Are You in Bed with Technology?

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Sleep is essential to our health and wellbeing. On average, most people sleep more than 2,500 hours per year, meaning they spend more time in bed than at work. Good sleep can positively affect our performance, while a lack of sleep can affect our memory, immune system, cognitive functioning, learning abilities, and alertness. This, in turn, can lead to poor work performance and increase our risk of getting injured. Furthermore, researchers have found correlations between sleeplessness and certain diseases, such as heart disease and diabetes.[1]

Spurred by these findings, researchers have investigated numerous technologies and approaches to monitor individuals' sleep behavior at home, beyond the detailed polysomnography done in sleep labs. One goal of such technologies is to collect information that can increase users' awareness of their sleep habits to persuade them to adopt healthier routines.

Many of these approaches have yet to leave the lab, but it's exciting to see new products in this space, ranging from smart alarm clocks to advanced monitoring devices.

SLEEP TECHNOLOGIES

There are four basic types of "sleep" technologies:

- alarms—devices that ensure people wake up at the desired time;
- sleep monitors—systems and devices that monitor users while they sleep;
- environment monitors—technologies that monitor the environment in which people sleep; and
- communication devices—systems for communication and staying in touch with others while in bed.

Here, we review some of these technologies.

Alarms

Recent advances in alarm clocks are occurring in two areas: *modality* and *time* selection. With regard to modalities, audio (a mechanical bell, for example) is the traditional solution, but computing technologies have expanded the options to include recorded, natural, or synthesized sounds and music or even other media.

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Additionally, modalities such as light levels, physical touches, winds, or vibration can be used as output. Furthermore, because the output is programmable, it's easy to control the intensity—for example, from gentle to very loud. Consider the Philips Wake-Up Light alarm clock (www.philips.de/c/wake-up-light/38748/cat), which gradually grows brighter to simulate the sunrise and wake up the user (see Figure 1). Alarm clocks by Nanda Home (www.nandahome.com), such as Clocky, are more intense—they jump off the nightstand and start rolling away when the alarm sounds, forcing users to get out of bed to turn them off.

Regarding time, users have traditionally selected the precise time when they want to awaken, but what if the user is in a deep-sleep state at that time? Combining time selection with sensing lets users specify a time interval, so the alarm can detect the best time to wake the user during that interval. This assumes that getting up at this time is easier than waking from a deep-sleep phase. For example, the SleepTracker is a wrist watch that uses motion to monitor its users' sleep states throughout the night. It wakes its user in the most appropriate sleep phase—for example, when the user is moving (see www.sleeptracker.com).

Another product is the Lark, which wraps a haptic alarm clock in a wrist band that vibrates to avoid waking up a partner or kids in the vicinity (www.lark.com). It wirelessly connects to a phone to manage the alarm and present the users with their sleep information. The Sleep Cycle alarm clock app also uses motion when the phone is placed on the mattress, similarly inferring sleep phases using a phone's built-in accelerometers (www.mdlabs.se/sleepcycle).

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Sleep Monitors

Sleep monitoring is performed for medical reasons in sleep labs, and a variety of sensors are available to monitor the sleep phases of the user as well as events during sleep (such as snoring or irregular breathing). Using accelerometer-based systems, cameras, microphones, or on-body sensing of electrical sensors, many of these monitoring functions can be made available for use at home.[2]

For example, the Zeo device uses fabric electrodes built in a headband to detect and monitor the user sleep phases (www.myzeo.com). It's connected wirelessly to a bedside display or a phone. Here, the estimation of sleep states is based on electrical signals measures. Developers can obtain a software library from Zeo that lets them view sleep phases and brainwaves in real time (see Figure 2).

Environment Monitors

Equally important to sleep quality is the environment in which people sleep. The opportunity to monitor environmental parameters is unique to systems for the home, as this can't be done in a sleep lab. Noise and temperature are of particular interest and are easy to monitor.

An inherent problem with the use of sensing in the bedroom is the users' need for privacy in this space. Devices with a camera and microphones, although useful for reviewing sleeping behavior, might not be acceptable to users. At the very least, users will need full control of the device in terms of the data it records and shares.

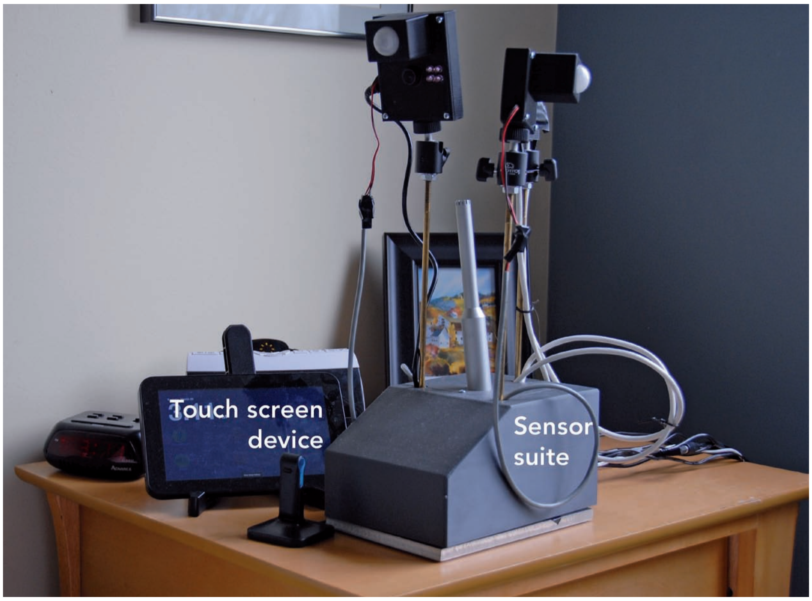
Communication Devices

Many people keep their smartphone on their bedside table at night, because they often send messages before going to sleep and check their phone when they wake up (to check email or Facebook, for example). There has been interesting research on implementing bed-to-bed communication—for example, for intimate communication and as a tool for bridging the distance between remotely located individuals.[3] Sharing sleep-related information (such as when people go to bed or wake up) is another interesting research area.

Figure 1. Philips Wake-Up Light takes a gentle approach to waking up the user by increasing the light level. (Photo courtesy Benjamin Poppinga.)

Figure 2. The Zeo device for real-time monitoring of sleep phases using a headband sensor. (Source: Zeo; used with permission.)

INNOVATIONS IN UBICOMP PRODUCTS



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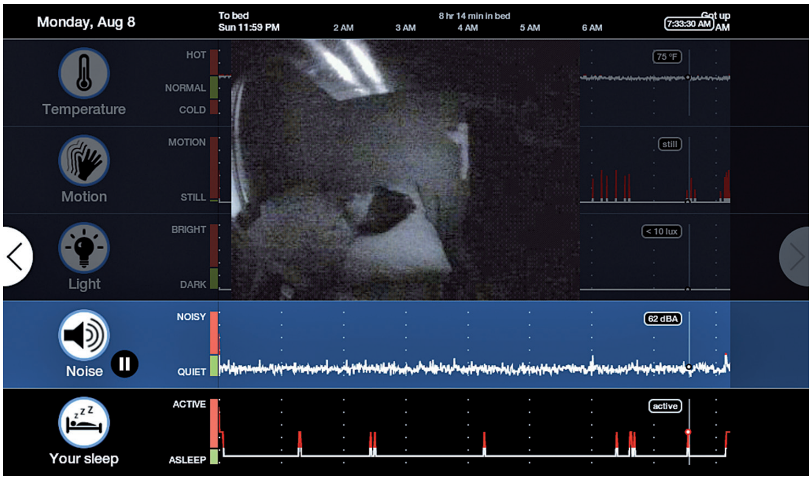

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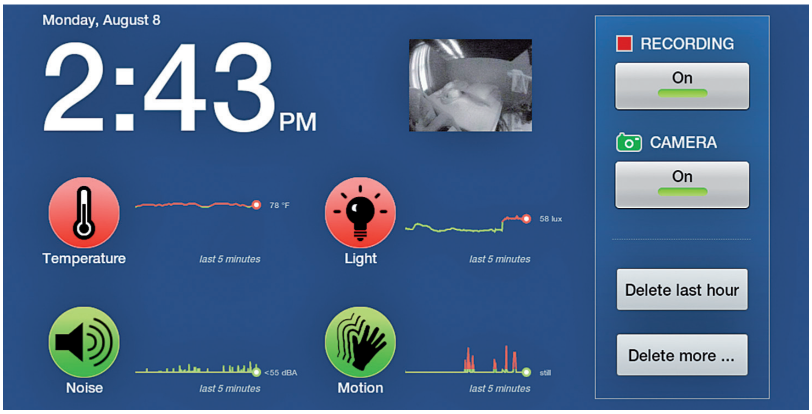

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RESEARCH SYSTEMS AND PROTOTYPES

In addition to the products just discussed, researchers are currently exploring new systems and developing innovative prototypes. Eun Kyoung Cloe's work offers a comprehensive overview of related design considerations and the challenges of using computing to support healthy sleep habits.[4]

Reverse Alarm Clock

Kurast F. Oznec and his colleagues have designed the Reverse Alarm Clock for improving children's sleeping behavior.[5] The goal is to help children know whether it's a good time to get out of bed by implicitly indicating whether their parents are awake. Similarly, in previous work, one of us (Albrecht Schmidt) proposed a networked alarm clock designed to use information about others (such as status and presence information) to set the wake-up time.[6]

The Lullaby System

Information such a body posture, snoring, and breath have also been sensed and used for monitoring a user's sleep.[7,8] Actigraphy devices are used to record full circadian rhythm data over the course of multiple, successive days. Accordingly, they can produce insight into a user's sleep habits and rhythms. Actigraphy devices have been validated and used in the medical community and are also available as consumer information devices.

The Lullaby system combines personal monitoring and environmental sensing in a single system and includes concepts for user control over the recording (http://dub.washington.edu/projects/lullaby).[1] Using various sensors, including a camera and a microphone, sleep can be recorded and reviewed (see Figure 3).

Figure 3. The Lullaby system: (a) the prototypical sensor device on the bedside table, (b) the main screen, and (c) the interface for browsing the sleep history combing video and sensor data. (Source: Matthew Kay, University of Washington; used with permission.[2])

An important result from this work is that users must be able to easily and temporarily disable the recording or delete parts of previously recorded material. However, this study reveals the potential of such technology to empower users by letting them reflect on their own sleep data.

The BuddyClock

Sleep patterns seem to have a tight correlation with awareness and connectedness. For example, BuddyClock is an alarm clock prototype that lets users in a social network automatically exchange sleep information with each other.[9] Another prototype is an eye mask that monitors eye movements and transmits muscle signals that indicate sleeping patterns to a remote device. The device then maps the patterns to music.[10] The aim was to increase awareness between noncollocated partners.

Many people are already in bed with technology. Who hasn't used their smartphone or tablet in bed? Yet others object to technology's invasion of their bedroom. In particular, they worry about their exposure to electromagnetic waves and want to minimize the electric field in their sleeping environment. Automatic mains-field disconnectors can help. Such systems, usually installed in the house's main power distribution hub, can disconnect the power supply to the bedroom when no energy is being used, minimizing the electromagnetic field in this space.

Overall, we believe that technologies support sleeping by improving the wake-up process, providing data for reflecting on sleeping behaviors, and persuading users to adopt healthier sleep behaviors.

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