep

Even if users were to regularly follow all of ShutEye's recommendations, they would not be guaranteed good sleep, as other issues—such as a noisy or bright sleep environment, stress, or medical conditions—can impact sleep. Participants reported experiencing a number of such issues. For example, one participant lives near a loud bar:

When the bar lets out at about 2 [in the morning], I almost always hear because people are screaming and loud and stuff, so if I was asleep, I'd almost always wake up then...[my apartment] is right next to it and it's like insanely loud on Thursday nights. {P5}

Several participants mentioned that their hectic schedules impacted their sleep, especially for participants who have more than one job:

To some extent, my work schedule has helped cause problems with that, you know, because some mornings I'm up at three in the morning and some mornings I'm not in bed until three in the morning. Working security, you're there until things shut down and clear up. And then sometimes I'll be wired after I get done doing security. And then when I work at the law firm, I'm up at three in the morning to catch the bus to go to the law firm. So my body's not necessarily sure what to think about that. {P1}

P1's schedule was an extreme case, but several participants had irregular schedules that they believed impacted their sleep quality. We acknowledge that though ShutEye appears to be helpful in improving awareness about many sleep recommendations, it does not address all issues that may impact sleep quality that are known within the sleep community. Sleep hygiene recommendations are usually the first step in treating sleep problems, but if that is unsuccessful, additional follow up is often necessary.

DISCUSSION

Our four-week field study of ShutEye helped us explore some of the issues regarding the design of mobile peripheral displays and technologies for health. We have derived several considerations for designing technologies in this space. In this section, we discuss these considerations and their applicability to similar systems, as well as other challenges and opportunities for future research.

Design Considerations

Based on the results of the field study, we provide the following considerations for designing technologies to promote awareness of healthy sleep behaviors.

Strictness of the recommendations. The primary concern people had with ShutEye was that they felt a bit overwhelmed with trying to do too many things at once and adhere to such a strict time schedule if they were not used to it. The most success came when participants stopped regarding the recommendations as hard rules, and instead, simply looked at them as suggestions or guidelines. Given that the recommendations from the sleep literature are based on averages, we think one thing that might help would be changing the hard lines around recommendation times to be more of a gradient to suggest that the recommendations are not overly strict. Figure 2 shows how ShutEye might be redesigned to adhere to this consideration. In expanding this to other domains, it would be important to consider when recommendations can be conveyed with a similar sense of flexibility.

“Encouraged” vs. “allowable.” Although we explained that thick bars in ShutEye indicated activities were currently unlikely to negatively impact sleep and thin bars would have a negative impact, some participants interpreted the recommendations as being “encouraged” and “not encouraged.” Several participants joked that because alcohol did not have a negative impact on sleep starting at wake time, that ShutEye actually encouraged them to drink that early. Others found it odd that smoking was “encouraged” by the system. This was an issue that we struggled with from the very beginning. Designers might consider setting three levels rather than two: encouraged, allowable, and discouraged, rather than having an impact or not.

Source of recommendations. The participants appreciated having the specific source of the recommendations, which came from the sleep research community. Several stated that this increased their trust in the recommendations, but others actually wanted to learn more behind the recommen-

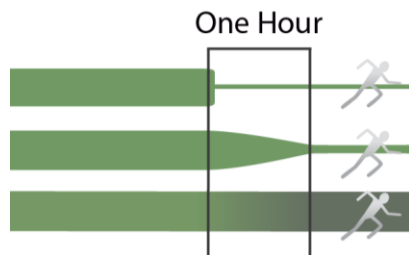


Figure 2: ShutEye's original design (top) and new alternatives (center, bottom) conveying different levels of strictness.

dation. Providing the brief recommendations such as those included in ShutEye were important, but also including links (not just citations) to deeper sources of information could be valuable for those who wanted to learn even more.

Interest and visibility over time. Although participants learned about sleep recommendations over the short study period, a few participants stated that they got bored with ShutEye being the same design on their phone over the 4-weeks, and thus noticed it less over time. If it is important to the system's goals to maintain interest for the long-term, designers might consider having the design change over time or perhaps allow users to swap the design out for new skins or color schemes. ShutEye still had success in educating users over a short period of time, and thus it may not be needed for the long term, but other applications may need this longevity.

Customizing user burden. ShutEye was an experiment with seeing whether an extremely low burden application without nagging or distraction could still encourage awareness of healthy sleep hygiene. While most participants appreciated the subtlety of the display, a few requested that ShutEye be more proactive. Participants would often not realize what time it was, and so they requested alarms or simple notifications to remind them that it was close to bedtime so they should start to relax, or to remind them to get that last cup of coffee before it is too late. Adding *optional* proactive notifications for users who would like them may be something to consider for these types of applications. In addition, we found variations in how much time people would be willing to spend with the application. Several had requested that there be a logging or journaling feature that enabled them to track sleep or caffeine use over time, which may appeal to those who enjoy lifelogging activities. However, because some were not willing to take on this amount of extra effort or had no interest in tracking, application designers should still consider how to add value without it.

Actionable suggestions for meeting recommendations. Although most participants agreed that meeting recommendations was important, some participants just did not have a good idea of how to fit it into their lifestyles. Providing some specific suggestions for things they can do to meet these recommendations may be helpful. For example, links to quitting smoking recommendations or alternatives to caffeinated beverages (e.g., decaffeinated tea or coffee,

milk, etc.) could be helpful. In addition, ideas for what to do to relax, and specific suggestions for the types of meals or physical activities that would be appropriate in the given time frame would also help participants grasp the recommendations and make steps toward longer term changes.

Evaluating awareness. One of the challenges of this work was determining if ShutEye achieved its primary goal of promoting awareness of sleep habits. Although the qualitative data shows that participants became more aware that activities they do throughout the day could impact their sleep, it was difficult to understand how much of this increased awareness came from ShutEye, participating in a study about sleep, or some combination of the two. In addition, because the goal was to help people make more educated decisions about their daily activities, it may be difficult or even impossible to measure progress in terms of the type of clinical outcomes that are often applied to health interventions. While qualitative data on this topic is valuable, designers should consider the limitations of these types of studies regarding traditional health outcome data.

Opportunities for Future Research

The results from our study suggest several opportunities for future work. For example, even though participants were divided on the utility of journaling and activity inference around sleep-related behaviors, there was some interest in including a behavior-tracking feature in ShutEye. Future work could compare the effectiveness of a system based solely on recommendations, as this version of ShutEye used, to one that supports tracking behaviors in addition to providing recommendations. This can help better understand the trade-offs between higher burden, higher accuracy applications and lower burden, lower accuracy applications.

In addition, although sleep is an important part of overall health and wellness, it is not the only important contributor. Proper nutrition and exercise, as well as reducing stress and maintaining social relationships are also important, and at times, these different factors can compete with each other—for example, when participants in our study struggled with the decision to exercise or have dinner after the recommended time if that was the only time that they could schedule them. While ShutEye helped educate users about healthy sleep practices, it may be useful to integrate it into a comprehensive overall health and wellness program that helps the user balance competing priorities. Also, as mentioned above, a wide variety of issues can impact sleep including poor sleep environments. Future work could explore these other issues, including how to help people prepare and maintain their environment for sleep.

Finally, we hope to explore the role of how awareness impacts sleep habits. One of the limitations of this study was determining the participants' awareness of the display. Prior to the study, we considered non-qualitative methods to evaluate awareness including a quiz from the medical community on healthy sleep habits and logging participants' use of ShutEye. However, not all of the items from the quiz

were time-based, and therefore not directly comparable. Logging participants' use of ShutEye was problematic because the main form of interaction occurred peripherally when the users glanced at their phones, and thus this activity could not be accurately logged. ShutEye has been released on the Android Marketplace with a supplemental survey to collect data from a large set of users to make additional iterations on the application's design. This will help set the stage for running a large scale, randomized controlled trial of ShutEye to determine if the awareness reported by our study participants leads to behavior change relating to sleep at a large scale. This may also help to mitigate issues that could arise from participants using phones provided by the research team instead of their own phone.

CONCLUSION

We presented the design and evaluation of a health and wellness technology—ShutEye—to promote mindfulness about how activities that users perform throughout the day may disrupt their sleep. ShutEye uses a glanceable peripheral display on the wallpaper of the user's mobile phone to present a timeline of temporally relevant sleep hygiene recommendations that are derived from the sleep literature and the user's preferences. The goal of ShutEye was to explore whether lower burden but lower accuracy health displays could still be effective. Results from our four-week field study indicate that ShutEye's peripheral display can increase awareness and mindfulness of healthy sleep habits. We provided several considerations for the design of similar technologies to encourage health and wellness, and we outlined opportunities for future work. Our results contribute to the growing body of knowledge of how technology can support healthy sleep and how mobile, peripheral displays can promote health and wellness.

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