Opportunities for Computing Technologies to Support Healthy Sleep Behaviors

Eun Kyoung Choe, University of Washington
Sunny Consolvo, Intel Labs Seattle
Nathaniel F. Watson, University of Washington, Harborview Medical Center
Julie A. Kientz, University of Washington
Only **21%** of U.S. people sleep the recommended 8 hours.

![Pie chart showing distribution of hours slept per night (weekdays).](chart.png)

- **9 hours or more**: 6%
- **Less than 6 hours**: 14%
- **6 to less than 7 hours**: 25%
- **7 to less than 8 hours**: 33%
- **8 to less than 9 hours**: 21%

**Mean (# of hours) = 6h 55m**

**Number of Hours Slept per Night (Weekdays)**
(2011 Sleep in America Poll)
Why Sleep?

Sleep: As Important as Diet and Exercise
(Only Easier!)

Make sleep your foundation for good health.

Source: www.sleepfoundation.org
Sleep is associated with health risks

Diabetes, heart disease, obesity, and shorter life spans
Alertness, memory, and cognitive function
Fatal car accidents due to driver drowsiness
A contributor to overall unhappiness
Our goal

Explore opportunities for HCI in the domain of sleep
Study Procedure

Literature Review
Contextual Inquiry
Online Survey
Interview
Design Framework

Formative work to identify design gaps
Literature Review

1. tracking sleep
2. waking and sleep aids
3. social applications
1. Tracking sleep

- Actigraph
- Fitbit
- Zeo
- Sleepcycle

2. Waking and sleep aids

- White Noise
- Clocky
- Zeo
- Sleepcycle
- BioBrite

3. Social applications

- Reverse Alarm Clock (Ozenc et al.)
- BuddyClock (Kim et al.)
- Network Alarm Clock (Schmidt et al.)
Opportunities for Innovation

There is limited discussion in existing literature about…

- people’s needs and current practices in regard to sleep
- design implications of technologies used in a bedroom
- the effectiveness & acceptability of in-home sleep sensing
Study Procedure

- Literature Review
- Contextual Inquiry
- Online Survey
- Interviews
- Design Framework
Contextual Inquiry

Four sleep experts
Learned about
- Good sleep hygiene
- Treatments
- Existing sleep technologies

Online Survey

- 230 people—female (57.8%) male (41.7%)
- 34 Questions with a mix of open-ended, multiple choice, and Likert type
- Helped define design requirements for technologies to support sleep

Interviews

- 16 people
- Interested in sleep technology
- Had experience with sleep disorders (insomnia, narcolepsy, parasomnia, sleep apnea, etc.)
Results
Sleep hygiene
Sleep disruptors
Sleep aids/ waking methods
Sleep-related health goals
Attitudes toward technology
Sleep Hygiene

**Recommendations for better sleep**

1. Keep a consistent wake time and amount each day, 7 days per week.

2. Get up at the same time every morning.

If you do not fall asleep within 15 minutes of going to bed, get out of bed and engage in a quiet activity.
## Sleep disruptors

### Commitments and Stressors

<table>
<thead>
<tr>
<th>Factor</th>
<th>Response Count</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Worries / Fears</td>
<td>106 (46.1%)</td>
<td></td>
</tr>
<tr>
<td>Work / School</td>
<td>101 (43.9%)</td>
<td></td>
</tr>
<tr>
<td>Temperature</td>
<td>94 (40.9%)</td>
<td></td>
</tr>
<tr>
<td>Loud Noises</td>
<td>80 (34.8%)</td>
<td></td>
</tr>
<tr>
<td>Presence of Sleep Partner</td>
<td>57 (24.8%)</td>
<td></td>
</tr>
<tr>
<td>Other Family</td>
<td>44 (19.1%)</td>
<td></td>
</tr>
<tr>
<td>Young Children</td>
<td>21 (9.1%)</td>
<td></td>
</tr>
</tbody>
</table>

### Environmental Factors

Response Count (multiple answers allowed)
Factors helping people sleep

- Temperature: 102 (44.3%)
- Physical Activity: 91 (39.6%)
- Presence of Sleep Partner: 74 (32.2%)
- Music: 55 (23.9%)
- Other: 44 (19.1%)
- Medications: 40 (17.4%)
- White Noise: 40 (17.4%)
- Mental Exercise: 34 (14.8%)

**Response Count** (multiple answers allowed)
Strategies for waking

gradaul vs. abrupt

[on success of dawn simulator]: “I think it was just something about *waking up more gradually* just felt more natural, like I’ve been rested as opposed to just like being jarred awake by a loud noise.”

Others use *multiple alarm clocks* to ensure that they would get out of bed.
User goals for sleep

- Improving the consistency of sleep
- Becoming a morning person
- Breaking bad habits
- Becoming better educated on good sleep habits
Attitudes toward technologies

“**A non-intrusive** and low-cost system which can **automatically capture** sleep data and then display results over time.”

“**Minimal effort** on my part. I wouldn’t do something that takes a significant amount of time or thought, especially in the morning.”
Sleep Technology Design Framework
Six Dimensions
<table>
<thead>
<tr>
<th>Goal</th>
<th>Diagnosis</th>
<th>Treatment</th>
<th>Monitoring</th>
<th>Waking</th>
<th>Sleep inducing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feature</td>
<td>Awareness</td>
<td>Tracking</td>
<td>Persuasive</td>
<td>Education</td>
<td>Social</td>
</tr>
<tr>
<td>Source</td>
<td>Sleep medicine community</td>
<td>Peer-reviewed literature</td>
<td>Other literature</td>
<td>Popular media</td>
<td>Folk wisdom</td>
</tr>
<tr>
<td>Technology Platform</td>
<td>Wearable</td>
<td>Stand-alone</td>
<td>Mobile</td>
<td>Web</td>
<td>PC/laptop</td>
</tr>
<tr>
<td>Stakeholder</td>
<td>With sleep disorders</td>
<td>Without sleep disorders</td>
<td>Indirect stakeholders</td>
<td>Sleep clinicians</td>
<td>Sleep researchers</td>
</tr>
<tr>
<td>Input Mechanism</td>
<td>Manual input by user</td>
<td>Automatic entry by sensors</td>
<td>None</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Goal</strong></td>
<td>Diagnosis</td>
<td>Treatment</td>
<td>Monitoring</td>
<td>Waking</td>
<td>Sleep inducing</td>
</tr>
<tr>
<td>----------</td>
<td>-----------</td>
<td>-----------</td>
<td>------------</td>
<td>--------</td>
<td>---------------</td>
</tr>
<tr>
<td>Feature</td>
<td>Awareness</td>
<td>Tracking</td>
<td>Persuasive</td>
<td>Education</td>
<td>Social</td>
</tr>
<tr>
<td>Source</td>
<td>Sleep medicine community</td>
<td>Peer-reviewed literature</td>
<td>Other literature</td>
<td>Popular media</td>
<td>Folk wisdom</td>
</tr>
<tr>
<td>Technology Platform</td>
<td>Wearable</td>
<td>Stand-alone</td>
<td>Mobile</td>
<td>Web</td>
<td>PC/laptop</td>
</tr>
<tr>
<td>Stakeholder</td>
<td>With sleep disorders</td>
<td>Without sleep disorders</td>
<td>Indirect stakeholders</td>
<td>Sleep clinicians</td>
<td>Sleep researchers</td>
</tr>
<tr>
<td>Input Mechanism</td>
<td>Manual input by user</td>
<td>Automatic entry by sensors</td>
<td>None</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Goal</strong></td>
<td>Diagnosis</td>
<td>Treatment</td>
<td>Monitoring</td>
<td>Waking</td>
<td>Sleep inducing</td>
</tr>
<tr>
<td>-------------</td>
<td>-----------</td>
<td>-----------</td>
<td>------------</td>
<td>--------</td>
<td>----------------</td>
</tr>
<tr>
<td><strong>Feature</strong></td>
<td>Awareness</td>
<td>Tracking</td>
<td>Persuasive</td>
<td>Education</td>
<td>Social</td>
</tr>
<tr>
<td><strong>Source</strong></td>
<td>Sleep medicine community</td>
<td>Peer-reviewed literature</td>
<td>Other literature</td>
<td>Popular media</td>
<td>Folk wisdom</td>
</tr>
<tr>
<td><strong>Technology Platform</strong></td>
<td>Wearable</td>
<td>Stand-alone</td>
<td>Mobile</td>
<td>Web</td>
<td>PC/laptop</td>
</tr>
<tr>
<td><strong>Stakeholder</strong></td>
<td>With sleep disorders</td>
<td>Without sleep disorders</td>
<td>Indirect stakeholders</td>
<td>Sleep clinicians</td>
<td>Sleep researchers</td>
</tr>
<tr>
<td><strong>Input Mechanism</strong></td>
<td>Manual input by user</td>
<td>Automatic entry by sensors</td>
<td>None</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Zeo Personal Sleep Coach

Source: Zeo Website
<table>
<thead>
<tr>
<th>Goal</th>
<th>Diagnosis</th>
<th>Treatment</th>
<th>Monitoring</th>
<th>Waking</th>
<th>Sleep inducing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feature</td>
<td>Awareness</td>
<td>Tracking</td>
<td>Persuasive</td>
<td>Education</td>
<td>Social</td>
</tr>
<tr>
<td>Source</td>
<td>Sleep medicine community</td>
<td>Peer-reviewed literature</td>
<td>Other literature</td>
<td>Popular media</td>
<td>Folk wisdom</td>
</tr>
<tr>
<td>Technology Platform</td>
<td>Wearable</td>
<td>Stand-alone</td>
<td>Mobile</td>
<td>Web</td>
<td>PC/laptop</td>
</tr>
<tr>
<td>Stakeholder</td>
<td>With sleep disorders</td>
<td>Without sleep disorders</td>
<td>Indirect stakeholders</td>
<td>Sleep clinicians</td>
<td>Sleep researchers</td>
</tr>
<tr>
<td>Input Mechanism</td>
<td>Manual input by user</td>
<td>Automatic entry by sensors</td>
<td>None</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Goal</td>
<td>Diagnosis</td>
<td>Treatment</td>
<td>Monitoring</td>
<td>Waking</td>
<td>Sleep inducing</td>
</tr>
<tr>
<td>--------------</td>
<td>-----------</td>
<td>-----------</td>
<td>------------</td>
<td>--------</td>
<td>---------------</td>
</tr>
<tr>
<td>Feature</td>
<td>Awareness</td>
<td>Tracking</td>
<td>Persuasive</td>
<td>Education</td>
<td>Social</td>
</tr>
<tr>
<td>Source</td>
<td>Sleep medicine community</td>
<td>Peer-reviewed literature</td>
<td>Other literature</td>
<td>Popular media</td>
<td>Folk wisdom</td>
</tr>
<tr>
<td>Technology Platform</td>
<td>Wearable</td>
<td>Stand-alone</td>
<td>Mobile</td>
<td>Web</td>
<td>PC/laptop</td>
</tr>
<tr>
<td>Stakeholder</td>
<td>With sleep disorders</td>
<td>Without sleep disorders</td>
<td>Indirect stakeholders</td>
<td>Sleep clinicians</td>
<td>Sleep researchers</td>
</tr>
<tr>
<td>Input Mechanism</td>
<td>Manual input by user</td>
<td>Automatic entry by sensors</td>
<td>None</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Considerations & Opportunities

Tracking sleep trends over time is important

Long-term, automatic in-home sleep sensing solution

There exists tensions between technology and sleep

Technology: not a cure for every sleep problem

Cultural differences can lead to different solutions

HCI community can make a meaningful impact
Acknowledgments

Co-authors,
Study participants, CHI reviewers,
Sajanee Halko, Dawn Sakaguchi,
Jacqueline Holmes, Andrey Maslov,
Amanda Fonville, and Amanda Ahn

Questions: eunky@uw.edu
Appendix
### Sleep Diary

#### SLEEP CLINIC PATIENT QUESTIONNAIRE

This refers to your usual way of life in recent times. Even if you have not done some of these things recently, try to work out how they would have affected you. Use the following scale to circle the most appropriate response for each situation.

**How likely are you to feel asleep (not just feel tired) in the following situations?**

<table>
<thead>
<tr>
<th>Situation</th>
<th>None</th>
<th>Mild</th>
<th>Moderate</th>
<th>Severe</th>
<th>Very</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sitting and reading</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Watching TV</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sitting inactive</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Riding as a passenger on a train</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lying down to rest or sleep</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sitting and talking</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sitting quietly</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>In a car, while driving</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>At the dinner table</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>While driving in a car</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### SLEEP DIARY

--- COMPLETE THIS SECTION AFTER GETTING OUT OF BED ---

<table>
<thead>
<tr>
<th>Day Date</th>
<th>Unusual stressors, time of alcohol &amp; sleep medications</th>
<th>Time you want to bed</th>
<th>Time it took you to fall asleep</th>
<th># of awakenings</th>
<th>Amount of time awake</th>
<th>Time you got up for the day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sunday</td>
<td>argument at dinner, 2 beers 6-8pm, Ambien 10 mg at 9:30pm</td>
<td>10pm</td>
<td>30 min</td>
<td>3</td>
<td>30 min</td>
<td>6am</td>
</tr>
<tr>
<td>October</td>
<td>5/20/00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2/5/2001</td>
<td>10:30</td>
<td>10 min</td>
<td>5 min</td>
<td>1</td>
<td>5 min</td>
<td>6:45</td>
</tr>
</tbody>
</table>

---

**How often do you:**

1. I have trouble falling asleep
2. I wake up during the night and have trouble getting back to sleep
3. I have frequent awakenings during the night
4. I wake up too early

**How do you feel about your sleep?:**

- Very satisfied
- Satisfied
- Unhappy
- Very unhappy

**Marriage Status:**

- Single
- Married
- Widowed
- Divorced
- Domestic partner

---

**Heart Disease:**

- Heart failure
- Heart attack
- Angina Pectoris
- Atrial fibillation
- Atrioventricular block
- Arrhythmia
- Asthma
- Pneumonia

**Lung Disease:**

- COPD/Emphysema
- Chronic obstructive pulmonary disease
- Mesothelioma
- Idiopathic interstitial pneumonia
- Pulmonary fibrosis
- Sarcoidosis
- Pulmonary hypertension
- Pulmonary venous hypertension

**Musculoskeletal:**

- Rheumatoid arthritis
- Lupus
- Osteoarthritis
- Rheumatoid vasculitis
- Fibromyalgia
- Spondylitis
- Scoliosis
- Herniated disc
- Degenerative disc disease
- Psoriatic arthritis
- Ankylosing spondylitis
- Osteoporosis
- Osteopenia
- Sudeck atrophy
- Carpal tunnel syndrome
- Lower back pain
- Upper back pain
- Neck pain
- Knee pain
- Hip pain
- Shoulder pain
- Elbow pain
- Wrist pain
- Ankle pain
- Foot pain
- Finger pain

---

**Sleep Habits:**

- Do you type messages on your phone?
- Do you use a computer when you sleep?
- What does it take you to fall asleep?
- How long do you sleep?
- How much time does it take you to fall asleep?
- How long do you sleep?
Sleep Data

- Hours of sleep
- Time it took to fall asleep
- Amount of time awake
- Actual sleep time / Total time in bed
- Number of awakenings

Sleep quality

How would you rate last night’s sleep quality?

1) Very bad
2) Fairly bad
3) Fairly good
4) Very good
Persuasive strategies

Motivation
Goal Setting and Commitment
Rewards and Incentives
Self-monitoring
Increasing Information Awareness
Summary Feedback
Suggestion
Social Aspect
Actigraphy
Actigraphy
ZEO personal sleep coach
BioBrite Sunrise Alarm
Clocky
White Noise Generator

Features:
- Beach Waves
- Fan
- Crickets
- TV
- Rain
- Air
- Chimes
- Clock

Controls:
- Volume
- Timer
Reverse Alarm Clock
Ozenc, Jeong, Brommer, Shih, Au, Zimmerman DPPI 2007
BuddyClock
Kim, Kientz, Patel, Abowd CSCW 2008