Unobtrusive Sleep Monitoring[1]

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Summary

In this paper we will briefly discuss the role of unobtrusive sleep monitoring in behavioral treatments of sleep deprivation and sleep disorders. Lack of sleep is an issue for a large number of people. Sleep quality metrics can help these people in getting an objective view upon the quality of their sleep and discover trends in that quality over time. The golden standard for diagnosis sleep disorder, polysomnography, is not suitable for this purpose because it is obtrusive and uncomfortable. Actigraphy is a better choice, but it is limited in the richness and the accuracy of its sleep metrics. In a persuasive setting, sleep hygiene and CBT-I approaches could benefit not only from unobtrusive sleep monitoring techniques, but also from monitoring of adherence to sleep hygiene rules and therapy compliance for CBT-I.

Sleep and sleep quality

Sleep is a universal phenomenon. All people and all animals sleep. In former times, sleep was highly associated with the night, but nowadays the association is weakened. In contrast to fires and candles, electrically-generated artificial light enables people to be active during the night. Sleep deprivation is not without risk, however, and adequate sleep is critical for optimal day-time functioning [1, 2]. Insufficient sleep may cause neurobehavioral impairments, including lapses of attention, reduced working memory and depressed mood. Chronic sleep deprivation is associated with poor health. There is evidence that poor sleep has adverse endocrine, metabolic and inflammatory effects. The underlying causes of sleep deprivation are diverse. It may be caused by sleep disorders, but also medical conditions, occupational or social demands, and environmental conditions can hamper the quality of sleep.

Many people suffer from a lack of sleep. An outcome of 'Het Grote Slaaponderzoek 2008' [3] was that one out of five people in the Netherlands sleep poorly. Fifteen percent report not sleeping well multiple nights per week, while 6% indicate they almost never experience a good night sleep. In the USA, the National Sleep Foundation found in the 2009 'Sleep in America poll' [4] that 26% of the respondents experienced a good night sleep only a few times a week, while 24% reported experiencing a good night sleep only a few days a month or even less.

In sleep science, sleep quality is a neglected area [5]. The term has not been rigorously defined and there is only a vague understanding of how objective measures relate to the subjective sleep quality experience. There is evidence that the need for sleep differs between individuals [1, 2] and that there is variation between people in neurobehavioral responses to sleep restriction. Nevertheless, in both clinical and sleep research settings sleep metrics are applied that serve as a sleep quality indicator. Examples of metrics are sleep onset latency, total sleep time, number of awakenings, amount of REM-sleep and amount of deep sleep.

Sleep monitoring

Sleep monitoring could help people to understand the quality of their sleep, their sleep behavior and the relation between the two. Since sleep state is characterized by limited consciousness, people may not be aware of the

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characteristics of their sleep. In sleep studies, it is not uncommon to find discrepancies between objective sleep metrics and subjective sleep reports e.g. acquired via sleep questionnaires or sleep diaries [5].

In sleep laboratories, polysomnography (PSG) is typically used for diagnosing sleep disorders. PSG is a diagnostic test during which a number of physiological variables are measured and recorded during sleep. Trained medical staff places sensor leads on the patient in order to record a large number of parameters, including brain electrical activity, eye and jaw muscle movement, leg muscle movement, airflow, respiratory effort (chest and abdominal excursion), ECG (electrocardiogram), and oxygen saturation. Information is gathered from all leads and fed into a computer and output as a series of waveform traces. This output enables the lab technicians to visualize the various waveforms and score the sleep of the patient. In this way the hypnogram is derived that reflects the stages and cycles of the sleep through the night. From it, sleep quality indicators are derived, such as the ones stated above.

For polysomnography, the sensors are mounted on or glued to the head and the body, making it a very obtrusive and uncomfortable way of assessing sleep. Therefore, this technique is not suitable for longitudinal, ambulatory monitoring. Home-based, longer-term monitoring of sleep can better be done using a technique called actigraphy [6]. An actigraph is a wrist-worn device that records the wearer's movements by means of an accelerometer. Actigraphy identifies sleep onset after a period of continuous inactivity that rarely occurs while people are awake. In a similar way, waking up is detected. In comparison to PSG, actigraphy is more comfortable to wear and more easy to install. However, it is limited to sleep-wake detection and is also less accurate because body movements are an indirect measure of sleep. In particular sleep-onset detection is less precise with actigraphy.

Sleep monitoring in persuasive settings

Persuasive settings in the domain of sleep deprivation can typically be found in the treatment of insomnia. Insomnia may be characterized as a persistent difficulty initiating and/or maintaining sleep [7]. Today it is widely accepted that cognitive and behavioral factors play an important role in the condition of insomnia, making cognitive behavior therapy for insomnia (CBT-I) a generally accepted, non-pharmacological treatment [8] producing sustainable positive changes in this condition. Basically, CBT-I and other behavior related treatments offer a number of exercise types whose effectiveness is proven for sleep therapy – i.e. sleep restriction, stimulus control, relaxation, and sleep hygiene [9]. Sleep restriction involves curtailing the time spent in bed to stabilize the sleep pattern and then lengthening sleep time as sleep efficiency improves. Stimulus control is aimed at the coachee's re-association of the bed and the bedroom with sleep and to re-establish a consistent sleep-wake schedule. Relaxation training involves methods aimed at reducing somatic tension. Sleep hygiene education aims to make the person aware of behavioral practices and environmental factors that may promote or hamper sleep; examples are the advice to keep a regular schedule, to avoid daytime napping and to refrain from caffeine, alcohol and nicotine before bedtime [10].

In general, behavior treatments such as CBT-I require a great deal of effort and extensive self-discipline of the insomniac. People may enthusiastically start a particular self-help sleep therapy and discover that sizing down their time spent in bed or getting out of bed in the middle of a cold and dark night requires a great deal of effort. Consequently, sleep quality deteriorates, people feel worse, get into a downward motivation spiral and the therapy is terminated prematurely. People may find the exercises too strenuous (e.g. sleep restriction), they do not believe that it contributes to a solution of the problem or simply forget to perform the exercise (e.g. a relaxation exercise).

In order to motivate the individual to adhere to the exercises, a combination of persuasive strategies may be applied. Some of these strategies pertain to the adaptation of the exercises to the individual's characteristics, such as ability and preferences. Other strategies refer to the ease of the activities that have to be performed during the therapy. For instance, people have to fill in a sleep diary to gain insight of the sleep behavior during the therapy. Not only are sleep diaries notoriously unreliable with respect to reporting sleep characteristics, they also put an extra burden on the individual of reporting and processing various types of sleep relevant information.

In this context, sleep monitoring may have important advantages. First, because individuals are never able to intentionally indicate that they are asleep, information can be obtained where direct access would otherwise be impossible (e.g. the individual's sleep stages). Second, insomniacs do not need to focus on the measurement process and do not have to worry about the timing of the measurement; as a result, they can avoid the tedium of tracking their own performance. Third, data can be collected in a more objective way than when entered by the individual. Fourth, sleep monitoring may smoothly be integrated with other behavioral measurements to offer (semi-) automated and individually tailored intervention programs. Consequently, sleep monitoring enables individuals to become aware of relevant unobservable behavior, provide sleep indicators to track sleep quality over time and feedback upon their sleep-hygienic behaviors, and may release the individual from a range of therapy related activities.

From the previous it should not be concluded that sleep monitoring is beyond doubt. Integrity of the data processing and reliable sensing are important prerequisites for acceptation of a sleep monitoring system. Also, intrusive measurements should be avoided wherever possible in a first step therapy. Consequently, a trade-off should be found between reliability, intrusiveness and integrity of the information. Since CBT-I and sleep hygiene requires longer-term, home-based monitoring, unobtrusiveness and comfort are important requirement for the assessment techniques, in combination with a sufficient level of accuracy to observe trends in quality of sleep.

Conclusion

We outlined the role of unobtrusive sleep monitoring in behavioral treatments of insomnia that aim to improve people's sleep by promoting more effective cognitions and behaviors around sleep. In a persuasive setting, sleep hygiene and CBT-I approaches can benefit from sleep monitoring techniques, not only by providing objective sleep information but also from monitoring of adherence to sleep hygiene rules and therapy compliance for CBT-I.

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