What kept you awake last night? - A context collection sleep-monitoring system

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ABSTRACT

Chronic insomnia is linked to a large number of contributing factors, thus Cognitive Behavioural Therapy for Insomnia (CBTi) is assisted by self-monitoring. Identifying contributing factors is a difficult task, as individuals lack clues on what to track to improve own behaviour. This study investigated how to assist for self-reflection in sleep-monitoring, by assessing users self-reflective behaviours using an sleep-monitoring application for 1 week in-situ use along with a sleep kit containing three tangible probes. Three bad sleepers, three good sleepers and one diagnosed with insomnia in the age range between 22 and 47 years old participated in the study. Results revealed that contextual clues from one the tangible probes (a poster) enabled users to identify factors associated with awakenings and longer sleep initiations. The study was followed by a design workshop, aimed at identifying features assisting users to self-reflect upon their sleep.

Author Keywords

Insomnia; Self-monitoring; Sleep-monitoring; Reflection; Awareness; Sleep Diary

INTRODUCTION

Sleep nearly occupies a third of our lives, and is a necessity for our immune system, learning abilities and for our body's ability to recover.

Continuous sleep deprivation can be an incipient indication of suffering from the sleep disorder insomnia - the subjective perception of difficulty with sleep initiation, duration, consolidation, or quality that occurs despite adequate opportunity for sleep [20]. Insomnia symptoms with associated distress or impairment occur in 10% to 15% of the adult population [20].

Chronic insomnia is linked to a large number of contributing *factors* - information that affect behaviour, such as environmental disruptions, emotional problems and cognitive stimulus. Treating insomnia is assisted by self-monitoring own behaviour in paper sleep diaries prominent in Cognitive Behavioural Therapy for insomnia (CBTi). *Self-reflection* is crucial in CBT's goal of behaviour change - the practice of exploring one's own thoughts, feelings and behaviour.

Paper sleep diaries provide free form comment sections for identifying contributing factors with no additional support. Without support, users fail to identify factors since they lack clues on what to track to improve own behaviour [7]. In addition, contributing factors affect people differently [22], which complicate predefining a set of factors to track. Recent efforts in sleep-monitoring used predefined factors (e.g. exercise, alcohol consumption), and were not found helpful to assist users in identifying relationships between sleep and factors. The predefined factors revolved on activities occurring *before* going to bed, which restricts opportunities to identify factors which affect individuals during sleep initiations and awakenings.

Prior research shows that tracking *context* (e.g. is the circumstances in which target behaviour occurs) enables users to identify factors affecting target behaviour [15]. Context can explain what effects sleep, by exploring anomalies in sleep associated with context - such as environment, social or emotional clues. To my knowledge, no prior sleep-monitoring systems provides support in identifying factors associated with anomalies in sleep.

I transferred context collection into sleep-monitoring aiming to encourage users to identify factors, by enabling them to self-reflect upon their anomalies in their sleep.

The study reveals the effects of a context collection sleep-monitoring system and contributes to the growing body of research on supporting self-reflection within Personal Informatics Systems. The study is followed by a design workshop, aimed at identifying features assisting users to self-reflect upon their sleep.

BACKGROUND

Managing chronic insomnia is difficult, due to the large number of contributing factors, such as dietary intake (e.g. coffee consumption), environmental disruptions (e.g room temperature, light) or emotional problems (e.g. anxiety) [20]. Each factor offers its own set of problems thus influence the choice of intervention.

Cognitive Behavioural Therapy for Insomnia (CBTi) is one of the dominant intervention approaches to treat insomnia. CBTi aims to dissolve dysfunctional beliefs about sleep, by bringing awareness of inaccurate thinking so patients can respond to them in an appropriate manner. Self-awareness

begins with *self-reflection*, the process of exploring our thoughts, emotions and actions. Self-reflection is crucial in CBT'is goal of behaviour change, thus extends the treatment by self-monitoring sleep-related behaviours in a *sleep diary*.

To asesses the degree of insomnia and to review progress, sleep diaries should record sleep onset latency (SOL), wakefulness after initial sleep onset (WASO), total sleep time (TST), total time spent in bed (TIB) and sleep efficiency (SE, i.e., the percent of the time asleep out of amount of time spent in bed) [4]. Patients commonly assess their subjective interpretation of sleep, by reporting on sleep quality and satisfaction. Patients experience unconsolidated sleep with several awakenings during the night (See Figure 1).

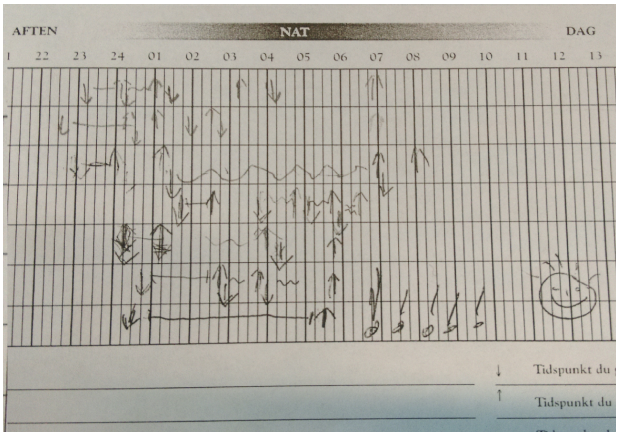

Figure 1. A paper sleep diary from Skoerping Hospital from Denmark. Going to bed is marked by an arrow down, going out of bed is marked by an arrow up, sleep is marked by lines and waves. TST, TIB and SE are calculated based on markings

Therapists discourage clock-watching for sleep-monitoring, to avoid disturbing sleep. Sleep-monitoring occurs when patients wake up, to ensure an accurate representation of the night.

Carney et al. suggested standardizing inconsistent sleep diaries [4] and found a strong desire to express personalized comments regarding sleep and wakefulness in both good sleepers and with people with insomnia (N = 47). Participants related sleep with dream experiences, effect of physical symptoms and medications, and the influence of environmental and emotional factors. Environmental, emotional and cognitive factors affect sleep quality in large scale studies (N = 572) [14]. Commonly, such factors are documented in free form comments in sleep diaries.

Sleep-monitoring

Paper sleep diaries are easy to grasp, but offer limited support in identifying factors and to summarize findings to assist interpreating the data [19, 15].

Sleep-monitoring benefits from collecting factors, to increase users self-awereness of what affects their sleep behaviours. Prior research associated sleep with environmental disruptions (e.g. temperature, light conditions, noise) [13] and predefined factors linked to corralte with sleep quality [10, 6]. It is not sufficient to solely track environmental disruptions, due to the diversity of the data reported within sleep-monitoring in CBTi.

Data representations of real-time collected data from wearables (e.g. Fitbit, Jawbone) fails to deliver or take into account individuals subjective interpretation of sleep [23]. The visual representation did not correspond with users own experience and disallowed to add contributing factors. Wearables and fully automatic sleep-monitoring systems disregards the user need of expressing personlized comments regarding sleep and wakefulness [4], and reduces self-reflection due to fully automated data collections [15].

Gartenberg et al. proposed an automatic sleep-monitoring application which allowed to collect contributing factors [10]. The factors were predefined (e.g. exercise, meds, mood), and the correlation between the factors and sleep was presented in natural language. The system restricted opportunities for identifying factors, by disallowing adding additional factors relevant to own behaviour. Gartenberg et al. evaluated the system in terms of usability, and thus unknown whether the system was able to assist identifying factors.

Choe et al. proposed a similar sleep-monitoring system as Gartenberg et al. [6]. Opposed to Gartenberg et al., users tracked information manually to provide additional opportunities for self-reflection. The system visualized factors in terms of the number of occurrences per type of reported sleep quality (e.g food consumption: 3.3 times per good night).

The system possessed five pre-defined factors (e.g exercise, dietary consumption), and allowed to add up to eight in total. Users reported to identify factors based on own observations, and not by feedback from the application. Users found the visualizations too text and data heavy to extract meaningful information. The system increased awareness of own sleep patterns, but did not help users in identifying factors.

Previous sleep monitoring systems restricted opportunity for identifying the variety of factors reported by patients during insomnia treatment. The predefined factors in the mentioned studies revolved on activities occurring before going to sleep, thus users were not encouraged to identify factors relevant to anomalies in sleep. It is unclear, whether current systems are able to enable users to identify factors responsible for their sleep behaviour, if factors available by the system do not correlate with own behaviour.

In summary, current research in sleep-monitoring did not yield information in how to assist users in identifying factors associated with anomalies in sleep. Assisting self-monitoring is a growing field within Personal Informatics Research (PI), in terms of the practices of *collection* and how it supports *self-reflection*, thus can inform how to design for reflection within sleep-monitoring.

Model of Personal Informatics Systems

Personal informatics systems require a data collection (e.g. quantitative, qualitative), a collection method (e.g. automatic, manual), and to be presented in a manner allowing exploration (e.g. statistics, natural language).

The motivation to self-reflect depends on whether it is for purely holistic reasons or to gain awareness of specific behaviours. Lupton distinguished five motivations for self-tracking [18]. Users self-monitor for private and personal reasons (*private*), in response to external encouragement e.g. a doctor, health care provider (*pushed*), to share data among a community of users (*communal*), imposed by an external source for these others' benefit (*imposed*) and for others to repurpose the data (*exploited*). Within CBTi, exploring data and reaching for conclusions is done in collaboration with professionals. Pushed self-monitoring requires adherence to the treatment and providing useful information, to ensure the proper intervention method from the therapist.

Li et al. devised a five stage model of personal informatics systems addressing users who most likely have a private or pushed self-tracking goal, due to the goal of behaviour change [16]: 1) *preparation*, the motivation and decision to collect data; 2) *collection*, the collection of data; 3) *integration*, the preparation process of the collected data to reflect upon; 4) *reflection*, the understanding and exploration of collected data; 5) *action*, the decision to act against unwanted behaviours based on newfound understanding of themselves.

Systems reaching to support a behaviour change goal, aim to provide opportunities for reflection to engage the individual to learn to self-manage unhealthy behaviours.

Previous research on reflection in learning environments shows that self-reflection already occurs when engaging in actions, better known as "reflect-in-action" [21]. Reflection is not limited to the reflection stage, thus can assist the user in identifying factors during collection for CBTi.

Fleck et al. identified five levels of reflection based on previous literature and research in the field of self-reflection [8]. *(Descriptive)*, statements without further elaboration;*(Reflective)*, statements are justified in a reportive or descriptive way; *(Dialogic)*, generalizing relationships between pieces of experience or knowledge to reach new levels of understanding; *(Transformative)*, statements are altered or transformed to provide a new perspective; *(Critical)*, consider the greater picture to explore social or ethical issues.

Reaching descriptive or reflective reflection alone is not sufficient to enable users in identifying relationships between their sleep and factors. Users must at least reach dialogic reflection, to be able to consider different explanations to their anomalies in sleep.

I use the term higher levels of reflection (dialogic reflection and those levels above) interchangeably henceforth. Facilitating higher levels of reflection are time-consuming as it does not come natural to people in all situations without additional encouragement. Reaching for higher levels of reflection within CBTi can enable users to identify the factors affecting their sleep.

Self-reflection within Personal Informatics Systems

Personal informatics systems are useful for assisting self-reflection that can support decision-making and promote behaviour change [3, 17].

Automated data collection reduces the tracking effort and increases chances for continued long-term use [5]. However, due to its non-invasive and unobtrusive nature, automated data collections decrease opportunites for self-reflection[15]. In contrast, manual data collection enables reflect-in-action [21] which provides opportunity to reflect and increased consciousness of daily practices [3] and intimacy with the data [7].

Engaging with limited type of data does not encourage higher levels of self-reflection and hence bring limited understanding on the reasoning behind unhealthy behaviours [8]. The solution to increase sleep quality could relies on physical activity, dietary intake or emotions [3], which might not come natural to track as individuals cannot predict, which factors contribute to their behaviours (relevance paradox) [7].

Context is useful to track in PI systems when the goal is to identify the factors responsible for types of behaviours [17]. Tracking location and social context enabled users to identify factors responsible for greater opportunities for engaging in desired physical activity [15]. Contextual clues reveals to enable users to identify relationship between target behaviour and factors, thus reaching dialogic reflection.

Presenting quantified collected information in terms of summaries, line graphs and bar charts promoted user exploration [17]. Visual feedback of collected information promoted exploration of trends and patterns, and bring attention to irregularities in behaviours. However, even simple graphs were not understood by everyone - previous studies found low graph literacy skills in approximately one third of both the US and German population [9]. Users appreciated the straightforward presentation of correlated relationships between context and target behaviour in natural language (e.g. "You walk significantly more on Fridays") [3].

DESIGNING FOR REFLECTION

Prior sleep-monitoring systems emphasise that self-reflection is a prerequisite to help individuals make sense of the relationships among factors to improve sleep [6], but with no guidelines in how to reach levels of reflection responsible to identify such relationships. Reflection takes time, thus creating time for reflection is important and to allow users to develop reflective skills.

According to Fleck's framework on levels of reflection [8], dialogic reflection is necessary to reach, to enable individuals to identify associations between sleep and factors - to generalize and reach a different level of understanding.

Dialogic reflection revolves on activities offering an extra perspective (e.g. context) to develop an understanding between pieces of experiences, reorganizing knowledge and review recorded events [8].

When designing for opportunites for reflection, goals as flow and efficiency are no longer as important as designing for pauses and moments where reflection can take place [2]. *Manual* tracking increases opportunity for reflect-in-action, providing the user time to engage with the data during collection.

Designing for both *opportunities* and *levels of reflection*, I propose to use *manual tracking to provide opportunities for users to explore the context of their anomalies in their sleep, in order to identify factors responsible for their sleep-related problems.*

To address this, I need to understand users reflective behaviours and how it is facilitated during register of sleep and factors. Methods for identifying user needs in such settings are limited and presents a set of design challenges.

Additional design requirements are that the design need to simplify tracking of *unconsolidated sleep* prominent in people with insomnia, and is devised to be used with CBTi therapists.

Application

I designed and implemented an application to register sleep and factors. The application tracked data manually to provide opportunities for reflection and allowed to identity factors responsible for anomalies in sleep. Sleep and factors were tracked in the *input screen*, and all recorded nights were presented in the *overview screen*. A *sleep kit* was a part of the evaluation of the application.

Input Screen

The input screen dealt with all registration tasks, including tracking sleep and factors. I reviewed paper sleep diaries from previous insomnia patients from a sleep clinic which assisted my design.

The paper sleep diaries informed my design by using a drag and drop system, where sleep participants recorded sleep by dragging icons to an interactive timeline (See (b) in Figure 2).

The interface had four draggable icons to track the following: (1) when going to bed; (2) going out of the bed; (3) periods of sleep and (4) comments. Underneath the draggable icons was an interactive timeline used for visualizing sleep and its implications. The timeline began at 18:00, and ended 18:00 the following day, and was divided into 96 slots, each representing 15 minutes similar to the paper sleep diaries. Users received instant visual feedback in terms of time spent sleeping and time spent awake on the timeline.

Factors identified during sleep initiation, awakenings or other anomalies, were registered by dragging the comment icon to a slot on the timeline. This invoked a pop-up text box, used to elaborate on the experience.

Overview Screen

All sleep entries created in the input screen were present in the overview screen (See (c) in Figure 2). Each entry contained a bar, visualizing the time spent sleeping (green) and time spent lying in the bed (red), while also providing the exact numbers of the time spent. The overview screen was merely meant as a navigation and entry screen, but included overview of sleep patterns used to review progress and to compare sleep between days. The application was implemented in Unity, and used SQLite to store and retrieve data.

Sleep kit

Inspired by cultural probes by Gaver [11], I designed a set of probes to engage the participants in their sleep practices.

The sleep kit contained three postcards, a poster and a notebook (See Figure 3).

Poster

The objective of the poster was to inspire the participants to reflect upon context which might affect their sleep. The poster included five contextual clues based on prior research [14], whereas sleep environment was merged with sleep partner, the contextual clues are as following: (1) sleep environment; (2) physiological; (3) cognitive; (4) emotional; (5) substances.

Each contextual cue was illustrated by its own colour, and each had its own description. The participants were instructed to place matching coloured post-it notes on the poster and provide the concrete factor they had experienced and when it happened. Each participant received one poster, and were instructed to use it voluntarily.

Postcards

Each participant received three postcards with one question allowed for completion (e.g "I was tired today, which resulted in ...") based on a specific domain: (1) *consequence* of not acquiring enough sleep, (2) the *Preparation* required to increase the chances of a good night sleep and (3) *Strategies* for when you have troubles falling asleep. The questions were designed to facilitate reflective thinking, and engage the user in their sleep practices.

The participants were instructed reflect upon the questions during each day, and write down their answers in bullet form on the postcards.

Notebook

The notebook served as a supplementary tool to keep, and included instructions in how to use the probes. Any thoughts or practices related to sleep, which did not fit any of the probes use, could be written in the notebook.

STUDY 1

This section describes the study procedure of a study assessing users reflective behaviours and practices using an application along with the sleep kit, and presents its findings.

Participants

Six females and one male in the age range between 22 to 47 years participated with an average of 26.6 years. Six of the participants were students and the last participant was employed part-time. Three participants had sleep-related issues resulting in impairment during the day, and one participant was formerly in treatment for insomnia at a sleep clinic.

Study Procedure

Participants filled out a consent form and a questionnaire assessing their sleep history during our first meeting. Each participant received a sleep kit along with the application, and was instructed in using the different materials. I recommended to use the materials when they woke up in the

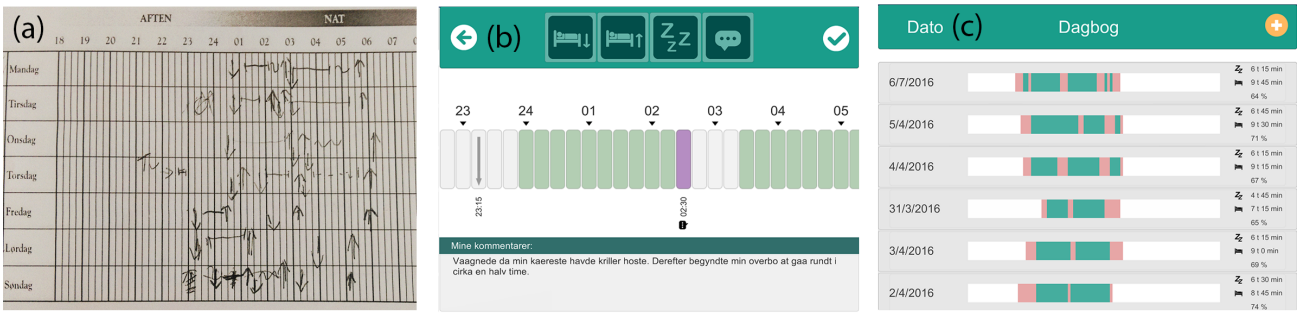

Figure 2. (a) A sleep diary from a previous insomnia patient revealing unconsolidated sleep (b) the input screen of the application (c) the overview screen of the application, the green colour illustrates time spent awake and the red colour illustrates time spent in bed

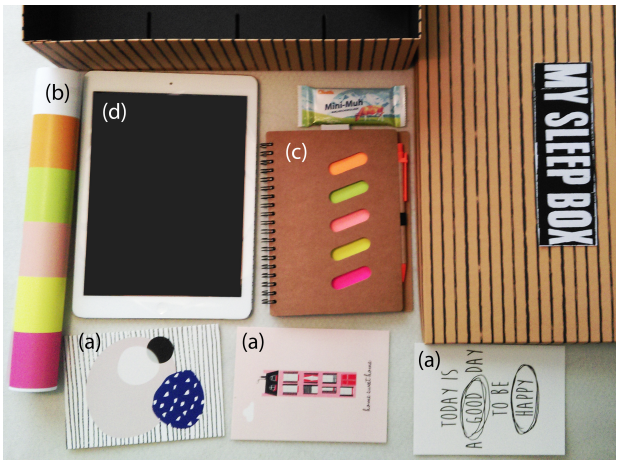

Figure 3. The sleep kit handed out to each participant, containing (a) three postcards, (b) a poster, (c) a notebook and (d) the ipad with the application

morning to imitate the practices during insomnia treatment. I collected the kit after one week in-situ use, and conducted exit interviews individually with each participant. The interview revolved on which factors users had identified and *how* they acquired that knowledge using the materials.

Dataset and analysis

All text from the postcards, posters and comments from the application log resulted on average 30 statements per participant, (for detail see Figure 1).

ID	Sleeper	Comments	Postcards	Poster	Total
P1	Bad	9	6	12	**21**
P2	Good	10	6	7	**23**
P3	Good	11	19	18	**40**
P4	Good	9	7	19	**29**
P5	Bad	23	7	8	**37**
P6	Bad	19	3	24	**39**
P7	Insomnia	0	15	6	**21**

Table 1. Table showing Participant ID, Type of sleeper (good sleeper, bad sleeper, diagnosed with insomnia), comments from the application, postcard statements, poster statements and total statements per participant

In contrast to Gaver's approach, rather than keeping it inspirational, I intended to extract data from the returned materials to analyse and to inform a design.

The materials did not inform users' reflective practices. I transcribed and coded the data from the interview and looked into what enabled users to identify factors, and whether it was based on help from the materials or on own observations. I looked into motivations for exploring sleep between good and bad sleepers, to explore differences in tracking behaviours.

Findings

I organized results into the following topics (1) Motivation for exploring sleep (2) Application usage and (3) Prompting reflective behaviour.

Motivation for exploring sleep

Participants expressed different motivations for exploring their sleep. Good sleepers wanted to know, whether they acquired the correct amount of sleep: *P4: "I would of course like to have those 8 hours of recommended sleep"*, bad sleepers were looking for reasons for bad nights of sleep, in order to respond to bad sleep behaviours in a more appropriate manner: *P6: "I think, if I explore my sleep, I will find out what the problems areas are, and if I find out what the problems are and why I cannot sleep properly, then I can make up a strategy"*. Some participants desired to increase their awareness on how their body reacts in relation to bad and good nights of sleep, thus learn to make better decisions.

Users diverse set of goals to explore sleep revealed different preferences among tracking and reflection behaviours. Good sleepers were more interested in looking for irregularities of their sleep patterns in the application. They also enjoyed answering the postcards, as it helped them reflect upon how to increase their sleep quality. They used the poster limited, as they described to have no severe issues with their sleep in general.

Those who experienced troubles during sleep, found the poster more useful in generalizing their problems, and were already to some degree aware of the irregularities in their sleep. However, all users despite different motivations expressed usage of all the probes, and expressed the probes provided them with several different perspectives to what have actually happened during the night.

Application usage

Each participant tracked their sleep for at least seven days. Due to holiday season, not all registered their sleep each day, and instead registered multiple days in several turns. Those with sleep-related problems, tracked their sleep more consistently. P7 found it easier and more effective to track unconsolidated sleep, compared to the paper diary she used at the sleep clinic.

The application brought more attention on sleep patterns rather than the causation of the irregularities of sleep. Users expressed concern on their sleep practices as some experienced long sleep initiations, several awakenings and extended periods of lying in bed awake. Both good and bad sleepers desired to improve their sleep routines by going to bed earlier or reduce sleeping during daytime based on the overview of their sleep patterns.

While the application increased awareness of sleep patterns, it was not sufficient for identifying factors: *P7: "I do not think that registering my sleep patterns is enough, it does not tell me enough"*.

Six out of seven participants used comments to elaborate on the irregularities in their sleep, but not all comments were related to factors but instead descriptive reports: *P2: "Awake in a good amount of time (1 hour), but felt asleep half an hour later"*. P2 did not provide any context to why she had troubles falling asleep or why she had awake. The representation of the anomalies encouraged users to leave comments, but was not effective to enable users to identifying factors. P7 did not not use any comments at all, since she found the poster sufficient for this purpose.

Correlating sleep with outside factors was not a common practice for all participants, and required additional support in facilitating their reflective practices: *P1: "In the application, I might just have written 'it was because I went too late in bed' or 'it was because I got up too early' I was tired, however with this [poster] it was actually because I had too many thoughts in my head, I could not fall asleep. It gave me something specific I could think about compared to the application"*.

Prompting Reflective Behaviour

Postcards

The postcards brought attention to how users respond to irregular sleep and their efforts to prevent sleep-related issues: *P3: "The questions made me think about on how sleep really plays into everyday things. I was more observing on how sleep affects me during the day"*.

In general, good sleepers appreciated being encouraged to establish their own advice in how to sleep better, while bad sleepers expressed discomfort answering the postcards or even avoiding it.

The postcards increased users awareness of their sleep quality, and on own initiatives to improve it. The postcards served a self-help purpose among the good sleepers, by increasing their effort and interest in maintaining appropriate sleep behaviours.

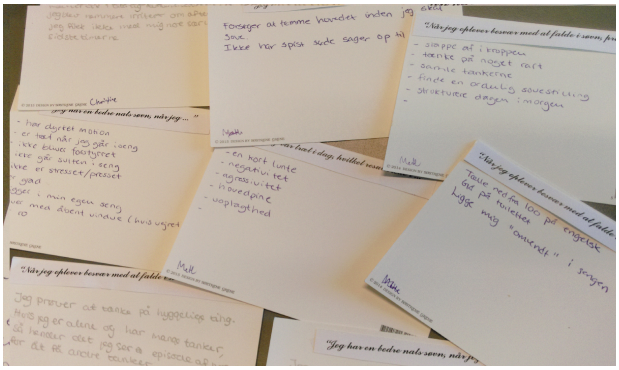

Figure 4. Returned postcards from three participants

Bad sleepers however expressed difficulties, displeasure or being overwhelmed answering the questions. Participants expressed that Strategy and Consequence brought up negative feelings: *P7: "That one (Strategy), was a bit (sigh). And this one, it is also a bit more negative (Consequence)"*. One participant did not answer Q2 with the following reason: *P6: "I think this one (Consequence) was really difficult to answer. Since I am always tired, I do not notice it anymore. I have learned to concentrate despite my tiredness"* and a participant answered Preparation with: *P5: "I do not know, it is such a long time since I had a good undisturbed sleep"*.

In summary, the postcards brought attention to sleep practices relevant to improving behaviours. When individuals were unaware or experiencing impairment due to sleep related issues, the postcards only brought attention to the fact that they have troubles sleeping.

Poster

The participants used the poster primarily for targeting factors responsible for irregularities in users sleep.

Participants used the poster to identify factors occurring before going to bed (e.g. alcohol consumption, work, dietary intake), factors which affected their ability to fall asleep (e.g. anxiety, pain, negative thoughts, sleep environment) and factors responsible for awakenings during the night (e.g. noise, sleep partner, toilet).

70 different statements (94 in total) was identified using the poster, this is in average 13.4 statements per participant, with 8.1 of those were unique per participant (See Figure 5).

The participants experienced problems across multiple contextual clues, each with their own unique issues. The poster brought awareness to several contextualized areas, which encouraged users to identify factors responsible for the anomalies in their sleep: *P5: "One of those things, which I found out, If I go to bed, then there is actually something which feels painful. The poster helped me to focus on, that it is actually because of the physiological I cannot sleep"* and *P2: "In substances it was alcohol, in sleep environment it was because I was continually disturbed by my sleep partner, it was something specific, and I could now say, it was because of that or because of that"*. The participants did not only provide elab-

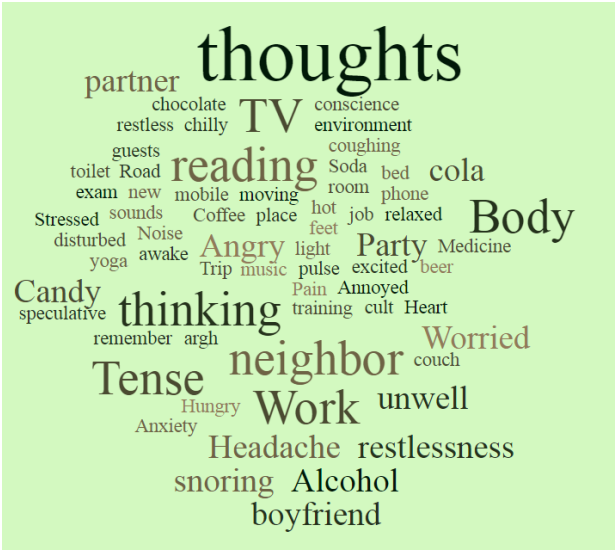

Figure 5. A word cloud of the words registered on the poster

orative discussions on their sleep troubles, they considered alternative explanations to their sleep-related issues.

Specific, concrete, and relatable were commonly used to describe the poster in how it helped them reflect. Some participants were unaware of what could affect their sleep: *P2: "All this with sleep environment, substances, physiological, I have actually not thought about it that those categories could play a role. It is first now it has come up"*. Users needed additional encouragement or being prompted into reflecting upon their sleep. Participants agreed on a hypothetical level, that they would not have discovered what affects their sleep using the application alone.

P6 reflected upon the contextual clues before going to bed, to specify the problems he experienced during the night: *P6: "When I went to bed, and I knew I had to write something on this (poster), then I just thought, I actually feel a lot of pain in my feet. And that have I never really thought about before, and I really think that is something I have learned about this"*.

Participants expressed that not all factors on the poster were unknown to them. P7 had already discovered during her insomnia treatment that stress and physiological related factors were the main reason why she had sleep-related issues. Despite not being unknown factors, the poster helped to concretize and structure her problems.

The poster was praised for its spatial representation: *P2: "I like when I put things up and can see them, and then put them into categories"* and *P7: "It has been more visual experience for me with the colours and the terms"*.

Users appreciated being more aware of what affects their sleep, however some expressed uncertainty in how to use this newly gained information to cope with their sleep-related issues: *P6: "Even though you come closer to the roots of your problems, then it is still extremely difficult to come up with a solution. I do not know what it would take, to change my thoughts and I do not what it would take to ignore those things which causes problems"*.

In summary, free form comments without additional encouragement results in users misses or ignore important characteristics of their sleep practices. The poster facilitated users to relate their anomalies with factors based on context, while the accessibility of the poster offered more opportunity for reflection.

Discussion

Sleep-monitoring

The findings suggest that future sleep-monitoring applications support tracking unconsolidated sleep in terms of effectiveness and visualizations. The drag and drop system allowed for affective tracking of awakenings and sleep periods, and provided instant visual feedback. It should be simple to track unconsolidated sleep without any calculations, and instead focus on how its presentation or collection method encourage reflection. Manual data collection systems provide more opportunities for individuals to identify what affects their sleep.

The timeline encouraged users to describe the anomalies in their sleep using the comment function. The comments however differed in terms from being entirely descriptive (e.g. "I woke up") to users identifying factors. In general, users enjoyed exploring the overview of their recorded nights, to measure own sleep sleep quality and exploration of trends.

Designing for reflection

Users reached dialogic reflection, by examine context information from the poster associated with awakenings and longer sleep initiations to identify contributing factors. While the opportunity for behaviour change derives from increased awareness, long term use must clarify whether dialogic reflection lead to behaviour change.

The poster differed from the application by *prompting* users with context information, and offered a *spatial* presence, which is difficult to provide digitally.

Prompting context information resulted in diverse set of factors, with each user having their own unique factors related to their sleep anomalies. Future sleep-monitoring systems needs to support users individual needs to express factors unique to own sleep behaviour in terms of collection and presentation. Sleep-monitoring should not restrict opportunities to identify factors as seen in previous studies [6, 10], but find ways to enable users in identifying factors themselves. The current state of the system had limited presentation opportunities to allow for interpretation and comparison. Future research should investigate, how such information can be presented to increase self-awareness.

The spatial presence of the poster increased accessibility, whereas the application required to be entered before reflection can occur. Previous research linked greater accessibility with increased opportunity for reflection, by using widgets instead of entering an application [6]. However, increased accessibility alone did not help users to identify contributing

factors [6]. P6 brought up that he looked at the poster before going to sleep, which enabled him in identifying factors while lying in the bed. It is unclear, whether such behaviours should be encouraged. It runs a risk of increasing attention to negative thoughts, emotions and behaviours keeping individuals awake, which is not consistent with the practices of CBTi. The trade-off between accessibility and levels of reflection needs to be further explored to identify the potential risks.

Examine context information alone was not enough to resolve sleep-related problems for bad sleepers. The lack of improvement can rely on the solution is either unknown or unreachable. Reaching higher levels than dialogic reflection can increase possibilities for behaviour change. Reviewing information from another perspective (transformative reflection) or consider the greater picture in an ethical or social context (critical reflection), establishes a more profound comprehension of one's own behaviour which can lead to behaviour change [8]. Reaching transformative or critical reflection without external involvement from a sleep therapist, is still unexplored in research, and could bring an in-depth understanding of self-reflective practices within sleep-monitoring.

In contrast to stating current solutions (e.g as in the postcards), users must be encouraged to devise solutions. For instance, enabling users to challenge their dysfunctional beliefs of sleep with alternative statements, forces users to perceive their current situation in another perspective. A prerequisite to this, is that individuals have to identify the factors responsible for their behaviours, before challenging them.

Limitations

Previous sleep-monitoring research emphasizes that it should be easy to remember to track data. Due to my study only lasted one week, I did not investigate such issues in-depth. I found that some participants did not track their sleep each day, which they blamed on the holiday season rather than motivational issues. Assisting users to remember to collect data throgh reminders (e.g. by an alarm, reminder from an application) increases adherence [6, 12].

Participants did not all suffer from sleep-related issues, which revealed different motivations for sleep-monitoring. Users received sleep-kits to engage them in their sleep practices, in order to receive more data. The creative and tangible design of the probes encouraged user involvement and established an informal environment for the participants to explore their sleep in. Further research could use probes when dealing with individuals not necessarily engaged in the task they are required to do.

DESIGN WORKSHOP

To overcome some of the limitations from study 1, I conducted a collaborative design workshop with four users, to explore the possibilities in designing for reflection in the context of sleep diaries (See Figure 6). I designed four design proposals to evaluate with the users, while also allowing time to generate own ideas.

Collaborate design ensured I assess multiple views, inputs and skills of people to address when designing for reflection,

Figure 6. Design Workshop during phase 1, users had pens, paper and sticky notes accessible and were provided with beverages and snacks

and to helped ensuring that the end result meet user requirements and needs.

Prior to the workshop, participants tracked their sleep in a paper diary, so they could relate their choices on own experience. Users tracked sleep similar as in the sleep diaries from the sleep clinic. The paper diary included the five contextual clues from the poster, used to identify factors.

Participants

Four participants attended the workshop (one female and three males), in the age range between 23 to 57 years old with an average of 40 years old. The participants had a diverse set of backgrounds (engineer in electronics, carpenter, psychiatric nurse and insurance agent). Two of the users reported having several awakenings during the night, while the other two did not report on any major issues with their sleep.

Procedure

The following sections explain the main phases involved with the rationale, procedure and duration for each phase.

Phase 1 (Discussions of past experiences - 30 min)

Prior to the workshop, all participants gained experience in tracking their sleep using a paper prototype. Phase 1 was set up to investigate the experience and usage of the sleep diary, and to explore what they had discovered in relation to their sleep practices. The discussions revolved on the concrete observations made during that tracking period, and how those discoveries were facilitated. This lead into a discussion about features to support self-reflection.

To consolidate the discussion, the participants wrote the discoveries on sticky notes and placed it on a paper wall. The discoveries were discussed in relation to what enabled them, and written on sticky notes and put on the wall. The sticky notes were placed in either categories: *Discoveries* & *What helps me reflect?*.

Phase 2 (Evaluation of Designs - 20 min)

The main purpose of Phase 2 was to evaluate four design proposals and try out the application from study 1.

The participants were introduced to a persona with characteristics prominent in people with insomnia. The persona was based on my previous work in the field, and included goals, motivations and frustrations during sleep-monitoring. Previous research revealed, that individuals without sleep-related

diagnoses prefer sleep-technology to be unobtrusive require a limited amount of active participation [5], this is however not preferred when designing for reflection. Thus the participants were instructed to keep the persona in mind, when exploring and discussing the different design proposals.

The four design proposals were derived from the data gathered from Study 1 (See Figure 7).

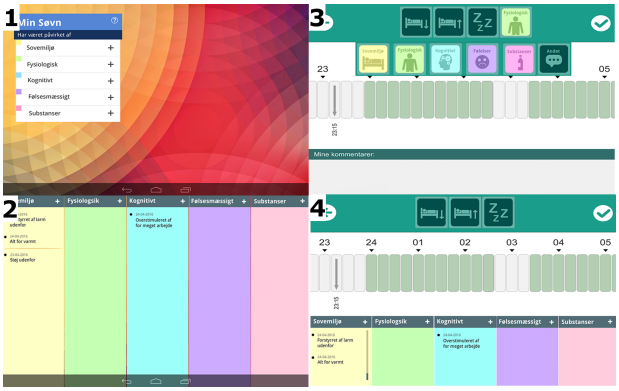

Figure 7. (Design 1) widget present on the front screen in the application (Design 2) A full scale widget present on the front screen (Design 3) application allowing to add comments based on contextual clues (Design 4) application including a separate section to track factors

Design 1 and design 2 increased accessibility of the the contextual clues, to provide more opportunities for reflection. Design 3 and Design 4 incorporated contextual clues into the application design from Study 1, to enable users to relate anomalies in sleep to factors.

Each design proposal was implemented using Google Slides for basic interaction and introduced on a tablet. The participants discussed the usefulness of the designs in how they support self-reflection in the following scenarios:

- *Scenario 1: Discover the factors during collection*
  Discussions on features in the designs which could help the participants reflect upon their sleep during sleep-collection to identify factors.

- *Scenario 2: Accessibility of discoveries*
  Discussions on how accessibility affects participants' abilities to identify factors in relation to the design proposals.

The participants used sticky notes to express their opinions of the several design proposals and put them on a paper wall.

Phase 3 (User Concepts and Sketching - 20 min)
In this phase, the participants created their own concepts for sleep diaries. The participants were restricted to only design for collection of sleep, rather than a complete system. The introduction given to them was:

"You are going to design for reflection. We are going to establish some design proposals, on how to support discovery of what influences our sleep during collection".

The participant played the gamestorming game, "Pass the idea parcel" [1]. The goal of the game was to come up with ideas in how to design a sleep diary to facilitate reflection. Participants passed each other ideas, and elaborated, expanded or added related ideas. Each player spent 5-10 minutes individually writing down (or drawing) as many ideas as possible. When the time passed, the players passed their ideas to the player to their left, and continued on the received idea. This ensured, that all participants had something to provide in the following group discussions.

Findings

The following sections describe some of the main thoughts shared among the participants during each phase.

Discussion Phase
In general, the participants described that registering their sleep provided opportunities for reflection, and brought more attention to their sleep practices. None of the participants had prior experience in tracking their sleep in combination with contextual information, which enabled users to explore their sleep and identify what affects it.

It was difficult for some participants to describe what helps them reflect upon their sleep. The two participants with sleep problems were prone to turn the discussion into about their sleep trouble, instead of providing knowledge in how their reflective behaviours were facilitated.

Participants desired to receive information from the facilitator, in how to solve their sleep troubles. The two participants found it unnecessary or confusing to discuss the their practices of sleep-monitoring. When we wrote the concrete observations on the wall, it facilitated discussions on users sleep-monitoring stories and they explained own reflective practices.

Participants agreed on the following statements for supporting them in discovering what influenced their sleep or increasing opportunities for reflection:

(1) Forcing to connect awakening to the contextual clues in the sleep diary helped me to reflect on what affects my sleep. Participants described to feel a natural urge to describe the 'gaps' in their sleep. Factors in the sleep diaries encouraged the participants to reflect upon what happened during the night, and connect it with the awakenings and longer sleep initiations.

(2) Focusing on the positive instead of the negative increases the change of me wanting to reflect upon my sleep. Users described that the sleep diary contained a lot of negative information about themselves, and therefore entailed a less enjoyable experience. Participants wanted to express good nights, and provide information which helped them sleep better. Participants wanted to distinguish between good and bad nights of sleep, in order to identify factors affecting both states.

(3) Having another individual to observe me during the night, and then tell me what I did. One participant expressed that external involvement (his sleep partner), helped him to elaborate on what he experienced during the night. He expressed that his sleep partner encouraged him to talk about his sleep, as the sleep partner sometimes observed anomalies in his sleep.

(4) Writing it down makes me more aware of my sleep. In general, all participants agreed on that monitoring own sleep manually, helped them to increase awareness on own sleep practices.

Evaluation Phase

We discussed the several design proposals, and elaborated on those features which enabled the persona in identifying what affects her sleep.

The participants found design 3 and design 4 most appropriate for the persona in mind. Information revolving awakenings and sleep initiations should be present, as it enables the persona to reflect upon the anomalies in her sleep. Design 1 and Design 2 did not include information about the tracked sleep, which would decrease reflection possibilities.

The participants found design 1 and 2 more accessible, but did not consider it of advantage in terms of opportunities for reaching higher levels of reflection. Users described to track their sleep in the morning nonetheless, and they did not see any reasons to be reminded of the contextual information on the screen every day. None of the participants expressed to have used, or looked at the sleep diaries prior to the workshop besides in the mornings, and were familiar with the contextual clues after a few days of tracking.

Users described design 3 to be more aesthetically pleasing due to pictograms illustrating the different contextual clues, which they believed would motivate them to reflect upon sleep. Some preferred design 4 due to the accessibility of the identified factors, and found that projecting the recorded factors into one section provided a more generalized image on what they experienced during the night.

Design Phase

The objective of the design phase was to encourage the participants to design a sleep diary based on the findings from phase 1 and phase 2. I noticed this exercise was difficult for certain participants. Things went better, when they were required to elaborate on others ideas, than making the ideas themselves. We ended up with several ideas from each participants (See Figure 8).

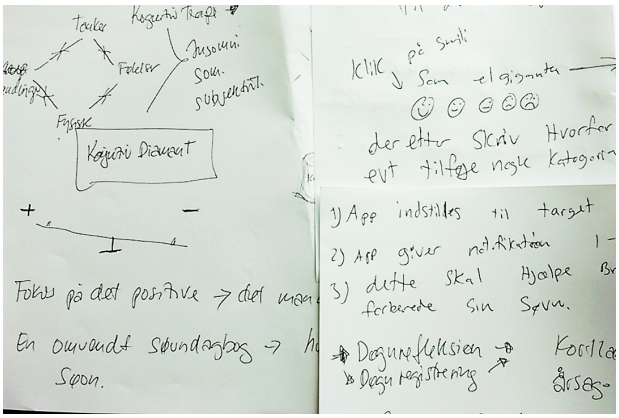

Figure 8. Design ideas generated from the workshop

Users took turn to explain their design ideas generated from the game, and explained those they preferred and why.

Tracking positive attributes served as a common theme in several of the generated design ideas. All participants believed, it would enable them to reflect upon their sleep and reach higher levels of reflection. One participant used techniques from CBTi, and suggested working with identified negative thought using a Cognitive Diamond - a model to treat people with anxiety, which assesses users thoughts, emotions, bodily sensations and behaviours. The diamond would help users to identify how several events trigger thoughts, that affect our emotions and actions - and eventually, the basic assumptions about our behaviours are revealed. Some expressed making a ”opposite” sleep diary, where users can write down those factors which helps them sleep, and then compare it with the factors which affects sleep negatively.

Several design ideas revolved on providing own subjective interpretation of sleep, to be able to differentiate between good and bad nights of sleep. Participant used likert scale consisting of smileys, ratings and other quantifiable measures. One participant suggested a mood barometer, to rate sleep based on his emotions and state of mind.

In general, users expressed a profound relationship with their sleep and emotional response, which they would like to express in a sleep diary.

Discussion

While many of these initiatives do not necessarily relate to the task of identifying what affects us during the night, the ideas brought an interesting aspect, that willingness to reflect is based on having a positive experience and on the aesthetic attributes in the design.

It is no surprise that users desire a positive experience. However, individuals suffering from insomnia are prone to associate sleep with negative thoughts and emotions, and would serve as a major focus in their sleep-monitoring if required to rate sleep. Even a red, frowny smiley, results in users enter skewed data overestimating own behaviour to avoid negative information [6]. Future research should consider the feedback between objectivity and subjectivity, in order to provide information judgement-free and avoid affecting individuals motivational drive to track due to the presentation of bad nights.

TENSIONS IN DESIGNING FOR REFLECTION

For future research, I identified a number of tensions to consider when designing for reflection aiming for behaviour change.

It is necessary to track target behaviour to assess status and progress - data collected in addition to target behaviour are factors and context. Tracking *factors and context* creates tensions in supporting tracking and presenting the collected data. Context, is the circumstances in which target behaviour occurs - such as tracking sleep, thus not restricted to a set of fixed categories.

Study 1 revealed that enabling users to describe the context, did not assist individuals to identify factors that impact their

sleep ability to fall and stay asleep. Self-monitoring assisted by contextual clues, enables individuals to identify contributing factors, but produces extensive unstructured text difficult for exploration, presentation and interpretation. To visualize this kind of data, we could organize information into categories (e.g. the poster from study 1), and assist data analysis using text mining (e.g. word clouds). In contrast, factors are quantifiable thus great for visualizing using graphs or other statistical approaches, but choosing a fixed set of factors restricts entering data relevant to own behaviour.

The second tension is between *subjectivity and objectivity*. Subjective interpretations allows us to understand how we respond to specific behaviours, but can lead to distress in individuals who only have negative information to provide (Study 1). Users should not be discouraged to collect information about themselves. Objective information is neutral and judgement-free, but limits opportunities to reflect upon which factors are associated with good and bad behaviours. Objective information involves the collection of data through observations not tainted by emotions - such as variables describing individuals sleep routines in sleep-monitoring (e.g. going to bed, going out of bed). Objective information works well for reviewing progress and status.

The third tensions is between *manual and automatic* data collections. Manual data collections provide moments and opportunities for self-reflection, but risk to impose a burden depending on the amount of data required to track [7]. Individuals with behaviour change goals might accept this burden, if through their reflection understand that collecting the data helps them.

Reflect-in-action stresses the importance of reflecting while engaging in activities, as part of the learning process. In contrast, automatic data collections increases adherence to track, but limits user involvement. More opportunities for reflection does not necessarily imply that time spent is revolved on activities useful for exploring own behaviour. Study 1 showed that textual data associated with sleep irregularities varied between being descriptive reports (e.g. I woke up) to identify factors (e.g. I could not sleep because I was *worried* about my exam). Self-reflection occurred in both examples, but with different outcomes due to different *levels of reflection*.

The fourth and last tension is between *opportunity for reflection and levels of reflection*. Allowing time and moments for reflection increases user-awareness which can support behaviour change. However, reflection itself can involve activities from stating events without further elaboration to challenging personal assumptions leading to a change in understanding. Designing for reflection should allow for opportunities to reflect, but reflection itself should be meaningful and reaching towards a goal. The goal of Study 1, was to enable users to identify factors associated with their sleep anomalies, and to ensure this, users had to reach dialogic reflection.

Reaching dialogic reflection assist individuals to interpret the relationship between pieces of knowledge. In study 1, such activities revolved on offering individuals with another perspective using contextual clues, and was used to associate individual awakenings and longer sleep initiations with other pieces of information.

Different activities are associated with different levels of reflection, and result in different outcomes. Assisting higher levels of reflection revolves on activities enabling users to see more than they possibly could see alone. Activities such as challenging personal assumptions, providing alternative perspectives and reorganizing collected information provide new opportunities to explore own behaviour.

CONCLUSION

I presented the design and evaluation of a sleep-monitoring system aimed to bring attention to the context of irregularities of sleep, in order to identify what affects individuals sleep. Along with the application, users were handed out a sleep kit including three probes, to engage them in their sleep practices.

I investigated users self-reflective practices using the application and the probes, in a one week in-situ study. I found that contextual information enabled users to reflect upon their sleep and identify contributing factors. Users reported to relate and use the contextualized information to explore and comprehend the irregularities in their sleep. Without this knowledge, users agreed on a hypothetical level that such discoveries would have stayed unnoticed.

I conducted a design workshop, aimed to design a sleep diary providing the best opportunities for self-reflection. I found, that visualizations of the anomalies in sleep enabled participants to identify factors responsible for longer sleep initiations and awakenings. Participants willingness to reflect were linked to having a positive experience and being able to express one's subjective interpretation of sleep.

REFERENCES

1. How to ditch meetings and start playing games. `http://www.uxforthemasses.com/blog/wp-content/uploads/2014/10/How-to-ditch-meetings-and-play-games-instead.pdf`. Accessed: 2016-05-29.
2. Bagnara, S., and Pozzi, S. Design for reflection. *Work (Reading, Mass.) 41* (2012), 1108–1113.
3. Bentley, F., Tollmar, K., Stephenson, P., Levy, L., Jones, B., Robertson, S., Price, E., Catrambone, R., and Wilson, J. Health mashups: Presenting statistical patterns between wellbeing data and context in natural language to promote behavior change. *ACM Trans. Comput.-Hum. Interact. 20*, 5 (Nov. 2013), 30:1–30:27.
4. Carney, C., Buysse, D., and S, A.-I. The consensus sleep diary: Standardizing prospective sleep self-monitoring. *Sleep. 2012;35(2)* (2012), 287–302.
5. Choe, E. K., Kientz, J. A., Halko, S., Fonville, A., Sakaguchi, D., and Watson, N. F. Opportunities for computing to support healthy sleep behavior. CHI EA '10, ACM (New York, NY, USA, 2010), 3661–3666.

6. Choe, E. K., Lee, B., Kay, M., Pratt, W., and Kientz, J. A. Sleeptight: Low-burden, self-monitoring technology for capturing and reflecting on sleep behaviors. UbiComp '15, ACM (New York, NY, USA, 2015), 121–132.
7. Choe, E. K., Lee, N. B., Lee, B., Pratt, W., and Kientz, J. A. Understanding quantified-selfers' practices in collecting and exploring personal data. CHI '14, ACM (New York, NY, USA, 2014), 1143–1152.
8. Fleck, R., and Fitzpatrick, G. Reflecting on reflection: Framing a design landscape. OZCHI '10, ACM (New York, NY, USA, 2010), 216–223.
9. Galesic, M., and Garcia-Retamero, R. Graph literacy: A cross-cultural comparison. *Medical Decision Making, 31(3)* (2011), 444–457.
10. Gartenberg, D., Thornton, R., Masood, M., Pfannenstiel, D., Taylor, D., and Parasuraman, R. Collecting health-related data on the smart phone: Mental models, cost of collection, and perceived benefit of feedback. *Personal Ubiquitous Comput. 17*, 3 (Mar. 2013), 561–570.
11. Gaver, B., Dunne, T., and Pacenti, E. Design: Cultural probes. *interactions 6*, 1 (Jan. 1999), 21–29.
12. Hicks, J., Ramanathan, N., Kim, D., Monibi, M., Selsky, J., Hansen, M., and Estrin, D. Andwellness: An open mobile system for activity and experience sampling. In *Proceedings of Wireless Health 2010*, WH '10, ACM (New York, NY, USA, 2010), 34–43.
13. Kay, M., Choe, E. K., Shepherd, J., Greenstein, B., Watson, N., Consolvo, S., and Kientz, J. A. Lullaby: A capture & access system for understanding the sleep environment. UbiComp '12, ACM (New York, NY, USA, 2012), 226–234.
14. LeBourgeois, M. K., Giannotti, F., Cortesi, F., Wolfson, A. R., and Harsh, J. The relationship between reported sleep quality and sleep hygiene in italian and american adolescents. *Pediatrics 115*, Supplement 1 (2011), 257–265.
15. Li, I. Personal informatics & context: Using context to reveal factors that affect behavior. *J. Ambient Intell. Smart Environ. 4*, 1 (Jan. 2012), 71–72.
16. Li, I., Dey, A., and Forlizzi, J. A stage-based model of personal informatics systems. CHI '10, ACM (New York, NY, USA, 2010), 557–566.
17. Li, I., Dey, A. K., and Forlizzi, J. Understanding my data, myself: Supporting self-reflection with ubicomp technologies. UbiComp '11, ACM (New York, NY, USA, 2011), 405–414.
18. Lupton, D. Self-tracking modes: Reflexive self-monitoring and data practices. *Imminent Citizenships: Personhood and Identity Politics in the Informatic Age workshop, ANU, Canberra* (2014), 0–19.
19. Oh, J., and Lee, U. Exploring ux issues in quantified self technologies. In *Mobile Computing and Ubiquitous Networking (ICMU), 2015 Eighth International Conference on* (Jan 2015), 53–59.
20. Schutte-Rodin, S., Broch, L., Buysse, D., Dorsey, C., and Sateia, M. Clinical guideline for the evaluation and management of chronic insomnia in adults. *Journal of Clinical Sleep Medicine: JCSM: 2008;4(5)* (2008), 487–504.
21. Shön, D. A. The reflective practitioner : How professionals think in action. *New York: Basic Books* (1983).
22. Stepanski, E. J., and Wyatt, J. K. Use of sleep hygiene in the treatment of insomnia. *Sleep Medicine Reviews 7*, 3 (2003), 215 – 225.
23. Vandenberghe, B., and Geerts, D. Oh, what a night! effortless sleep monitoring at home. *INTERACT 2015, Part IV* (2015), 417–424.