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SleepCompete:
A Smart Bedside Device to Promote Healthy Sleeping Habits in Children

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Abstract
We outline SleepCompete: a bedside device that encourages and promotes healthy sleeping behaviour in families, with a particular focus on children, in a fun and useful way. SleepCompete encourages children and their parents to monitor sleeping habits by introducing a 'sleep score'. By sharing this score with others we propose that SleepCompete persuades its users to improve sleeping habits. We outline the concept of our device and the preliminary study we conducted.

Keywords: Bedside device, Sleep patterns, Gamification, Human-computer interaction

1 Introduction

Sleeping behavior is an important factor that affects a person's health and well-being. While good sleep can positively affect people's performance, a lack of sleep can negatively impact the memory (Maquet, 2001), health [1], immune system (Bryant, Trinder, & Curtis, 2004) and cognitive functioning (Wagner, Gais, Haider, Verleger, & Born, 2004), etc. Sleep monitoring can contribute to raising people's awareness about their sleeping routines, which may change their sleeping behavior and lead to improvement of the quality of sleep. The relevance of this topic is

emphasized by the major role sleep takes in our everyday life: young children (4-12 years old) require between 9.25 to 11.5 hours of sleep every night (NHS, 2013). Even by adulthood, we spend more hours sleeping (on average 2500 hours per year) than at work (Schmidt, Shirazi, & van Laerhoven, 2012).

The prevalence of different apps and gadgets on the market (e.g., FitBit One, Jawbone Up, Sleepbot) indicates popularity and demonstrates interest in sleep monitoring among the public. Additionally, sleep monitoring plays a prominent role in research about sleep. In the medical domain, researchers have investigated numerous technologies and approaches in sleep labs in order to monitor individuals' sleep behavior (e.g., Ayas, White, Manson, Stampfer, Speizer, Malhotra, & Hu, 2003, Morillo, Ojeda, Foix, & Jiménez, 2010). In recent years, new technologies have also been leveraged to monitor sleep behavior in people's natural environment at home (e.g., Sahami Shirazi, Clawson, Hassanpour, Tourian, Schmidt, Chi, Borazio, & van Laerhoven, 2013).

Within the field of Human-Computer Interaction (HCI), most approaches focus on adults to use technology in order to increase awareness of their sleeping habits with the aim of persuading them to adopt healthier sleep routines (e.g., Schmidt, Shirazi, & van Laerhoven, 2012, Sahami Shirazi, Clawson, Hassanpour, Tourian, Schmidt, Chi, Borazio, & van Laerhoven, 2013). However, little work has been done leveraging technologies that promote healthy sleep patterns especially for children (e.g., Ozenc, Brommer, Jeong, Shih, Au, & Zimmerman, 2007).

In this work, we propose a bedside device called "SleepCompete", which has been designed to promote healthy sleep patterns in a fun and useful way for children. At the same time, SleepCompete aims to support parents who are trying to promote healthy sleeping habits in their children: providing transparency about children's sleeping behavior and reducing occurrences of children waking up their parents in the middle of the night.

2 Related Work

Our research draws upon related work that investigated how to efficiently monitor sleep behavior. Choe, Consolvo, Watson, & Kientz (2011) highlight relevant design concerns when using technology to improve sleep behavior. Mhóráin & Agamanolis (2005) derive sleep patterns from monitoring a person's eye movements; they use a wearable solution in the form of an eye mask. van Laerhoven, Borazio, Kilian, & Schiele (2008) use wrist-worn sensors (a combination of light and simple motion and posture sensors) and focus on body posture and movements during sleep as indicators for sleep quality.

In contrast to the aforementioned sleep monitoring systems, the social alarm clock app "Somnometer" (Sahami Shirazi, Clawson, Hassanpour, Tourian, Schmidt, Chi, Borazio, & van Laerhoven, 2013) requires the user to interact with the app on the smartphone in order to set the status of "awake" or "sleeping" respectively. Additionally, they add a social functionality to the app by allowing users to share their sleep ratings with friends on Facebook. The results of their study show that their app raises awareness of sleeping behavior and that sharing sleep information with others has the potential to positively affect sleeping behavior.

The "Reverse Alarm Clock" (Ozenc, Brommer, Jeong, Shih, Au, & Zimmerman, 2007) promotes healthier sleep patterns for children and parents alike. The clock communicates whether it is time

for sleep or for getting up in a way that children understand. As a result, the clock keeps children from getting out of bed in the middle of the night and interrupting their parents' sleep.

While previously published research has looked into different sleep related aspects separately, we aim to integrate the findings of these works into one package; creating a gamified application that will monitor and share sleep behavior with others in order to promote and encourage healthy sleep behaviour in children.

3 SleepCompete

3.1 The Concept

Our work targets families who wish to improve the sleeping behavior of children in their household: data gathered during sleep monitoring must interest and appeal to both children and their parents. Our intelligent device, which we call "SleepCompete", monitors children's sleep habits and then presents this information in a simplified (and even fun) way to children, which they can easily understand. This information is shared not only with parents, but also with friends or siblings as part of a competitive game (gamification) that persuades and encourages healthy sleep patterns. More concretely, SleepCompete allows children to play a game while they are sleeping. The objective is identifying and facilitating healthy sleep patterns: providing parents with transparency about children's sleeping behavior.

Whilst a child sleeps, they participate in the SleepCompete game. The goal of the game is to get a high 'score' by accumulating as many 'points' as possible: points are only awarded during phases of 'sleeping soundly'. The real-time score is shown on the SleepCompete device using an LED matrix. Additionally, children are able to compare their scores with friends' scores in (near) real-time, which is shown on a LCD touch display on the device. Moreover, parents can access and monitor their children's scores via a web interface: accessible both as a web portal and through an app for smartphones.

3.2 Objectives

SleepCompete aims to support parents who wish to improve their child's sleep routine and reduce stresses at bedtime. Its particular purpose is keeping children from getting out of bed in the middle of the night and interrupting their parents' sleep (Ozenc, Brommer, Jeong, Shih, Au, & Zimmerman, 2007). In addition, parents may use a dedicated web portal to monitor their child's sleep behavior (over days, weeks or months) as well as receive reliable information relating to their child's sleep. Additionally, we propose that SleepCompete may prompt parents to provide feedback and rewards to children beyond the scope of the device.

With the gamification concept, we expect children to enjoy and participate with SleepCompete on different levels. Firstly, children collect points as a reward for a good night's sleep, generating a 'sleep score'. This allows children to enjoy monitoring their own sleeping behaviors whilst also introducing a level of competition: children can try to beat their own or a friend's sleep score. This form of enjoyable competition with friends may encourage healthier sleep patterns. Children will benefit from the positive reinforcement that the device offers (better performance means better sleep scores).

The introduction of SleepCompete to reinforce positive, healthy sleep behaviors at bedtime may benefit the family as a whole. Children, engaged by SleepCompete, are expected to improve their sleeping habits. Parents may benefit as occurrences of nightly waking will likely decrease, the increased knowledge of healthy sleep habits may influences their own sleep behavior. We propose that positive attitudes to sleep will (1) reduce agitation at bedtimes and (2) improve overall household relations.

3.3 The Prototype

We designed SleepCompete as a cube shaped bedside unit; the outside of our prototype can be seen in Figure 1. The design of the device should allow the user to be able to choose which 'face' of the unit they can see.

Figure 1: SleepCompete prototype. The LED Matrix displays the score visualization

Whilst the LED dot matrix offers at-a-glance score information, those that find the light distracting can turn this side away from view. The LCD touch display of the device has two settings: a default setting which shows the time (like an alarm clock) and a numerical display

showing the sleep score of the user and selected friends. We believe that this approach satisfies important practical considerations: the cubed design caters for preference for those who may find the light and information displays of SleepCompete an impediment to sleeping.

The Sleep Compete device operates by 'sensing' sleepers' movements. This information is stored and displayed on the device and shared with selected friends' devices as well as with parents' analytical platform.

We built the prototype using the Microsoft Gadgeteer platform (Microsoft, 2013). Gadgeteer is a rapid prototyping platform, which allows for easy integration of hardware components. Within our device we included: a mainboard (GHI Fez Spider), a USB module with an SD card to provide power and data storage, an LED matrix module to display the sleep score visually, a button to turn the sleep sensing on and off, a Wi-Fi module (GHI Wi-Fi R521) which relays the data gathered to a web server, an LCD display (GHI T35 Display) to display time and score information textually, an accelerometer and a motion sensor (GHI PIR module) to sense sleepers' movements.

4 Pilot Study

For the pilot study, we created two fully functional SleepCompete devices to conduct an overnight experiment with adult participants from the development team. Each participant slept next to a SleepCompete prototype with an accelerometer module placed on their bed and the PIR module facing their sleeping position. Points were awarded if little or no movement was sensed during allocated time periods (for simplicity we divided each hour into 8 time segments in order to record a total of 8 hours of sleep). Additionally, to verify the effectiveness of the motion sensing, we used cameras to track the participants' movements as they slept. Analysis of these images in combination with gathered accelerometer data suggest that the accelerometer readings were mappable to physical movement: an example is shown in Figure 3.

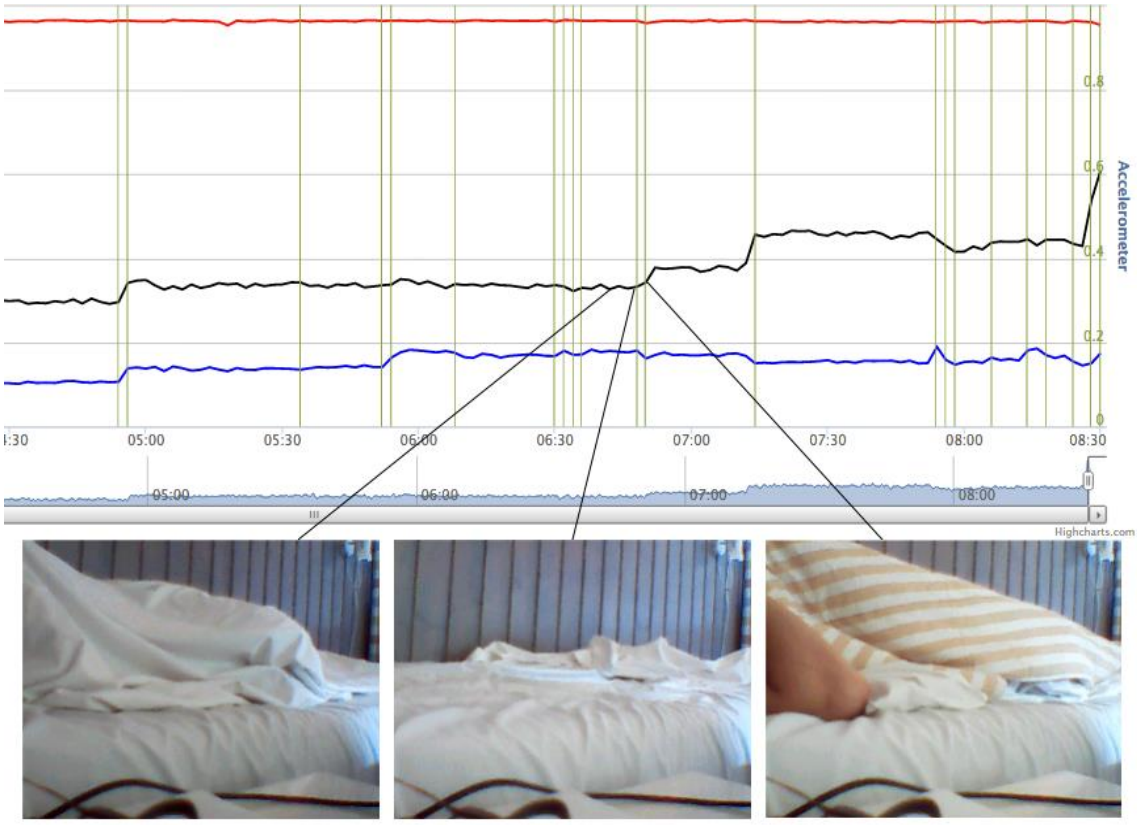

Figure 3: Camera images captured related to movements recorded from accelerometer during implementation

5 Ongoing and Future Work

We have described the design idea, objectives, and our pilot study with a fully functional prototype of SleepCompete. However, there are still open questions with regard to the suitability, effectiveness and feasibility of the design.

Through ongoing work and further pretests, we aim to improve the prototype system. This includes improving the robustness and accuracy of our prototypes and evaluating the effectiveness of the device in general and specifically establish how reliable the relationship between movement and quality of sleep. Further, we will develop the web portal for parents (a mock up is shown in Figure 4) including easy to understand visualization of data analysis. Additionally, we intend to incorporate further game features (such as levels) to improve motivations for children long term. We shall achieve these by running long-term trials with families and children, conducting semi-structured interviews with participants and surveys with larger user groups.

A limitation of our concept is that, in the case of sleep, more is not always better, as health recommendations provide an upper limit for daily sleep. Analysis of long-term effects should

provide insights into whether upper limits are reached and countermeasures have to be implemented in the game.

Overall, we believe that our work on SleepCompete can contribute to a better understanding of technology use in family environments that support healthy sleep behaviors, and explore how playful and social interaction with technological devices can positively impact health in a way that supports children and parents alike.

Figure 4: Mockup of SleepCompete Analytical Web Portal

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References

Ayas, N. T., White, D. P., Manson, J. E., Stampfer, M. J., Speizer, F. E., Malhotra, A., & Hu, F. B. (2003). A prospective study of sleep duration and coronary heart disease in women. Archives of Internal Medicine. 163 (11), 205-209.

Bryant, P. A., Trinder, J., & Curtis, N. (2004). Sick and tired: does sleep have a vital role in the immune system? Nature Reviews Immunology. 4 (6), 457-467.

Choe, E. K., Consolvo, S., Watson, N. F., & Kientz, J. A. (2011). Opportunities for computing technologies to support healthy sleep behaviors. In 2011 Annual Conference on Human Factors in Computing Systems (CHI 2011), 7-12 May (3053-3062). Vancouver, BC: ACM.

Maquet, P. (2001). The role of sleep in learning and memory. Science. 294 (5544), 1048-1052.

Mhóráin, A. N. & Agamanolis, S. (2005). Aura: an intimate remote awareness system based on sleep patterns. In 2005 Annual Conference on Human Factors in Computing Systems (CHI 2005), 2-7 April Portland, OR: ACM.

Microsoft. (2013). Microsoft .NET Gadgeteer is an open-source toolkit. Available: http://www.netmf.com/gadgeteer/ [Accessed 19 December 2013].

Morillo, D. S., Ojeda, J. L. R., Foix, L. F. C., & Jiménez, A. L. (2010). An accelerometer-based device for sleep apnea screening. IEEE Transactions on Information Technology in Biomedicine. 14 (2), 491-499.

NHS. (2013). How much sleep do kids need? : Gov.uk. Available: http://www.nhs.uk/Livewell/Childrenssleep/Pages/howmuchsleep.aspx [Accessed 19 December 2013].

Ozenc, K. F., Brommer, J. P., Jeong, B.-K., Shih, N., Au, K., & Zimmerman, J. (2007). Reverse alarm clock: a research through design example of designing for the self. In International Conference on Designing Pleasurable Products and Interfaces (DPPI 2007), 22-25 August (392-406). Helsinki, Finland: ACM.

Sahami Shirazi, A., Clawson, J., Hassanpour, Y., Tourian, M. J., Schmidt, A., Chi, E. H., Borazio, M., & van Laerhoven, K. (2013). Already up? Using mobile phones to track & share sleep behavior. International Journal of Human-Computer Studies. 71 (9), 878-888.

Schmidt, A., Shirazi, A. S., & van Laerhoven, K. (2012). Are You in Bed with Technology? IEEE Pervasive Computing. 11 (4), 4-7.

van Laerhoven, K., Borazio, M., Kilian, D., & Schiele, B. (2008). Sustained Logging and Discrimination of Sleep Postures with Low-Level, Wrist-Worn Sensors. In 12th IEEE International Symposium on Wearable Computers (ISWC 2008), 28 September - 1 October (69-76). Pittsburgh, PA: IEEE.

Wagner, U., Gais, S., Haider, H., Verleger, R., & Born, J. (2004). Sleep inspires insight. Nature. 427 (6972), 352-355.

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