SleepLight: Improving perceived quality of sleep through sharing

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ABSTRACT
The majority of people is still experiencing a lack of sleep in their everyday routine. This research discusses a correlation between sharing subjective sleep data among couples, who are living apart, and the perceived quality of sleep of the individual, while acting within the periphery of people's attention. This can be supported with various related studies, which claim an emerged form of connectedness between people who share their perceived quality of sleep. SleepLight, the design presented in this paper, was evaluated by four individuals, two couples, in a two-week study. The results indicated no positive correlation yet between the sharing sleep data with SleepLight and the improvement of perceived quality of sleep. However, it showed an increase in awareness on sleep and hints to a possible increase of perceived quality of sleep during the 14 days of research.

Author Keywords
Perceived quality of sleep, couples, peripheral interaction, tangible interaction, light interaction.

ACM Classification Keywords
D.4.4 Sending, Message.

INTRODUCTION
Sleeping is part of the everyday life routine of people. People tend to neglect sleep to do more activities during the day [3], which eventually leads to a lack of sleep, leading to a decrease in overall performance [21]. While looking at the statistics of National Institutes of Health (NIH) [12] around 70 million Americans encounter effects of sleep disorder and regular lack of sleep. As a result, productivity was decreased with a loss of almost 50 billion dollars.

Sharing sleep data has become a promising solution on improving the overall quality of sleep. Previous work about sharing personal sleeping data by Kim [9] revealed that it leads to a more intimate bonding between people. Furthermore, when being aware of each other's perceived quality of sleep, people might become aware of each other's lifestyle and take people's sleep rhythms more into account. Sharing sleep data might as well enhance reflection on oneself to improve their own sleep quality [9]. A different study of Scherini et al. [18] revealed the positive increment of connection between partners living apart, who shared their sleep status. Since the presented paper addresses similar aims it can be promising in order to influence perceived quality of sleep.

Since sharing sleep data enhances connectedness between people, implementing this in a design might have benefits for both partners and might consequently improve their perceived quality of sleep. It could enable partners to become more aware of each other's sleep behavior, when sleeping apart. The objective of the presented research was: seeking for changes in people's perceived quality of sleep, while sharing subjective sleep data with their partner who is living apart.

In this user study two couples, four individuals, were given the opportunity to share their perceived quality of sleep through a physical device, called SleepLight. The device enables the individuals to interact with their partners by submitting sleep data. The aim of this study was to find a correlation between sharing subjective sleep data among couples, who are living apart and the perceived quality of sleep of the individual, while acting within the periphery of people's attention. By enabling participants to share their perceived quality of sleep, they are stimulated to be more occupied thinking about their sleep behavior. Also, because the participants will be asked to share their perceived quality of sleep with their partners. It might also be a stimulation to become more aware of their sleep behavior which could result in an improvement in their perceived quality of sleep.

THEORETICAL BACKGROUND

The influences of sleep
The field wherein this research was conducted is the psychological science on how sleep affects us people and to what extent people are aware of their sleep behavior. Sleep is labeled as mysterious aspect in people's daily routines [19], but is one of the basic needs people have. When people become more aware about their sleep behavior, the sleep quality might improve [13]. Awareness on sleep behavior might be improved with the use of its surroundings. An

ambient environment as well as scheduling sleep pattern has resulted in improving quality of sleep [13]. Sleep disorders are labeled as public health issues, since a lack of sleep decreases performances [14] and might influence the mood condition of people. This can affect anyone in their surroundings [14].

Peripheral interaction

Since the deployed device, SleepLight, is used every day, there is a focus on facilitating peripheral interactions. Most of the everyday systems that are equipped with technology require a focused interaction of the users according to Bakker et al [1]. This study accentuated the fact that people are able to perform physical actions in the background while perceiving other information. Regarding to the presented aims of the design SleepLight, this could be useful in order to let participants interact with a minimal amount of focus. The product then can be fluently embedded in their daily life and might shift from the focused attention to the peripheral attention. This might benefit the way the participants submit their perceived quality of sleep through the device, in order to obtain quick and intuitive data.

Color scale

The device SleepLight used a light interaction in order to enable the participants to submit their perceived quality of sleep. The colors green and red were used in order to convey respectively good- versus bad sleep. These colors are based on other research studies conducted by Mottola et al. [11], Hughes et al. [6] and Schapira et al. [17] for example, since there could not be found sufficient research on the colors in contrast to each other. Both colors are separately conveying a quality, whereas together there cannot be found any relations. Therefore the color scale of red to green was verified before the user study by ten independent individuals. They all unanimously agree with the color scale which either conveys bad sleep (red light) or good sleep (green light).

RELATED WORK

There are several examples which maintain elements of the objective presented in this paper: to find a correlation between sharing subjective sleep data among couples, who are living apart, and the perceived quality of sleep of the individual, while acting within the periphery of people's attention. Kim [9] revealed strengthened connectedness within a social network of people, while sharing sleep behavior. The study of Kim relates to a social network, whereas the study presented in this paper relates to the connectedness between partners. In a 3-6 weeks deployment study participants used 'BuddyClock', an alarm clock, in order to eventually create better connections in a group. Moreover, Scherini et al. [18] presented how the design 'Somnia' could enhance the sleep quality of partners living apart. The system of 'Somnia' is a pillow designed to support remote couples to fall asleep faster and to improve their quality of sleep.

Another topic in the presented research is the connectedness of partners living apart. The couples both are connected via separate SleepLight devices. A study by Design Incubation Centre [5] developed a product called 'RolyPoly', with which they researched the connection between partners who are living apart. RolyPoly is an installation realized to let two individuals experience the presence of each other, even though they might be physically apart. The study, presented in this paper, might benefit from the research on the design RolyPoly.

SleepLight, the presented design, is also contributing to the field of peripheral interaction. In another sleep study, Bauer et al. [2] found some sufficient results on how peripheral interaction in the sleep domain affects the awareness on sleep behavior. According to Bauer et al. there was still an increased awareness, while interacting in the periphery of people's attention. However this particular study designed a display, whereas SleepLight is a physical device and might therefore will obtain different results.

DESIGN

The study, elaborated in this paper, aims finding a correlation between sharing subjective sleep data among couples, who are living apart, and the perceived quality of sleep of the individual, while acting within the periphery of people's attention. In order to realize connectedness in the design, multiple designs in pairs of two were coupled. SleepLight (see figure 1) functions as a communication tool between the two partners and involves a few interactions. The design is able to send and receive data. Sending implies submitting own perceived quality of sleep whereas receiving implies obtaining the data of one's partner.

The design of SleepLight aims at presenting the perceived quality of sleep in the periphery of the user's attention. This interaction then tends to become a subconscious interaction, because it might decrease the level of attention and effort to communicate the perceived quality of sleep. In order to accomplish this, the interaction needs to be as simplistic as possible. In the design a color scale versus a number scale was chosen, since color ratings like a 5.0 and 5.5 can be harder to distinguish against each other as color than as number. Therefore the interaction might shift more to a peripheral interaction eventually. The main interaction consists of turning the upper part of the device to a certain position which correlates to the user's perceived quality of sleep grade. This rotation is supported by light gradually scaled from yellow to red or green. In this scale, red relates to bad sleep and green to good sleep. Just after grading through this color scale the sending interaction ends when pressing the device as confirmation of a final grade or by stopping to turn the device. This last function is added in order to lower the amount of effort while interacting with the

Figure 1. SleepLight prototype which was used to perform the field study.

device, which makes it more peripheral. This peripheral interaction is needed to obtain sleep data that is as close to the actual perceived quality of sleep as possible. It is assumed that when people analyze their own sleep of a specific night for too long, they will indicate a value that is closer to their objective perceived quality of sleep. To put this in perspective, a participant can wake up feeling lousy but over time realize that they slept for a long period of time which will make them indicate another value for that night.

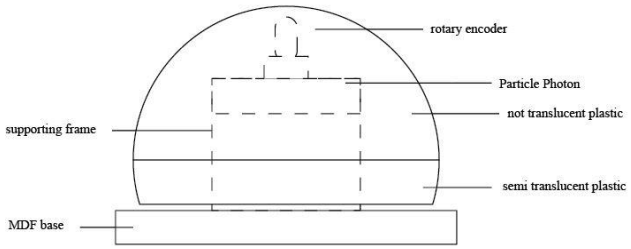

Figure 2. Schematics of the SleepLight prototype.

The receiving interaction consists of multiple interactions. When receiving the data from the partner's SleepLight, the lights will gently start 'breathing'; fading between the colors white and yellow. This 'breathing' light functions as notification or signal to the user for new data. In order to see the received data, the user presses the upper part of the device(see figure 2) once and lights will slowly turn on and give an indication about how his/her partner rated his/her sleep that day. After pressing the device, a signal is sent to the partner too, which shows that the partner saw the data. This second signal is integrated to enhance communication and that might eventually comfort one's partner.

These send- and receive interactions are possible in two directions such that partners both can submit their sleep to the other. When the user wakes up he/she can see the data of the other, if it is already sent, and then evaluate his/her sleep. In order to prevent users from waking up by the design, the light source is directed downwards to a fixed surface where the device is located on. Due to this vertical direction of light, SleepLight carefully considers the way it signals its users.

USER STUDY SETUP

The aim of the user study is to find a correlation between sharing subjective sleep data among couples, who are living apart, and the perceived quality of sleep of the individual, while acting within the periphery of people's attention. The involvement of one's partner, who is living apart, might improve or worsen perceived quality of sleep. Besides, there was examined whether using SleepLight as an intermediate to share sleep data, would support the fact that visualizing sleep data would have more impact on one's feeling about sleep than a standard text message. With the use of SleepLight, the communication between partners would become more physical and possibly more valuable. Lastly, insights could be gained on the user's behavior with SleepLight. There was expected that the device would shift from the center of attention towards the periphery of attention over time. As mentioned, this is needed to obtain insights in the perceived quality of sleep rather than the objective quality. The interaction with the device could need time to be integrated gradually into people's daily routines which will also be evaluated during the research.

Participants

During this study two couples, four participants, with the age of eighteen to twenty-five years old, with a long-distance relationship were recruited. In this particular study a long-distance relationship was defined as a relationship in which both partners are only able to sleep together during the weekend or less. The selected age scale was based on the fact that most of the people around this age encounter a lack of sleep on a daily basis [10]. Besides this, participants need to use Wi-Fi, since SleepLight let participants interact over the internet.

Before the user study started, the participants had to be informed about what was going to happen during the research and what was expected of them. They were given certain insights into they could install and use the device, including the way they are able to indicate their perceived quality of sleep to their partner. They were not informed with the purpose of this research.

Setting

The field study was conducted in a home setting, wherein the SleepLight devices were placed for 14 days. Each individual received a SleepLight device connected to the device of their partner. It was expected that the SleepLight would be used mainly during the morning routine of the participant in their bedroom. Each morning the participant was asked to indicate how well he/she thought he/she had slept and then send this data to their partner by setting a color from yellow to red or green. The partner performs the same interaction.

Procedure and analysis

Before and after the field study a semi-structured interview was performed to make a comparison on what changed in the

daily routine of the partners and the way they evaluated how SleepLight affected their sleep behavior. During these interviews questions were defined in advance to the interview in order to be able to guide the interview to obtain the insights that were needed. In order to obtain insights into the sleep behavior of the participants it was needed to understand them. During the interview there was needed the ability to differ from the standard set of questions in order to fulfill this goal. Especially during the interview at the end of the field study, wherein it was also needed to obtain insights into events that were the cause of values that differ extremely from the obtained average values. With the use of the qualitative data from the semi-structured interviews there is a possibility to observe changes in the perceived quality of sleep and how the involvement of a partner contributes to their sleep routine. This qualitative data gave insights into how the participants experienced their perceived their quality of sleep each day. This can be the same or different than the obtained quantitative data. Questions were asked regarding to their sleep behavior and the sleep behavior of their partner to an extent that they were aware of.

Apart from this qualitative data, real-time quantitative data was received via the online platform Google Drive [15] during the user study. This data was also needed for the research, due to the fact that there was a possible difference between how the participants perceive their quality of sleep each daily and their perceived quality of sleep while reflecting over an entire week. Each time a participant submitted their color rating for their perceived quality of sleep, this value was sent to Google Drive. Then a possible change of perceived quality of sleep can be evaluated over time as well, which could differ from their perceived quality of sleep which they indicated during the interviews. A self-report questionnaire, sent over the web, was conducted at the end of each week in order to evaluate whether the actions of the participants were equal to what they actually intended. There was aimed to measure to what extent the interaction was peripheral. This was translated into questions which mainly addressed the way participants thought they used the device. Using this information during the study, there can be found possible instances of an inequality between their daily indicated perceived quality of sleep and their perceived quality of sleep which they indicated weekly. These differences could be interesting, since participants might interact with less attention and can forget what they submitted. Therefore the participants can note another sleep quality grade in the questionnaire. Combining these research methods, an elaborate overview of the perceived quality of sleep of the participants can be evaluated, and if the SleepLight had any influences on their communication.

FINDINGS

During this study the participants used SleepLight in their home environment for 14 days. The aim in this study was to find a correlation between sharing subjective sleep data among couples, who are living apart, and the perceived quality of sleep of the individual, while acting within the periphery of people's attention. Before and after the study a semi-structured interview was performed. This part of the study together with the self-report questionnaires was the qualitative data, whereas the real-time data obtained via Google Drive was quantitative data. In order to analyze the interviews correctly there was used a specific coding method [16]. All answers and remarks were noted on paper and several iterations of affinity diagramming [20] were done. This resulted in a clustering of all the qualitative data. Afterwards the clusters were labelled and interpreted in order to draw conclusions.

First interview

The aim of the first qualitative interview was to gain insight on how perceived quality of sleep is communicated between partners without SleepLight. During this first interview there was found that all the participants, for instance, thought that the perceived quality of sleep was connected to the duration of sleep at night. Therefore they did not surely foresee that there would be much improvements in perceived quality of sleep. To evaluate how the involvement of one's partner could have influence on the perceived quality of sleep, the communication concerning perceived sleep quality towards each other as well as the amount of time spent together each week were asked. Since all the participants sent a text message to their partner in the morning to communicate about how they slept, the participants stated that the communication was preferred digitally. At this moment they did not believe that changing the habit of sending a text message into a more physical interaction could stimulate their sleep behavior and eventually improve the perceived quality of sleep.

Real-time data and self-report questionnaire

A possible change in the perceived quality of sleep can be as well evaluated over time with the use of the real time data and self-report questionnaires. Some interesting findings were acquired in the real-time data. There were several moments when the participants rated their sleep with a deep green light, which indicates a maximum value of ten. There was found that this referred to the weekends, since then the duration of sleep was higher. In other occasions they slept a lot less several times, namely a deep red light, which indicates approximately zero. From the self-report questionnaires a few things were found. The participants rated their sleep quality average of the week somewhat higher than they submitted during the week (the real-time data). Next to that, the participants still sent a message toward each other to communicate about their perceived quality of sleep.

Second interview

The aim of the second qualitative interview was to gain insights on how the device had influences on the perceived quality of sleep and how the device was used in the everyday life of the user. In the user study there was no direct relation found concerning improvement of perceived quality sleep. One of the participants stated: "I do not think that my perceived quality of sleep has improved, but I have become more aware about my quality of sleep." Other participants reported similar thoughts. The participants did become more aware of perceiving sleep quality, since they actively thought about it each day. Furthermore, participants reported that they still sent text messages to each other. Despite this fact, the participants stated that the experience with the device had extra value for them in comparison to a simple digital text message. The notification which SleepLight sends back after reading gave a confirmation which again provoked communication between the partners. The participants stated that the notification itself did not provide extra value, because there was still a need to communicate with each other about the submitted colors. For one participant, the red color triggered to communicate with their partner, whereas the yellow or green colors did not. Besides, the participants preferred the light scale versus a number scale since it gave more ambience and was a more beautiful interaction.

The participants stated that they used SleepLight in their morning routine, since the light of the device caught the attention. The participants stated that when waking up, the first action they performed was sending their perceived quality of sleep towards their partner. Although, when one participant for one day did not send data earlier, the other intended to forget to use the device. After a while the focus as well as the effort, while interacting, became less. As one of the participants stated "Over time I became less focused on the device". The interaction became part of the routine and therefore easier to do subconsciously.

DISCUSSION

As found in the obtained quantitative data (real-time data) there was a small improvement in the perceived quality of sleep. Although, the participants did not experience any improvements in their perceived quality of sleep during the user study. This finding can be clarified with a study of Irwin et al. [8], which claims that changes in sleep behavior can only be noticed after 16 weeks. This can explain the difference between the obtained data and the participants' answers in the interviews. The improvement in perceived quality can also be argued by the possible change in baseline of color ratings. Whereas the first day orange relates to a five another day the same orange color can relate to a six. So the ratings can be based on other parameters about changing personal behavior as well. However, all the participants stated that they had become more conscious about their quality of sleep. A few

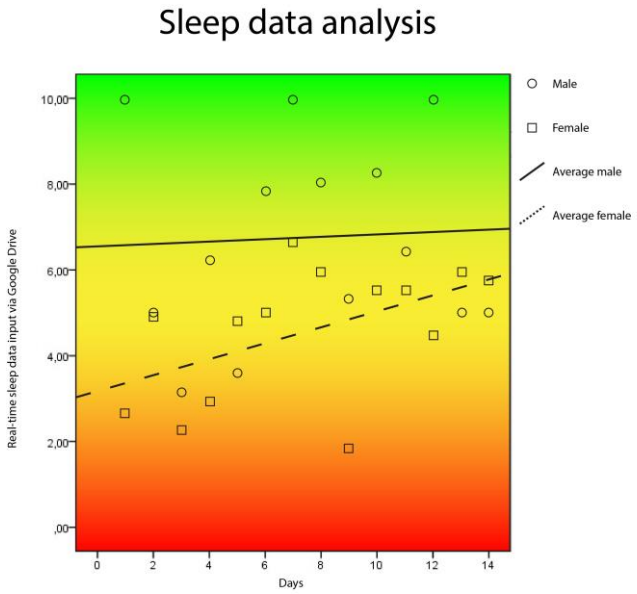

Figure 3. Sleep data analysis; the graph shows the rating of the perceived quality of sleep over time of couple 1.

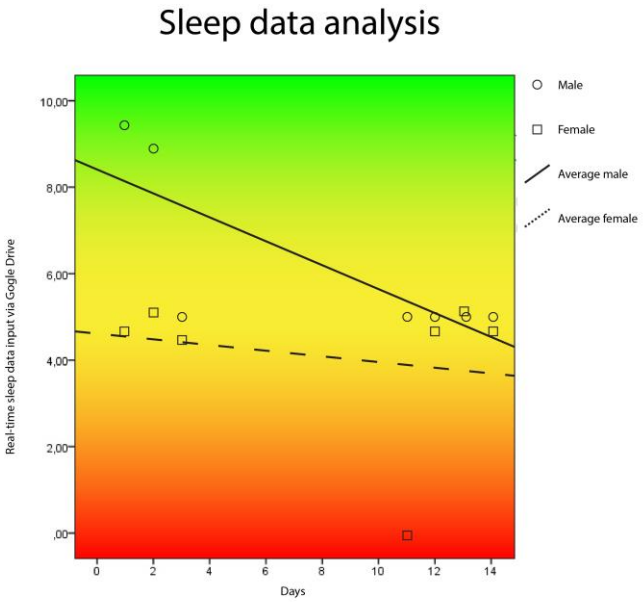

Figure 4. Sleep data analysis; the graph shows the rating of the perceived quality of sleep over time of couple 2.

participants even accentuated that the research study changed their perspective on sleep quality.

The obtained data on Google Drive was used to create a scatter plot per couple via SPSS [7], which is a program, developed by IBM, which is able to execute statistical analysis. The background of the graphs correspond to the color that the participants submitted related to a value in a

number scale from zero to ten. In the first graph (figure 3) there can be seen minor improvements for the male participant, and major improvements for the female participant with regard to their perceived quality of sleep. This average line illustrates a distorted view of improvement, since sleep quality could vary each single day. As can be seen, the perceived quality of sleep differs a lot each day, but it is still worth mentioning that a slight improvement can be seen at the first couple. At the second couple (figure 4) there can be seen behavior which is completely different. During the 14 days of in-field research, the second couple didn't use the device for multiple days in a row. After these days of not using the device, they submitted completely different grades, in colors, for their perceived quality of sleep. This observation is especially clear while looking at the male of couple 2. His average line shows a major decrease in the grade of perceived quality of sleep. However, while focusing on this graph there can be seen that this individual only submitted two high values at the beginning of the research and average values during the remaining days of the user study. This results in an average line that decreases tremendously.

It is also noticeable that there are some submitted values that differ from the average a lot. While analyzing the corresponding dates, there could be concluded that these extreme values mostly relate to the weekend days. There could be observed that on average, the values were submitted later in the morning which could indicate that the participant was able to sleep for a longer amount of time on these days. This analysis was confirmed in the interviews at the end of the user study.

There was intended to get the interaction with SleepLight in the periphery of attention. The device was intended to integrate within the morning routine of the user, where it could be beneficial for the intended interaction thereafter. As expected during the first days, the interaction with the device was mainly with focused attention. After a while the interaction started to shift from focused attention to peripheral attention. The participants did mention that the interaction of sending their perceived quality of sleep was still intentional. However, they mentioned that there was an imprecise control on the device which might indicate that this shift is in progress: "Over time, I focused less on the interactions with the device." This shift can be related to the work of Clear [4]. This research was about getting used to new habits. In this study Clear found that it takes 66 days to get used to a new device. For further research it can be valuable to conduct a user study of this duration in order to discover interesting results in the field of peripheral interactions. Despite the learning curve in the interaction, the participants stated that in some cases the interaction was much focused. This was mostly due to received values at unexpected moments, e.g. in the afternoon. Occasionally, this unexpected message was just because it was during that time slot. However there were also messages which the participants did not even send to each other, which were eliminated from the research in discussion with the participants. This was caused due to an error in the technology of the design. The participants did not bother a lot about these errors as they mention in the interviews, although it might had some effects on the focused interaction.

Limitations

During this research a lot of attention was spent on the mechanics and the aesthetics of the design. Yet there were several difficulties with the mechanics of the presented design. For example, the mechanism that made SleepLight able to rotate and push was quite fragile and weight-depended, which bothered one of the participants in usage. As a result of this difficulty, brazed components could break. Next to that, the design was handmade due to limitations, which made the design vulnerable in its imperfections. For further research a more exact method (e.g. laser cut) is recommended. These limitations could be taken into account to create a more solid design, which has less weaknesses during the study. The fact that the presented design had these weaknesses hindered the research in a way that the participants once struggled to interact with the device.

Furthermore, it is needed to consider the privacy issues of participants, since multiple participants prefer to install the device themselves. This is reasonable, due to the fact that the study was meant to be located in the context of their bedrooms, which is their so-called private space. This caused some difficulties with the installation and construction of the device, since the participants needed to be able to connect the SleepLight to their internet by themselves. Apart from this, the privacy issues also caused participants to possibly reject participating in the research.

Another issue that was encountered during the installation was the internet connection itself. The used devices connected via the participant their home networks. However, this connection might be secured or using a through connection which is unsupported by the used microcontroller. This could also be a reason for a participant to drop out.

Future improvements

In order to obtain significant results, a 14-days research with four participants was insufficient. For a significant ($P < .05$) result, this research had to endure for at least twenty-seven days, equal to 27 data samples. This is based on findings via SPSS [7]. These 27 samples hold, as long as the participants continue to show the same developments as they did in this research until now. Also, in order to obtain a more general result more couples will be needed. The amount of couples needed, could not be determined since there was no indicator of a good couple or participant found.

Something that also has to be taken into account is the context of the research. Some of the participants indicated that they woke up due to the light of SleepLight. Since the research context is sleep, a better indicator could be used in

order to visualize the participant's perceived quality of sleep, or the "breathing" notification could be set less bright. This might benefit the research on multiple aspects, because it then can make the device less obstructive. Since light in this design tends to get too much attention, it could also shift to a more subconscious/peripheral interaction with the device.

CONCLUSION

In this paper a correlation between sharing subjective sleep data among couples, who are living apart, and the perceived quality of sleep of the individual, while acting within the periphery of people's attention. The study was conducted by four participants (two couples) in a home setting for 14 days. The presented study in this paper hinted that there was no significant relation between perceived quality of sleep and the involvement of one's partner in the 14 days of the aforementioned user study. The participants did not explicitly notice changes, whether they do notice an increase in awareness on their sleep behavior. The participants argue in the evaluated interviews that the involvement of the participant their partner in sharing sleep data had this particular influence, because the device activated the participants to rate their sleep very accurately each day.

Furthermore, the device provoked additional conversations towards each other to gain better understanding about the partner their perceived quality of sleep. Concluding from the interviews, the device was eventually used in the daily routine of the participants. The interaction has become more subconscious, which indicated that there is indeed a possible shift in attention from focused to peripheral. There is expected that the device might be fully used in the periphery of attention, after a few months.

Although the design methods and approaches were near to be perfect, this research study might have some promising results. Future studies could do more research on other possible parameters on the actual impact of the design, since there is lack of research specifically done. A more extensive research can be conducted to get more significant results in order to draw solid conclusions.

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