# Does Being Monitored during Sleep Affect People on a Cognitive and a Behavioral Level?

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Abstract: Nowadays it is possible to monitor behavior or physiological features with specially-made devices that make self-monitoring an accessible and simple activity. Unknown is the effect these wearable devices may have on people's lives and this also applies to the area of sleep monitoring devices. The aim of this preliminary study is to address the extent to which sleep monitoring devices affect people on a cognitive and behavioral level. Four participants aged from 34 to 60, filled out a sleep diary for three consecutive weeks and wore in the latter two weeks a sleep monitoring device. Adjustments on a cognitive and behavioral level were observed, but this was probably due to participating in this study and completing the sleep diary as was indicated by the participants. Since the market for self-monitoring devices is rapidly developing and more accessible for lay people, it is important to investigate the reactive outcomes of these devices as they may have consequences for people who have a high adherence to self-control. Moreover, the knowledge about self-monitoring will improve which will lead to better interventions carried out by, for example, sleep coaches.

## 1 INTRODUCTION

An international collaboration between users and producers of self-tracking devices has emerged, called the 'Quantified Self' (www.quantifiedself.com). By exchanging information and with reviews of the products they keep each other updated. Due to the monitoring, users achieve more knowledge about their bodily functions and performance during the day. Self-tracking devices may additionally operate as an aid for interventions. The collected data are then transferred to a 'personal' coach, for example, through an application on the mobile phone. These coaches are able to advice and monitor patients remotely and for a sustained time period. Self-tracking devices utilized for these kind of purposes are rising (LeMaster et al., 2008; Going et al., 2003). According to Swan (2012) the health care industry is shifting towards an approach of personalized preventive health maintenance and away from an exclusive attention to disease treatment. For self-monitoring this means that due to the development of wearable devices the possibility emerges to monitor unaware processes, such as physiological features, instead of relying on self-reports.

Previous literature in diverse research areas shows that when self-monitoring is used as an intervention, successful results are obtained, for example: weight loss (Burke et al., 2011; Boutelle and Kirschenbaum, 1998; Wang et al., 2012; Butryn et al., 2007) improved academic performance (Amato-Zech et al., 2006; Maag et al., 1993; Shimabukuro et al., 1999) control of blood glucose levels (Karter et al., 2001; Martin et al., 2006) and less substance use (Litt et al., 1998; Helzer et al., 2002), although sometimes the effect of self-monitoring is small or not found (Hufford et al., 2002; O'kane et al., 2008). These results make the effect of self-monitoring ambiguous, which may have several causes, such as different study populations (different size and patient populations), diverse methods used and variable duration of the studies.

Much attention has been paid to the reactivity of self-monitoring. Reactivity is a phenomenon that occurs when individuals adjust their performance or behavior due to the awareness that they are being observed (Korotitisch and Nelson-Gray, 1999). Self-monitoring consists of two processes: firstly, self-observation: one must discriminate or notice the

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occurrence of the target behavior. Secondly, self-recording: one needs to record when the target behavior is occurring (Korotitsch and Nelson-Gray, 1999). Kazdin (1974) investigated with the performance on a sentence-construction task, different aspects of self-monitoring, such as response desirability, goal setting and feedback. They found several interesting results, but particularly relevant in this case were: (i) supplying a performance goal or feedback enhanced the reactive effects of self-monitoring, (ii) monitoring one's own behavior or being monitored by someone else was equally reactive, (iii) the process of self-recording, independently of observing the results, led to behavior change. These results indicate that when a person purely monitors himself, reactive behavior is seen. Moreover, the impact of the adjusted behavior can be augmented by setting a goal and/or providing feedback and an insight in the observed data is not necessarily needed to alter behavior.

The study of McFall (1970) shows that effects of self-monitoring can occur even without the determination of a goal. The participants were not motivated to stop smoking and every effort was made to minimize the participant's motivation to stop smoking during the study period. After 13 days of self-monitoring the frequency of having a cigarette significantly increased in comparison to the baseline condition, where the participants were secretly monitored by others. The long-lasting effect of a behavior modification after self-monitoring is unclear and longitudinal studies are needed to provide more insight in this matter. Subsequent studies after the 70s put more emphasis on self-monitoring as a tool for an intervention as opposed to investigating the aspects related to the process of reactivity of self-monitoring.

A recent article illustrated the possibility of reactivity in the baseline assessment of physical activity when using an accelerometer device (Motl et al., 2012). Two identical studies were carried out wherein persons with multiple sclerosis (MS) wore an accelerometer for seven days to collect baseline data and one week later wore a pedometer over a seven days period (first week of a behavioral intervention). They found a decrease of the average steps per day over the first week of the behavioral intervention compared to baseline measurements. Apart from the study of Motl et al. (2012), underemphasized are the consequences wearable devices may have on a cognitive and behavioral level.

This study investigates the reactivity effects of wearing a monitoring device during sleep. As where it is unclear to which extent people are affected when being monitored during sleep, although one is able to monitor their sleep at their own home and independently. Being monitored during sleep, regardless of the subconscious state of sleep, may influence the behavior before going to bed as well as the behavior after waking up. Additionally, persons may modify their cognitions about sleep because they become more aware of their sleeping habits. As a result, the device might show different results than it otherwise would have shown (normal night without monitoring). Sleep studies have traditionally required users to fill out a diary every morning (Carney et al., 2012; Keklund and Åkerstedt, 1997), but the opportunity arises to support sleep studies with a monitoring device for the home or to replace the diary altogether.

The sleep monitoring devices, available on the consumer market, all postulate that they are unobtrusive in a way that they do not disturb people during their sleep. Nevertheless, they can have an effect on a cognitive and behavioral level, but this has not been researched. As a result, with the current development of sleep monitoring devices increasingly being used by lay people, the aim of this explorative study is to address the extent to which sleep monitoring devices affect people on a behavioral and cognitive level. In this study the self-monitoring is occurring automatically and no specific attention is needed and no goal is set or feedback is given. Moreover, the awareness of being monitored plays an important role in this study.

# 2 METHODS

## 2.1 Participants

For this study four adults were recruited, aged between 34-60 years. Men and women were equally distributed. All participants stated that they do not experience any sleeping problems, but one of the participants reported sleeping somewhat different than usual at the time of the study because of her pregnancy. The participants were blind to the experimental hypotheses and were told that the purpose of this study was to research the overall sleep experience when being monitored during sleep.

## 2.2 Measures

The sleep quality at baseline was measured with the

Pittsburgh Sleep Quality Index (PSQI) questionnaire which determines sleep quality and disturbances over an one-month time interval (Buysse, et al., 1989). Based on a cut-off score of 5, participants can be categorized into "poor" sleepers (> 5) or "good" sleepers (≤ 5) The PSQI consists of 19 self-rated questions, divided into seven components: subjective sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbances, use of sleep medication and daytime dysfunction. An overall PSQI score was calculated from the seven components with a score range between 0 and 21 and higher scores reflect worse sleep quality. The sensitivity and specificity of the PSQI are respectively 89.6% and 86.5% (Buysse et al., 1989). In our sample it turned out that the two men had a score of lower than 5 as where the women had a score of 6. This suggests that the women may have some sleeping problems. However, the scoring range of sleeping problems runs from 6 to 21. The score of 6 falls in the lower end of this range.

The sleep monitoring device used in this study was the Actiwatch by Philips (Figure 1). It was developed to distinguish between physical activity and rest, and it is widely used in the sleep field for detecting sleep-circadian rhythm disorders. The Actiwatch uses an accelerometer to detect and log wrist movement, also known as actigraphy that indicates gross body movement. The model worked with was the Actiwatch Spectrum; it weighs 21 g, measures 31 x 28 x 10 mm and has a maximum sampling frequency of 32 Hz (Philips / Respironics, URL: http://www.healthcare.philips.com). The Actiwatch feels and looks like a standard wristwatch and was used as a tool to measure the effect of being monitored during sleep as unobtrusively as possible. As we believe the Zeo headband (Shambroom et al., 2012) is more obtrusive to wear during sleep than a wristwatch, since most people are already used to wear a watch and not to wear a headband. In addition, Cole et al., (1992) found that when comparing polysomnography with actigraphy, a wrist actigraph is able to measure sleep/wake parameters relatively accurately.

Subjective sleep experience was assessed by the Consensus Sleep Diary (CSD; Carney et al., 2012). The CSD was developed with the intention that it should be a consensus and standardized sleep diary for sleep researchers, who before its development would use a variety of divers diary formats.

For this study the core CSD was used which consisted of 8 items, including questions about initiating and maintaining sleep as well as a global appreciation of sleep (Table 1). Moreover, an

Figure 1: The Actiwatch Spectrum.

additional question was added to the diary whether the participant was well rested the next morning, to assess an insight in the sleep experience after wearing the device. In addition, to obtain a more complete answer on the behavioral effect of being monitored another question was affixed to the diary, namely: 'What did you do in the last hour before going to bed?'.

Table 1: Consensus Sleep Diary-Core.

| Consensus Sleep Diary-Core |
|---|
| 1. What time did you get into bed? |
| 2. What time did you try to go to sleep? |
| 3. How long did it take you to fall asleep? |
| 4. How many times did you wake up, not counting your final awakening? |
| 5. In total, how long did these awakenings last? |
| 6. What time was your final awakening? |
| 7. What time did you get out of bed for the day? |
| 8. How would you rate the quality of your sleep? (very poor, poor, fair, good, very good) |

Three structured interviews were held to analyze the cognitive and behavioral effects of sleep monitoring. The questions in these interviews are self-made and deal specifically with how participants experienced the device and questions concerning the cognitive and behavioral effects of wearing the sleep monitoring device. Examples of questions are: 'Did you feel the device last night?', 'Did you wake up of the device last week?', 'Did you think more of your sleep during the two weeks of being monitored?', 'Did you change any sleeping habits during the two weeks of being monitored?' and 'Did you sleep differently last week?'. In all three interviews the same questions were asked, including open as well as closed (with response options) questions, and some questions were only asked in the last interview, as a consequence of withholding the purpose of this study.

## 2.3 Procedure

At the start of baseline phase, the demographic variables like age, gender and the PSQI were assessed to characterize the sample. To establish how sleep was when not being monitored by a device, participants completed a sleep diary for a week prior to the two weeks of wearing the Actiwatch. In addition, participants also maintained the sleep diary during the two weeks of being monitored by the Actiwatch, as the sleep diary contained supplementary questions about sleeping habits. Participants were instructed to wear the Actiwatch when they went to bed and to take off the Actiwatch after the final awakening. During the two weeks of wearing the Actiwatch the three interviews were executed; after the first night, after one week and after two weeks. The reason for the time period of this study was that participants needed to get used to wearing the Actiwatch. In the last interview participants were debriefed regarding the purpose of this study and questions were answered.

# 3 RESULTS

All participants answered to the question 'if they changed any sleeping habits' negatively. However, further on in the interview it became clear that one participant did not drink any coffee anymore after dinner time and tried not to work after 10:00 pm (Table 2). As was indicated by the participant, this adjustment was probably a result of participating in this study. The same participant wanted to change the time of going to bed due to filling out the sleep diary, but did not succeed because of other obligations. The three other participants did not change any sleeping habits during the study period. Participants held a particular regularity in their activities before going to bed, according to the answers given in the sleep diary. The most prominent activity performed before going to bed was watching television, closely followed by browsing the web and reading. The activities showering and having a conversation were also often referred to. In addition, the bedtimes of the participants did not vary between the week of non-monitoring and the two weeks of being monitored by the device, as was shown in the Actiwatch data and the sleep diary (Figure 2). As answered in the last interview participants did not have the feeling of having slept differently when being monitored during sleep.

On a cognitive level, two out of four did think more about their sleep but stated that it was more a result of filling out the diary than of wearing the sleep monitoring device (Table 2). By completing the sleep diary these two participants got more conscious about their sleeping times. As said earlier, one of those participants tried to shift the time of going to bed to an earlier time, but accomplishing that was harder than expected because of other obligations. Two participants did not show any adjustments on a cognitive and behavioral level. One of the latter two had a strong 'Big-Brother is watching you' feeling during the study, but as was indicated by the participant, this feeling would be less when being monitored for own purposes.

Table 2: Results of reactivity in this study.

| | Cognitive changes | Behavioral changes |
|---|---|---|
| **Participant 1** | Went to bed later than expected. | Did not drink coffee anymore after dinner time. - Tried not to work after 10:00 pm. - Tried to go to bed earlier but failed due to other obligations. |
| **Participant 2** | Did not sleep as much as thought. | No changes in behavior towards sleep. |
| **Participant 3** | No changes in thoughts about sleep. | No changes in behavior towards sleep. |
| **Participant 4** | No changes in thoughts about sleep. | No changes in behavior towards sleep. |

*Note.* The cause of the changes above is not clear.

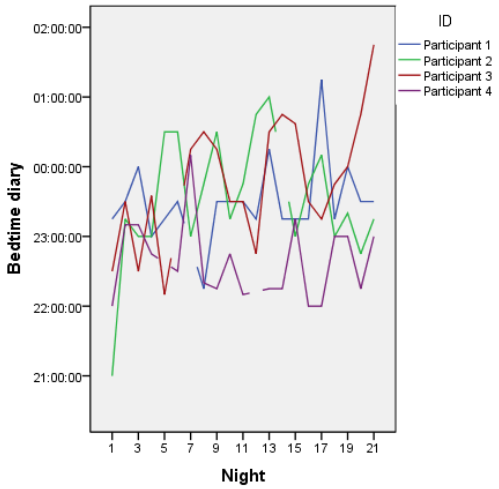


Figure 2: The diary bedtimes of the three weeks, displayed separately for each participant.

With regard to wearing the Actiwatch, after wearing the device for the whole study period two out of four did not feel the device anymore. The two other participants still felt it a bit because of the dimensions of the device and one of the latter two was not used to wear a watch during the night. To the question 'if the device bothered them' they all responded negatively and their sleep was not affected by the device. Two participants would wear the device in the future, but then for limited periods only.

# 4 DISCUSSION

This preliminary study shows adjustments on a cognitive and behavioral level, but could not separate whether these were due to the monitoring device or hose to participation in the study as such, and the daily diary keeping, as was indicated by the participants. Completing the sleep diary was more excitatory than wearing a sleep monitoring device. It was expected that due to wearing the sleep monitoring device people would pay more attention to their sleep. However, in this study, two out of four did not think more about their sleep. One explanation may be that, apart from the awareness of being monitored, utilizing the device was commissioned by this study and probably the participants were not interested enough in the subject of sleep for themselves. This means that they focused their attention to other concerns rather than to their sleep or sleep related properties. The medium obtrusiveness of the device may have played a substantial role in this as well. Moreover, the results may be dissimilar when there were participants involved who experience sleeping problems, but this point will be discussed in more detail later.

Regarding the effect of being monitored during sleep on a behavioral level, one participant did not drink any coffee more after dinner time and tried not to work after 10:00 pm. What the cause is of this change is unclear. However the participant indicated that due to participating in this study, the thought about sleep increased and the participant decided to carry out this behavioral change (also known as the Hawthorne-effect). Additionally, the same participant tried to modify his or her bedtime because of filling out the diary, but failed to go to bed earlier because of other obligations. No behavioral changes were observed for the other three participants. Kazdin (1974) proved with their study that when setting a goal or providing feedback the effect of change in behavior augmented. In our study no goal was set and no feedback was given. Despite this, our research indicates some behavioral changes, even with the open setting of this study and this is in comparison with the study of McFall (1970).

As mentioned before, being active with the sleep diary had a much greater impact on the study results than expected. This means that solely completing the sleep diary could have had a similar effect. Expected was that filling out the sleep diary would become more an automatic process, as is shown in several other studies (Litt et al., 1998; Stone et al., 2003). To know in the future whether these outcomes attributed to completing the diary or wearing the device, these measurements should become separate conditions in a study setup. However, due to the self-report nature of interviewing, the results found in this study still can be a result of the process of reactivity on wearing the device. Besides this, the results found in this study might be different if the sleep monitoring device would be more interactive and providing feedback.

Additionally, results could be different if the study population would comprise of people who experience sleeping problems or people who want to improve their sleep. This implies, when choosing people with sleeping problems as the study population, that a motivation or goal is implicitly set and feedback may be provided. These conditions could be expected to produce different results (Kazdin, 1974; Motl et al., 2012). As the wearable monitoring devices evolve into accessible objects for everyone, ignoring the reactivity of self-monitoring could be a serious omission. As is mentioned earlier, in this study some reactivity was observed, even with the open setting of this study. In contrast, two participants did not show any reactivity on each of the measurements (wearable device or sleep diary).

# 5 CONCLUSIONS

This explorative study shows that when people - who experience no sleeping problems - use an unobtrusive sleep monitoring device, it barely has an effect on a cognitive and behavioral level. Conversely, reactivity effects were observed, although unclear is what the cause is of these effects. It is important to note that due to the explorative character of this study no hard conclusion can be drawn. However, this study shows that filling out a sleep diary may be more intrusive than wearing a sleep monitoring device. As a result, we are

currently running a study which investigates the reactivity of filling out a sleep diary. Additionally, this study demonstrates that there are many unknowns about the effect of being monitored during sleep and this is also true for the wearable device in general. Whereas there has been substantial research into the development of wearable devices, there remains considerable scope for research on the effect these devices may have on people's lives. It is important to know the reactive outcomes of self-monitoring devices as the market for these devices is rapidly growing and this may have consequences for people who have a high adherence to self-control. Moreover, a better insight in the consequences of wearing such devices may improve interventions carried out remotely by, for example, sleep coaches.

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