Conducting a Polysomnographic, Automated Auditory Stimulation Sleep Experiment Using a Portable High-Tech Sleep Mask

BACHELOR THESIS

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Declaration of Authorship

I hereby certify that the work presented here is, to the best of my knowledge and belief, original and the result of my own investigations, except as acknowledged, and has not been submitted, either in part or whole, for a degree at this or any other university.

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Abstract

Sleep experiments are usually conducted manually in a laboratory environment in the presence of an experimenter. In contrast, we evaluated whether it is possible to conduct home-based, fully automated experiments that could facilitate sleep research enormously and promise several other advantages. For this purpose, the suitability of a recently developed portable high-tech sleep mask - the *Traumschreiber* - for home-based sleep experiments using polysomnography was tested in the present field study. Additionally, we investigated whether the arousal threshold of individual participants can be determined by exposing them to auditory stimulation during the night. Overall, the findings show that sleep quality is decreased when sleeping with the sleep mask and even more when additionally exposed to auditory stimulation. However, the study proved that the *Traumschreiber* is generally suitable for home based experiments, although the signal quality of the obtained sleep data needs to be improved in future studies. Through the auditory stimulation experiment, a general arousal threshold was obtained for each participant respectively. As one major goal, subsequent studies should also take into account the different sleep stages. In order to conduct fully automated home-based sensory stimulation experiments, future research needs to focus on enabling automatic real-time scoring of sleep stages, such that only specific sleep stages can be stimulated.

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1 Introduction

Sleep is an essential part of our lives, taking up one third of our time each day. Nevertheless, many processes that occur during the night are still unexplored, as sleep experiments are elaborate in terms of time, costs, and manual effort. In order to facilitate experiments that investigate different fields of research such as memory consolidation during sleep or dream research, devices that are portable and easy to use could enable the execution of sleep experiments at participants' homes. The recently invented portable monitoring device *Traumschreiber* is able to measure and manipulate human sleep and was therefore tested in this study and its suitability for conducting home-based sleep experiments was evaluated. As sensory stimulation experiments are essentially important in sleep research, the usability of portable monitoring devices such as the *Traumschreiber* for sensory stimulation experiments was additionally tested by exposing participants to auditory stimulation during the night.

In order to understand the experiment in detail, the first chapter of this thesis provides a general overview of normal human sleep and memory consolidation during sleep, including enhancement of memory consolidation via sensory stimulation as well as other applications of sensory stimulation. Additionally, a brief introduction to portable monitoring devices will be given, and the recently developed portable sleep mask will be presented.

1.1 Normal Human Sleep

Normal human sleep is defined as a natural state of reduced responsiveness to external stimuli and relative inactivity, accompanied by a loss of consciousness (Rama et al., 2013). It is divided into three non-rapid eye movement (NREM) stages N1, N2, and N3, and the rapid eye movement stage REM. During the night, these four sleep stages alternate in 4-6 cycles with a period of approximately 90-110 minutes (Carskadon et al., 2011; Rama et al., 2013).

N1 is the transitional sleep between wakefulness and other sleep stages. It is of short duration, makes up 3-8% of total sleep time and is characterised by drifting thoughts and imaginative dreams from which the sleeper is easily awakened (Malhotra et al., 2013). After approximately 10-12 minutes of N1 sleep, stage N2, also named spindle or intermediate sleep, starts, comprising 45-55% of the night. Stage N3 comprises 15-20% of total sleep and is also referred to as deep sleep or slow wave sleep. During this stage, the threshold of arousal is higher than in stage N1 or N2 sleep (Rama et al., 2013). Combined, these three sleep stages constitute NREM sleep, comprising 75-80% of total sleep time. REM sleep constitutes the rest of the night (20-25%) and was named after the characteristic rapid eye movements that appear in this stage. If woken up during REM sleep, dream recall is generally higher than in NREM sleep (Nielsen, 2000; Schredl, 2007). As shown in *Figure 1*[1], N3 sleep is dominant early in the night while REM sleep dominates sleep later in the night (Rama et al., 2013).

[1]Sleep Architecture, in *The biology of sleep: Circadian rhythms, sleep stages, and sleep architecture.* Retrieved from https://www.helpguide.org/harvard/biology-of-sleep-circadian-rhythms-sleep-stages.htm [Accessed 24.02.2017].

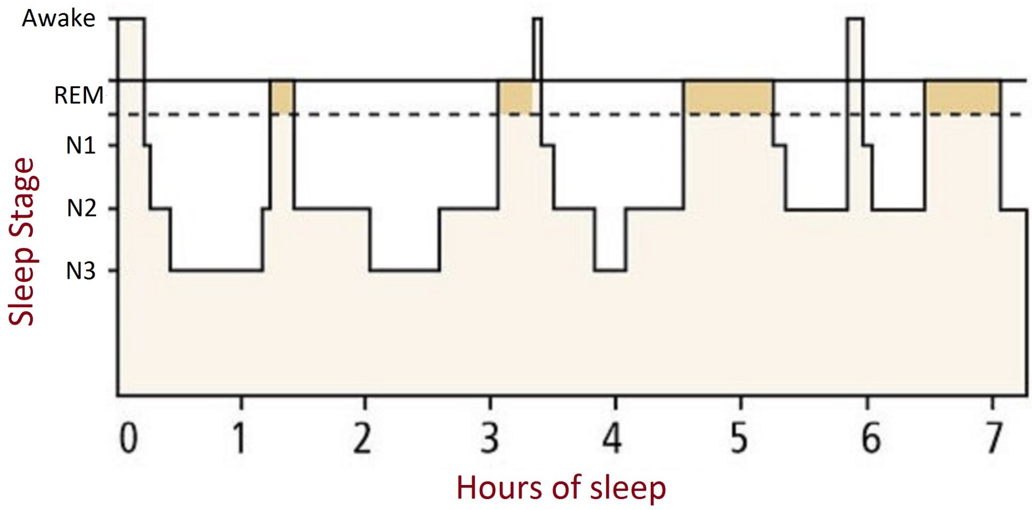

Figure 1: Normal human sleep is divided into four different sleep stages - N1, N2, N3, and REM sleep - that alternate cyclically throughout the night [1].

1.1.1 Memory Consolidation during Sleep

A great variety of studies have shown that sleep supports the process of memory consolidation (Diekelmann et al., 2009; Feld et al., 2015). First, it is important to distinguish between declarative and non-declarative memories. Declarative memory includes episodic memories of events and semantic memories as facts, which can explicitly be recalled if intended. On the other hand, non-declarative memories are unconscious, such as procedural memories (motor skills and perceptual skills) and emotional memories (Rasch et al., 2013).

Researchers agree on the fact that consolidation of declarative memories is supported by reactivation of these memories during slow wave sleep (N3) (Feld et al., 2015; Rasch et al., 2013). For investigation, participants in these studies performed tasks as learning word lists, word-pairs or spatial locations before going to bed and recalling them when woken up after the first half of the night, in which slow wave sleep predominates sleep (Rasch et al., 2013). In contrast, the role of REM sleep is mostly associated with motor learning, but is not yet clarified. Whereas studies by Plihal et al. (1997) and Smith (2001) suggest that REM sleep is important for consolidation of non-declarative memories, the more recent review by Rasch et al. (2013) as well as a study by Ackermann et al. (2014) oppose that the role of REM sleep for consolidation is unclear, as procedural memories also seem to be influenced by NREM sleep. Summed up, research shows that sleep plays a major role in memory consolidation, also indicating that different sleep stages take different roles in the process of forming memories during the night.

1.1.2 Sensory Stimulation during Sleep

Enhancement of memory consolidation can be achieved by presenting environmental cues during sleep, which seem to prime or reactivate memories that were previously associated with the presented cues (Donohue et al., 2011). For example, in a study by Rudoy et al. (2009), object locations were learned and associated with sounds during wakefulness. During subsequent NREM sleep, participants were again presented with the sound cues. If a location was cued during the night, recall in the morning was better than for locations which were not cued. There are multiple similar studies using auditory stimulation as well as studies using olfactory stimulation as cues, finding equal results (Rasch et al., 2013; Rihm et al., 2014) and thereby, providing evidence that information cues presented during NREM influence memory consolidation and facilitate retrieval in subsequent wakefulness.

Not only is sensory stimulation used in memory consolidation studies, but also by researchers investigating neurophysiological sleep patterns and arousals through olfactory (Perl et al., 2016), auditory, visual, or tactile (Sato et al., 2007) stimulation during sleep. Other studies use sensory stimulation in order to manipulate dream content (Rahimi et al., 2015), induce lucid dreams (Paul et al., 2014; Stumbrys et al., 2012), or communicate with the sleeping person via Morse code (Appel, 2013). Studies by Pace-Schott et al. (2012) and Hauner et al. (2015) even showed that re-exposure to sensory cues during sleep can enhance fear extinction. Moreover, light stimulation during the night was proven to have effects on the circadian rhythm (Zeitzer et al., 2000). Conducting research in the field of visual stimulation therefore promises advances in treatment of jet lag and possible applications for shift workers, where the alterations of rotating night-shifts can disrupt the circadian rhythm and cause health disorders (Rahman et al., 2008; Rahman et al., 2011).

Thus, it becomes obvious that sensory stimulation during sleep is an important topic in different fields of sleep research. Since awakening of the subjects should be prevented, the intensity of stimulation processed by the participant during sleep without causing awakening is of high importance for conducting these experiments. Nevertheless, experiments using sensory stimulation still struggle to determine this threshold of arousal as several variables need to be taken into account. One important factor is that the threshold of awakening differs for each person and has to be determined for each participant respectively (Rechtschaffen et al., 1966). Moreover, several studies provide evidence that individuals have different arousal thresholds in different sleep stages and that these thresholds also depend on the time of the night (Ermis et al., 2010; Rama et al., 2013; Rechtschaffen et al., 1966).

Already Dement et al. (1958) as well as Paul et al. (2014) just recently emphasized the necessity for future research to focus on determining individual arousal thresholds, as stimulation often leads to awakening. Especially in the case of memory consolidation experiments, high numbers of awakenings are not desired, as sleep disturbances can impair memory consolidation functions (Diekelmann et al., 2009). In previous studies, either an additional night in the laboratory was needed to determine the arousal threshold (Rechtschaffen et al., 1966), the intensity of stimulation was increased manually during the night in the laboratory by the experimenter (Ermis et al., 2010), or the threshold was determined during wakefulness before the experimental night (Ruby et al., 2008; Sato et al., 2007).

These methods imply a high manual effort and are elaborate in terms of time and costs. Therefore, a portable monitoring device was used in this study in order to determine the arousal threshold for each individual respectively at home in an automated sleep experiment. Before describing the approach in detail, an overview of portable monitoring will be given and the device used in this experiment will be presented.

1.2 Portable Monitoring

As experiments in the laboratory are time consuming and costly, devices which are portable and easy to use in order to record human sleep at participants' homes were developed during the last years, especially for the diagnosis of obstructive sleep apnea. During the night, portable monitoring devices are used for polysomnography. In general, polysomnography is a multiparametric test that records human sleep by measuring - depending on the purpose - Electroencephalography (EEG – records electrical brain activity), Electromyography (EMG – measures electrical muscle activity), Electrooculography (EOG – records eye movements), Electrocardiography (ECG – measures electrical activity of the heart) and other biophysiological variables (oxymetry, airflow, snoring, body position etc.) if desired (Shah et al., 2013, Collop et al., 2007). The obtained data can then be used in order to analyse sleep, score sleep stages, or diagnose sleep disorders.

Using portable monitoring devices also for research purposes promises several advantages. Since the portable design allows to collect sleep data in an automated experiment at subjects' homes, more subjects and subjects of different ages and social groups can be tested simultaneously, leading to higher numbers of experimental nights and a greater variety of participants. At the same time, experimental costs are reduced as no experimenter and no sleep laboratory are needed. Additionally, previous research found that the first night in a laboratory is associated with less total sleep time, less REM sleep and more awakenings, called the first-night effect (Agnew et al., 1966; Le Bon et al., 2001). As one influencing factor for sleep perturbation is assumed to be the change of environment (Le Bon et al., 2001), being tested in familiar surroundings can possibly diminish the first-night effect.

In the scope of this bachelor thesis, a portable monitoring device, the *Traumschreiber* (*Figure 2* [2]) was used for polysomnography. It includes eight channels that can measure EEG, EMG, EOG and ECG, which are essential for staging human sleep. For manipulating sleep during the night, features included in the design of the sleep mask are LED lights for visual stimulation and speakers for auditory stimulation. The *Traumschreiber* was invented by two PhD students who are studying at the Neuroinformatics Department of the Institute of Cognitive Science at the University of Osnabrueck - Kristoffer Appel and Johannes Leugering. Their goal was to develop an automatized, high-tech sleep mask in order to facilitate sleep and dream experiments.

[2] The image of the *Traumschreiber* was taken by the experimenter.

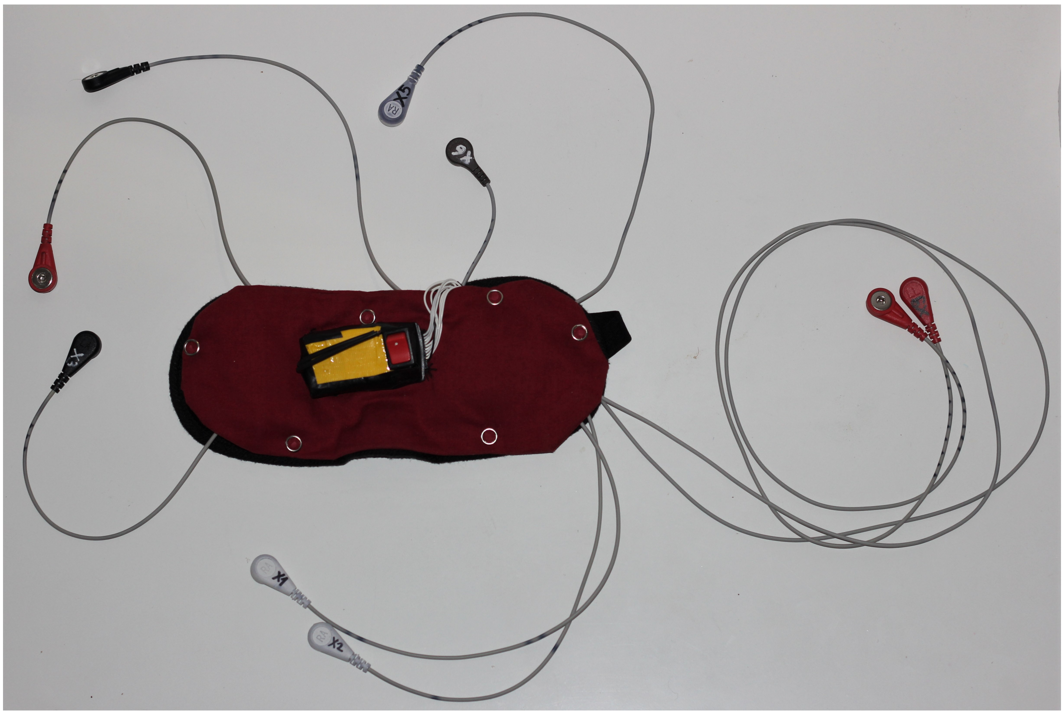

Figure 2: The *Traumschreiber* was used for polysomnography in this study. It is a portable sleep mask that is able to record human sleep by measuring EEG, EOG, EMG and ECG during the night [2].

1.3 Aim of the Study

So far, the *Traumschreiber* had not been tested in an experimental design, but only in some piloting experiments from the developers themselves. Therefore, one major goal of this thesis was to investigate usability and comfortability aspects when conducting an experiment with the sleep mask as well as evaluating the goodness of the obtained data and the influence of sleeping with the *Traumschreiber* on human sleep. More precisely, this includes the clarification of the following questions: How understandable are the instructions for participants that are unfamiliar with sleep experiments? How difficult is it for the participants to set up the experiment at home? How good is the obtained data of the sleep mask? Is it good enough to score sleep stages? To what extent does the sleep mask influence sleep quality? Does the mask influence the dream content of participants? Are portable monitoring devices such as the *Traumschreiber* suitable for conducting experiments outside of the laboratory?

As mentioned earlier, experimenters often face the problem of finding the right amount of sensory stimulation which influences sleep without causing awakening. Thus, the second goal of this thesis was to investigate whether portable monitoring devices such as the *Traumschreiber* can be used for determining an arousal threshold for each individual participant. Therefore, 50% of the participants were exposed to acoustic stimuli played in random intensities. Sounds were played during the entire night, as knowledge about the arousal threshold in all stages of sleep is attractive for different fields of research: While for declarative memory consolidation studies, the arousal threshold in N3 is important, dream researchers are more interested in the threshold during REM sleep and researchers

investigating neurophysiological sleep patterns are interested in the arousal threshold of different sleep stages. If the arousal threshold can be determined via a portable monitoring device, future studies will be simplified enormously as no experimenter and no sleep laboratory will be needed for arousal threshold determination. Additionally, participants will not be woken up by mistake any more during the experimental night, saving a lot of time, effort and unusable data. We also investigated if this sensory stimulation has an impact on sleep quality compared to participants that were not exposed to auditory stimulation during the night.
In summary, the conducted experiment evaluates different aspects of the *Traumschreiber* and tests its suitability for auditory stimulation experiments.

2 Materials and Methods

2.1 Participants

Twenty-four healthy students (15 females, 9 males; mean age = 21.2 years; range = 18 – 27 years) of the University of Osnabrueck were recruited via word-of-mouth advertising and e-mail announcements. All participants were healthy and spoke German fluently. Exclusion criteria were pregnancy, taking sleeping pills or ataractics and having sleep disorders or hallucinations. Participation was only permitted if no alcohol was consumed in the last 24 hours, no nap was taken during the day and subjects did not have a lack of sleep from the previous night. One female participant dropped out because of not meeting the criteria for participation, yielding a total number of 23 subjects. They received three test-person hours[3] in return for their participation. The experiment was approved by the local ethics committee of the University of Osnabrueck. Written consent was obtained prior to the study and subjects were free to quit the experiment at any time.

2.2 Materials

For polysomnography, the previously introduced sleep mask - the *Traumschreiber* - was used during the night. Ten sticky, single-use electrodes recorded eight channels of EEG, EOG, EMG and ECG activity. A minicomputer (Raspberry Pi Model 3 B) was connected to the sleep mask via bluetooth. The activity measured by the *Traumschreiber* was sent to the minicomputer where all data was saved. For auditory stimulation, two small speakers (model: Trust Leto 2.0 USB Lautsprecher) were connected to the Raspberry Pi via a jack cable. A one second long sinus tone with a frequency of 1000Hz was used for auditory stimulation, played at random intensities (between inaudible and room volume) every 10 minutes throughout the night [4].
A video previously recorded by the experimenter was used for illustration reasons. In the video, the experimenter explains and executes the most important steps of the experiment in order to give the subjects a first impression of their task and to later facilitate understanding and following the experimental procedure (*Figure 3*). The full video is to be found on the enclosed DVD (*Experiment-Video*). The instructions usually given by the experimenter in a laboratory environment were replaced by the experimental schedule. Moreover, participants received verbal instructions via the speakers which aimed at supporting the execution of the different steps.
Testing of suitability for participating in the study was done with the standardized *LISST* (*Landecker Inventar zur Erfassung von Schlafstörungen*) questionnaire, which was designed in order to detect sleep disorders. The standardized *Schlaf-Fragebogen A* was used in order to obtain changes in sleep characteristics between different conditions. Additionally, a questionnaire concerning the usability and comfortability of the sleep mask was

[3] Psychology and Cognitive Science students at the University of Osnabrueck need test-person hours for their studies.

[4] The Raspberry Pi was programmed by Kristoffer Appel, such that it would automatically start the program when turned on, connect to the sleep mask, play the acoustic stimuli, and save all data that was sent from the mask during the night.

Figure 3: For clarification of the task, a video was recorded and shown to the participants before they set up and started the experiment. The pictures are example excerpts of the video, showing how the electrodes should be attached (left) and how the cables of the sleep mask should be connected to the electrodes (right).

designed by the experimenter (*Fragebogen zum Gebrauch des Traumschreibers*) and participants were asked to report their dreams (all questionnaires are found in the *Appendix*).

2.3 Design

In order to evaluate whether the *Traumschreiber* is suitable for executing experiments at participants' homes, a field study was conducted in which subjects slept one night with the mask (experimental night) and one night without it (control night). A within-subjects design was used to analyse differences of sleep characteristics when sleeping with the *Traumschreiber* compared to when sleeping without it. In the experimental night, participants were divided into two groups: The Non-Cueing group which slept with the sleep mask and the Cueing group which also wore the mask and which was additionally exposed to auditory stimulation throughout the night. A between-subjects design was employed to compare the effects of exposure to auditory stimuli.

For the participants within the Cueing group, we aimed at determining an arousal threshold for each individual and every sleep stage. Therefore, we calculated how many data points we would obtain per night per sleep stage if acoustic stimuli are played every ten minutes (*Table 1*), based on the amount of time spent in each sleep stage (Rama et al., 2013). This lead us to the assumption that one experimental night would provide sufficient data points for determining arousal thresholds.

2.4 Procedure

During the first meeting, testing of suitability for participation in the study was done with the *LISST* questionnaire. If the participants were not excluded by this questionnaire,

Table 1: Calculation of data points per night per sleep stage for the Cueing group if sounds are played every 10 minutes. Percentages of time spent in each sleep stage were taken from Rama et al. (2013).

Sleep stage	Time spent in each sleep stage	Data points per person
N1	3% - 8%	1 - 4
N2	45% - 55%	22 - 26
N3	15% - 20%	7 - 10
REM	20% - 25%	10 - 12

they were given the consent form, which was read and signed by the participants and the experimenter. All information concerning the experiment was then given to the subjects in written form (*Versuchspersoneninformation-/aufklärung*) as well as verbally explained by the experimenter. The sleep mask and the Raspberry Pi were presented to the participants and their functions and set-up were explained. Additionally, the video link was given to the participants, such that they would later be able to watch the video at home before starting the experiment. All open questions were answered and all materials were given to the participants to take them home. This includes: The sleep mask, the electrodes, the minicomputer, speakers, written information, experimental schedule and the questionnaires for the experimental, and the control night.

2.4.1 Experimental Night

Participants were randomly assigned to either the Non-Cueing group - without auditory stimulation during the night (n = 9; 4 females, 5 males) - or the Cueing group - with auditory stimulation during the night (m = 12; 10 females, 2 males) by the program of the Raspberry Pi. Because of technical issues, the first two participants were exposed to the same intensity of auditory stimulation throughout the experimental night and were therefore not included in either of the groups. Before going to bed in the evening, participants were asked to read the experimental schedule in detail and follow each step carefully. This includes the following steps: First, watching the video in order to get a first impression of the task. Second, attaching the electrodes to their skin at the locations shown in *Figure 4*. Two more electrodes had to be attached at the chest in order to measure heart rate. Therewith, eight channels were used for measuring EEG, EMG, EOG and ECG (*Table 2*).

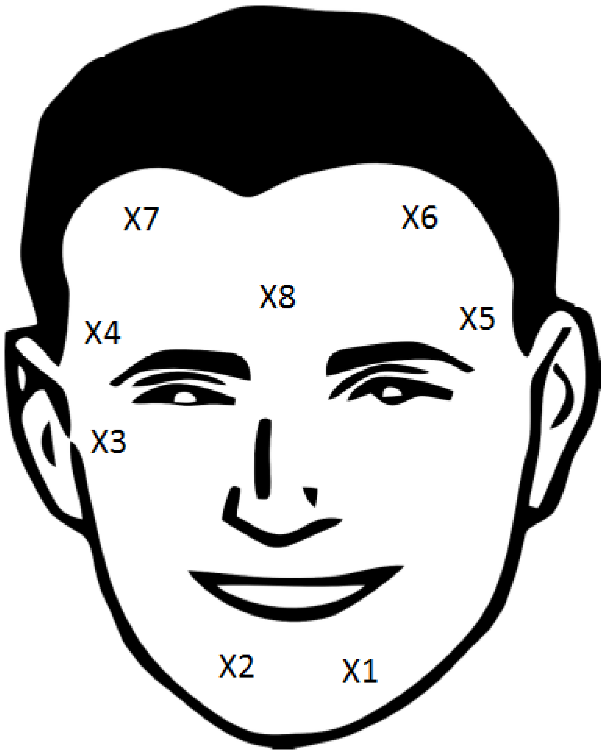

Figure 4: Locations where the participants were asked to attach the electrodes in the evening.

Table 2: Channels that were measured between the corresponding electrodes at the locations shown in *Figure 4*.

Measured activity	Electrodes
Vertical EOG	X3 - X4
Horizontal EOG and EEG1	X4 - X5
EEG2	X5 - X6
EEG3	X6 - X7
EMG	X1 - X2
ECG1	X7 - X9
ECG2	X9 - X10
- - -	X2 - X3

Third, starting the Raspberry Pi and - together with the speakers - placing it two meters from and directed towards the subject's pillow. Participants were then asked to follow the verbal instructions given by the Raspberry Pi through the speakers: Turning on the sleep mask, attaching the cables of the mask to the electrodes on their skin, and finally, going to bed. A short period of calibration then started, requesting participants to roll, open, close, or move their eyes in certain directions. The participants were then asked to relax and fall asleep as they would usually. During the night, participants that were randomly assigned to the Cueing group were exposed to sounds of different intensities while participants in the Non-Cueing group were not hearing sounds. In the morning, subjects were asked to report their dreams and to fill in the questionnaires concerning sleep characteristics (*Schlaf-Fragebogen A*) and aspects of the sleep mask (*Fragebogen zum Gebrauch des Traumschreibers*). The mask and the electrodes were then taken off and all materials were returned to the experimenter the same day.

2.4.2 Control Night

One week later, participants were asked to sleep as usual, only reporting their dreams the next morning and filling in the questionnaire on sleep characteristics (*Schlaf-Fragebogen A*). The questionnaires were then returned to the experimenter within the next days. For further details on the procedure see *Versuchspersoneninformation-/aufklärung* in the *Appendix*.

2.5 Analysis

The analysis of the data was split into three parts: (1) Usability aspects of the *Traumschreiber*, (2) evaluation of the quality of the recorded data, and (3) analysis of the sleep characteristics. The two participants that were exposed to the same intensity of auditory stimulation throughout the experimental night were excluded in the analysis of sleep characteristics (n=21), whereas they were included in the remaining analysis (n=23). All data analysis was done in R.

In the analysis of the usability and comfortability of the sleep mask based on the questionnaire *Fragebogen zum Gebrauch des Traumschreibers*, the focus was on descriptive statistics. Similarly, the data quality of the *Traumschreiber* was analysed descriptively, taking into account the amount of time in which data was transmitted from the sleep mask to the Raspberry Pi, the sampling rate (how many data points were transmitted per second), and the signal quality of the measured channels.

Descriptive and inferential statistics were used to analyse sleep characteristics. The analysis was split into three parts: Evaluation of the questionnaire *Schlaf-Fragebogen A*, obtained polysomnographic data, and dream reports. The dream reports were evaluated by summarizing the number of recalled dreams and analysing incorporation rates of the experiment into dream content. For evaluating the *Schlaf-Fragebogen A*, sleep quality and the feeling of recovery after sleep were calculated as described in the manual by Görtelmeyer (1986). Accordingly, sleep quality is evaluated by taking into account the following aspects: Time to fall asleep in the evening, number of awakenings during the night, time period of being awake when woken up during the night, and self-assessment whether the own sleep was constant, deep, restless, relaxed, undisturbed, and good. The feeling of recovery was calculated by evaluating if sleep was ample and whether the subject felt even-tempered, drowsy, cheerful, fresh, relaxed, and well-rested the next morning. These scales range from 1 to 5, with 1 denoting impaired quality, whereas a score of 5 stands for positive ratings. Statistical differences between the Cueing and Non-Cueing group as well as between the experimental and control night were computed using permutation tests. In contrast to a t-test that can only be applied if several assumptions are fulfilled (e.g. random sample of the population and normal distribution of data), a permutation test limits the assumption on the data distribution as no formal assumptions are made about the population or the distribution. As we hypothesized that sleep quality and feeling of recovery would be best in the control, worse for the Non-Cueing, and worst for the Cueing group in the experimental night, a one sided permutation test was used for analysis. A p-value < 0.05 was set for significance. The effect size d was calculated according to Cohen (1992), who defined a small effect as $d > 0.2$, a medium effect as $d > 0.5$, and a large effect as $d > 0.8$.

As a detailed analysis of the obtained polysomnographic data (as scoring of sleep stages or scoring changes of sleep stages after stimulus onset within the Cueing group) would have exceeded the scope of this thesis, reactions after stimulus onset were only classified into three different categories by visual inspection: If no change in frequency or amplitude was observed in the EEG signal between the preceding and the following 10 seconds of stimulus onset, no arousal was scored, even if other channels showed a slight change of activity (*Figure 5*). If a distinct change in polysomnographic activity was observed, an arousal was scored (*Figure 6, Figure 7*). If an arousal occurred within the preceding 10 seconds of stimulus onset, an unclear activity was scored (*Figure 8*). In order to find out whether these arousals were random occurrences or due to a mismatch between real stimulus onset and stimulus onset displayed in the visualization of polysomnographic activity, 20 randomly chosen time windows of 20 seconds were analysed for each night. We scored whether an arousal occurred during this period or not and then compared the percentage of randomly occurring arousals to the percentage of arousals scored before stimulus onset. Overall, sleep data was only scored if the obtained polysomnographic data provided sufficient information that guaranteed accurate scoring, e.g. if the signal of two EEG channels did not provide a good signal quality, arousals were not scored. As the channel between the electrodes X2 (attached at the chin) and X3 (attached close to the eye) did not provide informative data, it was not used for analysis while all other channels were included in the analysis. For analysing whether correlations between the scored arousals and the self-reported sleep characteristics (such as number of awakenings or sleep quality) exist, the Pearson correlation coefficient was employed.

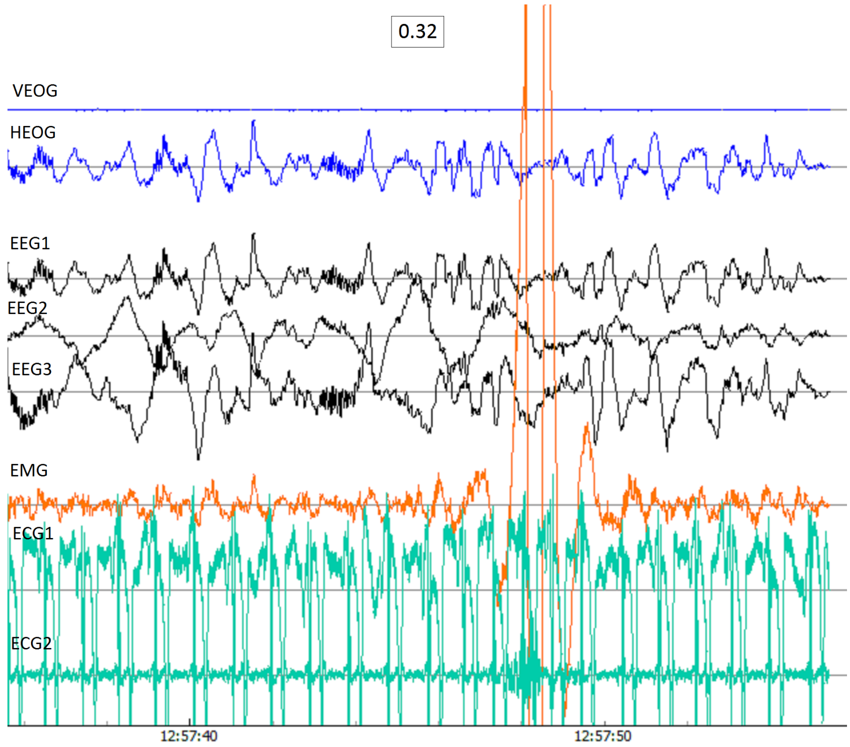

Figure 5: Twenty seconds of polysomnographic activity. Stimulus intensity: 32% of full intensity. Although EMG and ECG channels indicate some changes in activity after stimulus onset, no arousal was scored as no distinct change in EEG activity is visible.

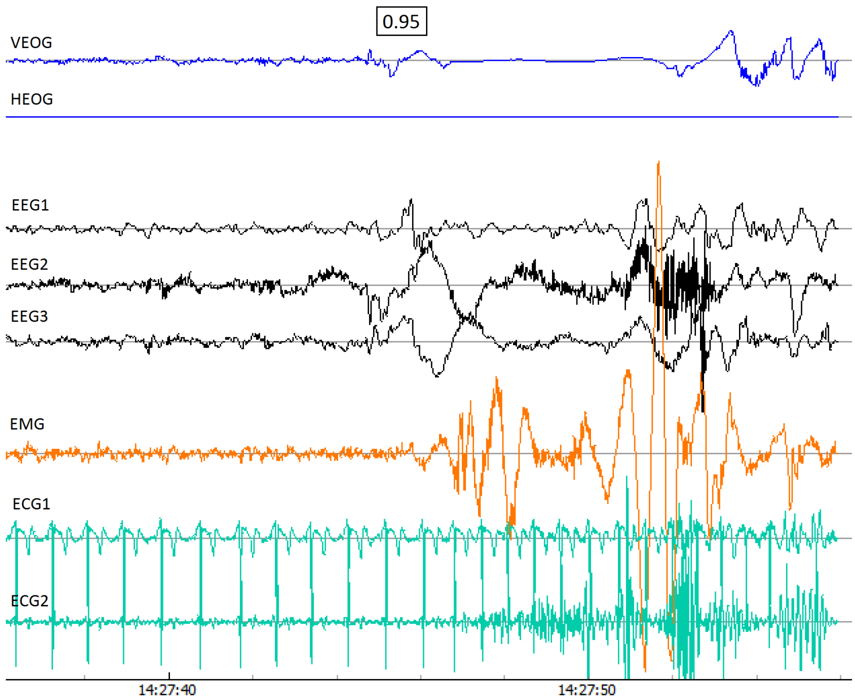

Figure 6: Twenty seconds of polysomnographic activity. Stimulus intensity: 94.9% of full intensity. The reaction was scored as an arousal, as a distinct change in frequency and amplitude in all channels is visible.

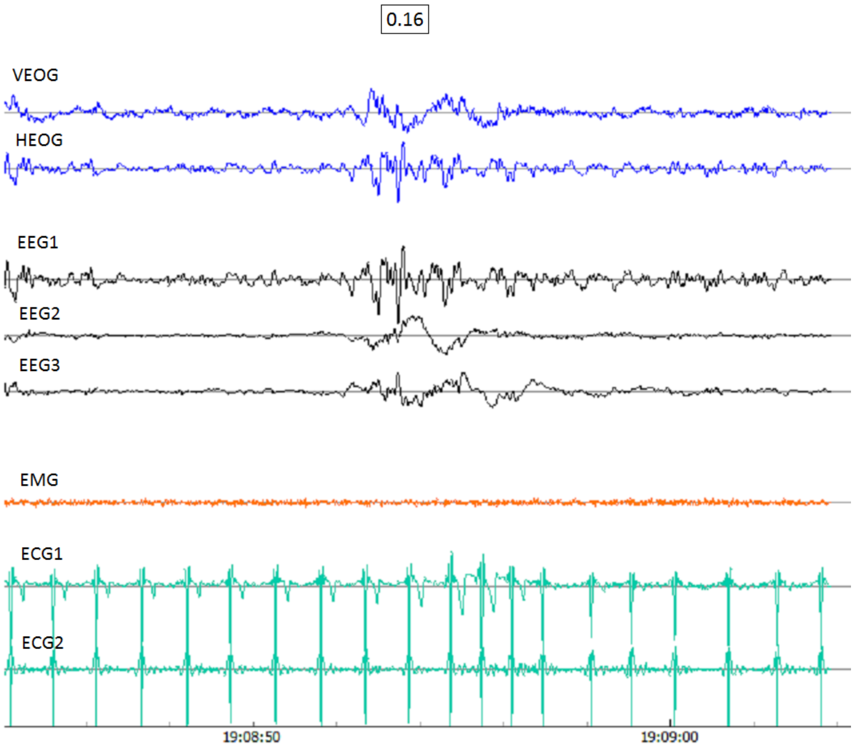

Figure 7: Twenty seconds of polysomnographic activity. Stimulus intensity: 16.4% of full intensity. The reaction was scored as an arousal, as a distinct change in frequency and amplitude is visible, although the change is not as big as in *Figure 6*.

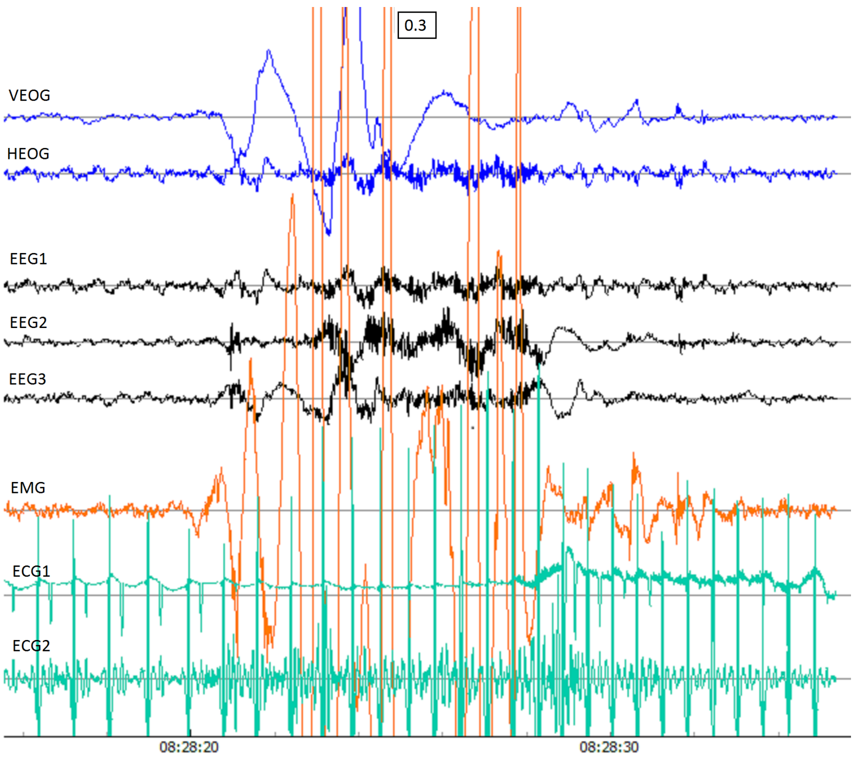

Figure 8: Twenty seconds of polysomnographic activity. Stimulus intensity: 30.1% of full intensity. A change in activity just before stimulus onset is visible and was therefore scored as an arousal before stimulus onset.

3 Results

3.1 Usability of the *Traumschreiber*

For all participants, the instructions given to them were easy (65.2%), rather easy (30.4%) or medium (4.3%) to understand. During the meeting after the experimental night, participants mentioned that watching the video was very helpful to get a first impression of the task. The minicomputer worked properly for all participants except for one, for whom the verbal instructions did not work well. In the case of another participant, the sleep mask was turned off during the night.

On average, attaching the electrodes in the evening took 15:02 minutes (range: 3 - 30 minutes) and was found rather easy by the majority of participants, while two participants (8.7%) perceived it as rather hard. In the morning, taking off the electrodes took on average 5:38 minutes (range: 2 - 15 minutes) and was described as rather easy. However, four participants (17.4%) reported that it was difficult or painful to detach the electrodes while none of the other participants mentioned any difficulties. Fourteen participants (60.9%) reported that all electrodes were worn the entire night, while the remaining nine stated that some of the electrodes fell off during the night. More specifically, for one male participant the electrodes attached at the chin were rather loose because of his beard. Three participants reported that either one or both electrodes measuring ECG activity got detached during the night and two more subjects stated that one electrode fell off - not specifying which one. In the case of three other participants, the cables for collecting EMG activity were not attached to the sleep mask previously because of technical issues with the *Traumschreiber* that occurred during the study and on which I will elaborate later (*Discussion*).

3.2 Data Quality of the *Traumschreiber*

Concerning the transmission of sleep data via bluetooth from the sleep mask to the Raspberry Pi in the experimental nights, no data was transmitted during one night (4.3%), and during two other nights (8.7%) only less than 20 minutes of sleep data was saved. For three other participants (13%) less than three hours were recorded. In the case of all other participants (74%) the sleep mask transmitted data to the minicomputer during the entire night.

For the periods of time in which data was collected, data transmission between the sleep mask and the Raspberry Pi worked perfectly in 34.8% of all nights, transmitting approximately 238 data points per second (e.g. *Figure 9*) and almost perfect (less than three minutes of missing data points) in 26.1% of all nights. Only during two nights (8.7%) data transmission was very bad (e.g. *Figure 10*), while for the remaining nights the connection was not stable for an accumulated time period of less than one hour respectively. For more details on the quality of the sampling rates see *Table 3*. For all participants, a figure of the sampling rate is to be found in the *Appendix*.

In terms of the signal quality of the data that was transmitted (22 nights as no data was saved in one night), in four nights (18.2%) all channels recorded a good signal quality of

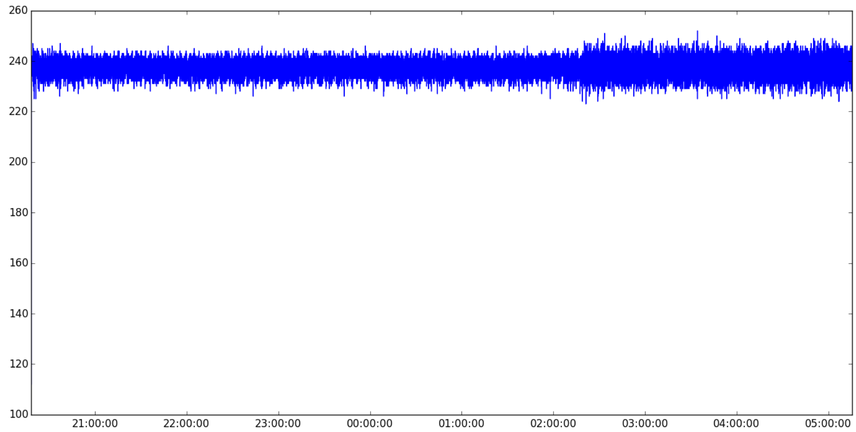

Figure 9: Sampling rate of 9 hours of sleep. Perfect sampling rate throughout the night, transmitting approximately 238 data points per second.

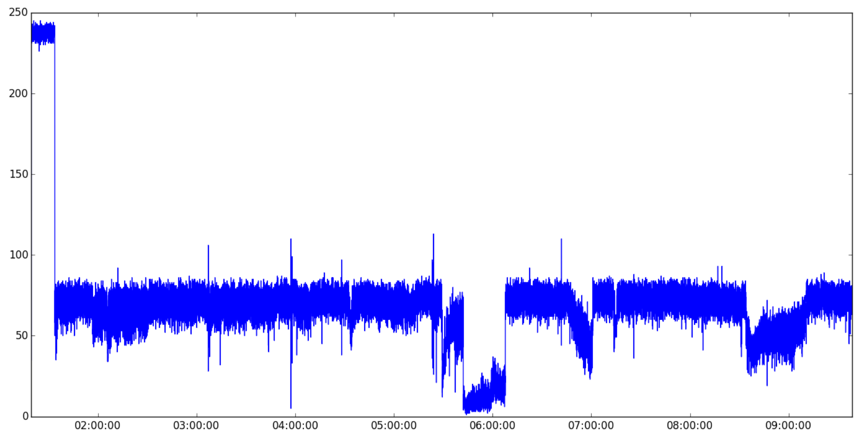

Figure 10: Sampling rate of 8:20 hours of sleep. Perfect sampling rate during the first minutes, but bad throughout the rest of the night. Transmission of approximately 70 data points per second.

Table 3: Quality of the sampling rate for all participants, independent of the time period that was collected. Figures of all sampling rates are found in the *Appendix*.

Quality of Sampling Rate	Experimental Nights	ID
238 data points per second (*Fig. 9*)	34.8%	2,4,7,10,12,18,19,22
< 3 minutes of missing data points	26.1%	1,14,16,17,20,21
3 - 10 minutes of missing data points	8.7%	5,15
10 - 60 minutes of missing data points	17.4%	8,9,13,24
Data points missing throughout the night (*Fig. 10*)	8.7%	6,23
No collection of data	4.3%	11

Table 4: Reported disturbance of the sleep mask and the cables when trying to fall asleep. The majority of participants were either slightly or quite disturbed by the sleep mask. More than half of the participants were not at all disturbed by the cables of the mask.

Disturbance	Sleep Mask	Cables
Not at all disturbing	4.3%	52.2%
Slighty disturbing	60.9%	26.1%
Quite disturbing	34.8%	17.4%
Extremly disturbing	0%	4.3%

polysomnographic data throughout the night. In seven nights (31.8%) the signal quality of one channel was not good. In six nights (27.3%) two channels did partly not transmit a good signal quality, in two nights (9.1%) three channels, and in three nights (13.6%) four channels transmitted a bad signal quality. One EEG channel (EEG2) obtained a bad signal during ten nights (45.5%), while the remaining channels did not transmit a good signal quality in four nights (18.2%) on average. For more details on the quality of measured activity, a table is to be found in the *Appendix*, showing for each participant which channels obtained a bad signal quality. No correlation between the self-reported time needed to attach the electrodes and the quality of the obtained sleep data was found.

3.3 Sleeping with the *Traumschreiber*

3.3.1 Questionnaire Evaluation

The majority of participants felt slightly disturbed by the sleep mask and not at all disturbed by the cables when trying to fall asleep, independent of their usual sleep position (either back, side, or belly). For more precise information see *Table 4*. In terms of comfortability, subjects rated the overall feeling of sleeping with the sleep mask as okay (*Figure 11*). No group differences were obtained. The material was overall perceived as comfortable. Four subjects (17.4%) reported sweating slightly under the mask while the rest did not sweat. In terms of supervision, five participants (21.7%) felt slightly watched while the other subjects did not.

Experimental Night Concerning the sleep quality in the experimental night between the Cueing and the Non-Cueing group, a one-sided permutation test yielded a trend towards significance ($p = 0.062$), suggesting that sleep quality was better within the Non-Cueing group. When evaluating the feeling of recovery after sleep between both groups with a one-sided permutation test, similar results were obtained ($p = 0.055$). In both groups, participants needed an equal amount of time to fall asleep.
As hypothesized, participants in the Cueing group woke up more often than participants in the Non-Cueing group. In the Cueing group, one participant (8.3%) reported waking up once every 30 minutes, seven participants once every hour (58.3%), and four participants (33.3%) three times or less, whereas all subjects except one in the Non-Cueing group

(88.9%) reported that they woke up only three times or less. As reasons for waking up, participants assigned to the Non-Cueing group reported waking up because of the sleep mask, dreaming, or unknown reasons. In contrast, subjects in the Cueing group woke up mostly because of either sounds, dreaming, or the sleep mask. For more details on reasons for waking up see *Table 5*.

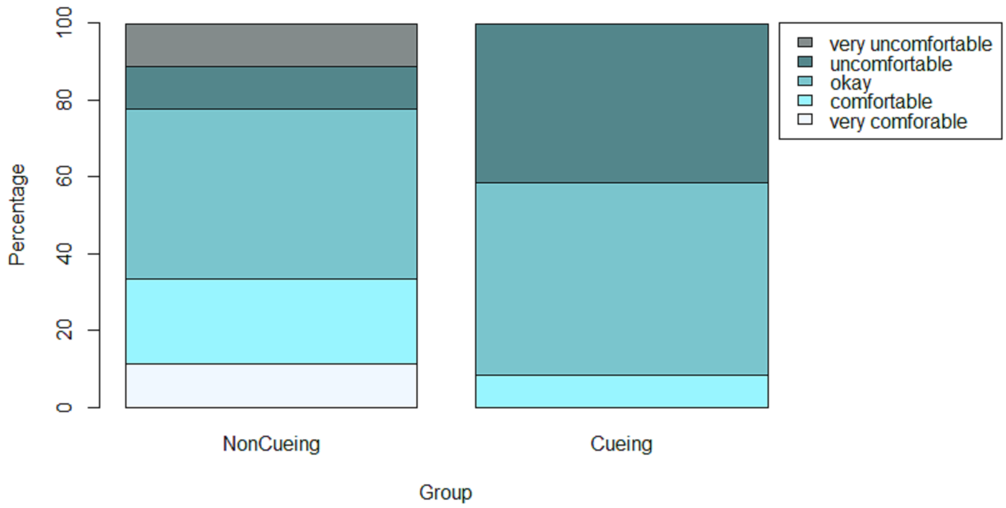

Figure 11: Reported comfortability of sleeping with the *Traumschreiber*, for each group respectively. Although no significant group differences were obtained, it seems that participants within the Cueing group rated sleeping with the mask more uncomfortable than participants within the Non-Cueing group.

Table 5: Reasons for waking up for the Non-Cueing and Cueing group in the experimental night and for all participants in the control night. Participants were allowed to give multiple answers.

Reasons for waking up	Experimental night		Control night
	Non-Cueing	Cueing	
private reasons	-	8.3%	-
sounds	-	75%	8.7%
bathroom	-	8.3%	17.4%
dreams	22.2%	16.7%	13%
sleep mask	33.3%	17.7%	-
no reason	11.1%	8.3%	47.8%
don’t know	33.3%	8.3%	8.7%

Concerning the exposure to auditory stimuli during the night, on average, subjects in the Cueing group reported hearing sounds seven times during the night (range: 1 - 20 times). More precisely, 41.7% of participants heard a tone less than five times, 41.7% between 6 and 10 times, and 16.7% more than 10 times. Two participants (14.3%) that heard the sound once reported hearing it only in the evening, two other participants heard the tones mainly in the evening and in the morning while the remaining participants heard them at different times throughout the night.
When evaluating the comments of the participants concerning sleeping with the *Traumschreiber*, some factors were mentioned that were perceived as disturbing. Four participants (17.4%) criticised that the string of the sleep mask was too loose and therefore, an adjustable string was recommended. Difficulties in breathing because of the sleep mask, distracting smell and disturbing heavy weight of the battery were also reported. Additionally, one participant reported that he often needed to change position before falling asleep because the locations of the electrodes applied pressure to the face, which was disturbing and uncomfortable. Another subject felt tense because of the sleep mask and thus, had the feeling that he was only half asleep during the entire night. Even more extreme, one participant in the Non-Cueing group reported that he was awake throughout the night, not being able to fall asleep.

Between Nights Total sleep time was inconspicuous for all subjects during both, the experimental (mean sleep time: 7:56 hours) and the control night (mean sleep time: 8:06 hours). In the control night, sleep quality was overall (irrespectively of the groups to which participants were assigned in the experimental night) significantly better than in the experimental night with a large effect size ($p < 0.001$, $d = 1.97$), obtained by a one-sided permutation test. When regarding sleep quality for each group during both nights respectively, results were also significant (Non-Cueing group: $p < 0.01$; $d = 1.5$, Cueing group: $p < 0.001$, $d = 2.9$), as shown in *Figure 12*.
Likewise, feeling of recovery of participants was overall significantly better in the morning of the control night ($p < 0.01$, $d = 0.82$). However, when applying a one-sided permutation test for each group respectively, feeling of recovery was not significant for the Non-Cueing group ($p = 0.08$), but significantly better in the control night for the Cueing group with a large effect size ($p < 0.05$, $d = 1$). A paired one-sided permutation test confirmed that overall, subjects needed less time to fall asleep in the control night than in the experimental night ($p < 0.01$, $d = 1.06$). Reasons for not being able to fall asleep in the experimental night were mostly because of the sleep mask, the electrodes, unusual circumstances and - within the Cueing group - sounds. For detailed information see *Table 6*.

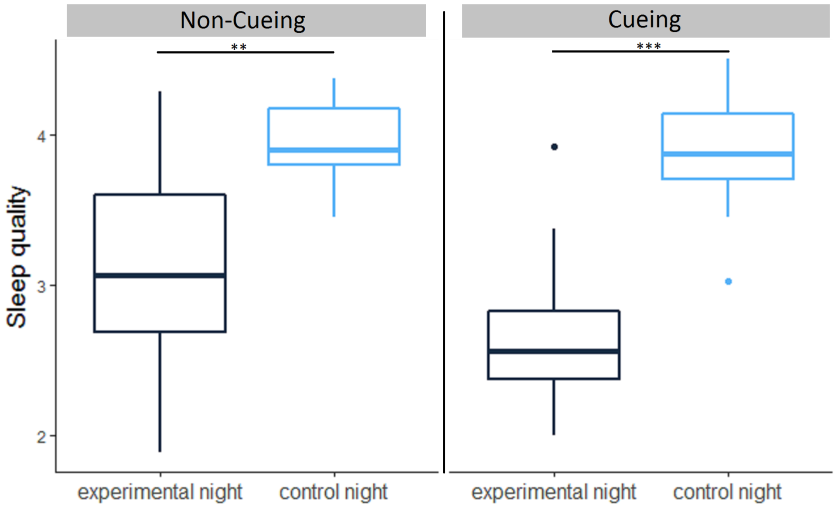

Figure 12: Sleep quality for the Non-Cueing and Cueing group in the experimental and the control night. One denotes impaired sleep quality, whereas five stands for positive ratings. Results were significant for each group respectively between the two nights, showing that sleep quality was decreased when sleeping with the sleep mask. In the control night, sleep quality was similar for both groups.

Table 6: Reasons for delayed sleep onset for the Non-Cueing and Cueing group in the experimental night and for all participants in the control night. Participants were allowed to give multiple answers.

Reasons for not falling asleep	Experimental night		Control night
	Non-Cueing	Cueing	
private reasons/experiences	22.2%	25%	39.1%
sounds	11.1%	33.3%	8.7%
unfamiliar circumstances	22.2%	41.2%	-
sleep mask	44.4%	41.7%	-
exitement	11.1%	8.3%	-
no reason	33.3%	16.7%	60.9%

Concerning awakening rates in the control night, 12 participants (57.1 %) did not wake up at all, 8 participants (38.1 %) woke up once, and one participant (4.8 %) woke up twice (*Figure 13*). Thus, applying a permutation test showed that participants woke up significantly more often in the experimental than in the control night ($p < 0.001$, $d = 2.4$).

As no differences in sleep quality and feeling of recovery were obtained in the control night between the Non-Cueing and the Cueing group, all three conditions - Cueing group in the experimental night, Non-Cueing group in the experimental night and all participants in the control night - were compared. We found that slept quality was best in the control night, worse when wearing the sleep mask in the experimental night and worst when participants were additionally exposed to sounds in the experimental night (*Figure 14*). A similar result was obtained for the feeling of recovery after awakening (*Figure 15*).

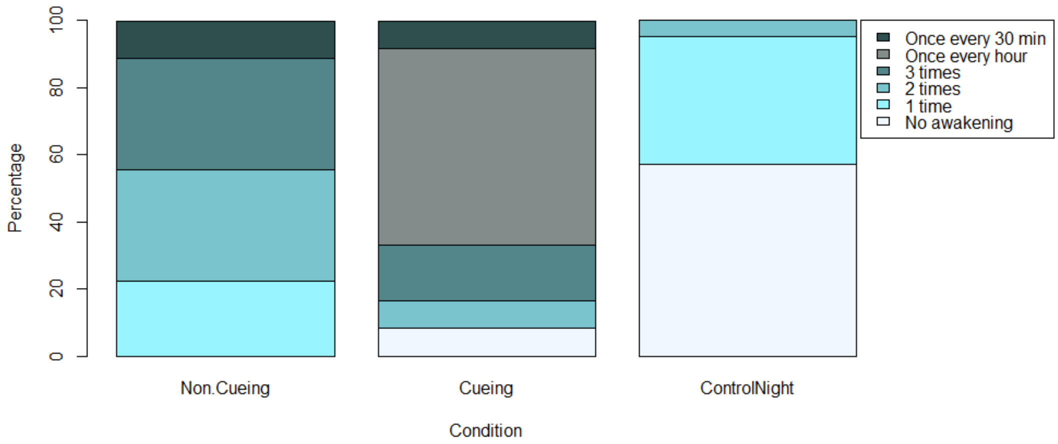

Figure 13: Number of self-reported awakenings in three different conditions: Non-Cueing group in experimental night, Cueing group in experimental night and all subjects in control night. Participants woke up significantly more often in the experimental night than in the control night.

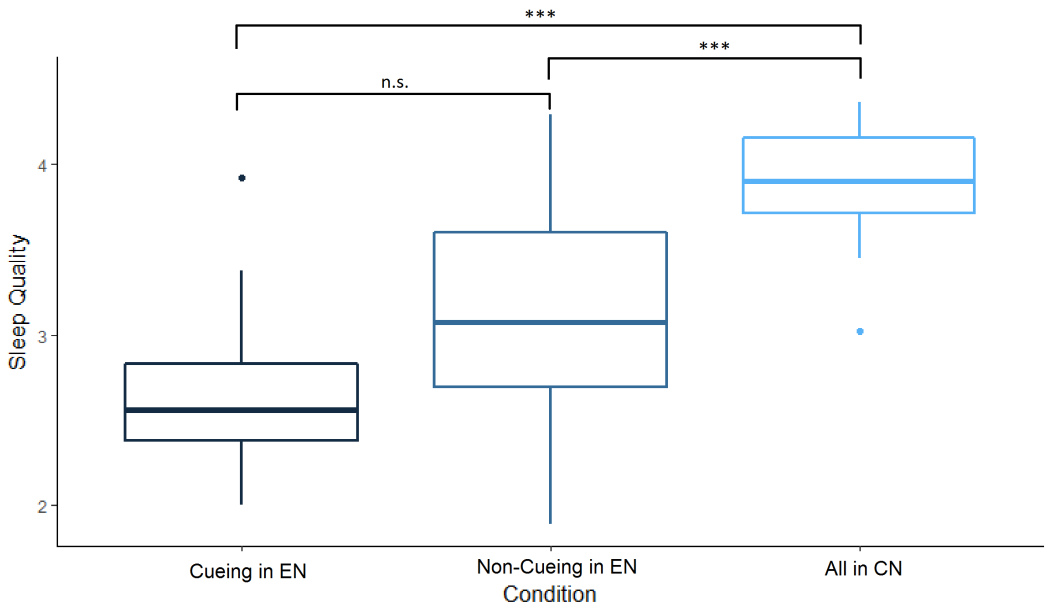

Figure 14: Sleep quality in three different conditions: Cueing group in experimental night (EN), Non-Cueing group in experimental night and all participants in control night (CN). One denotes impaired sleep quality, whereas five stands for positive ratings. Sleep quality was not significantly better between both groups in the experimental night. A comparison between all participants in the control night and each group in the experimental night respectively yielded significant results, showing that sleep quality was best in the control night.

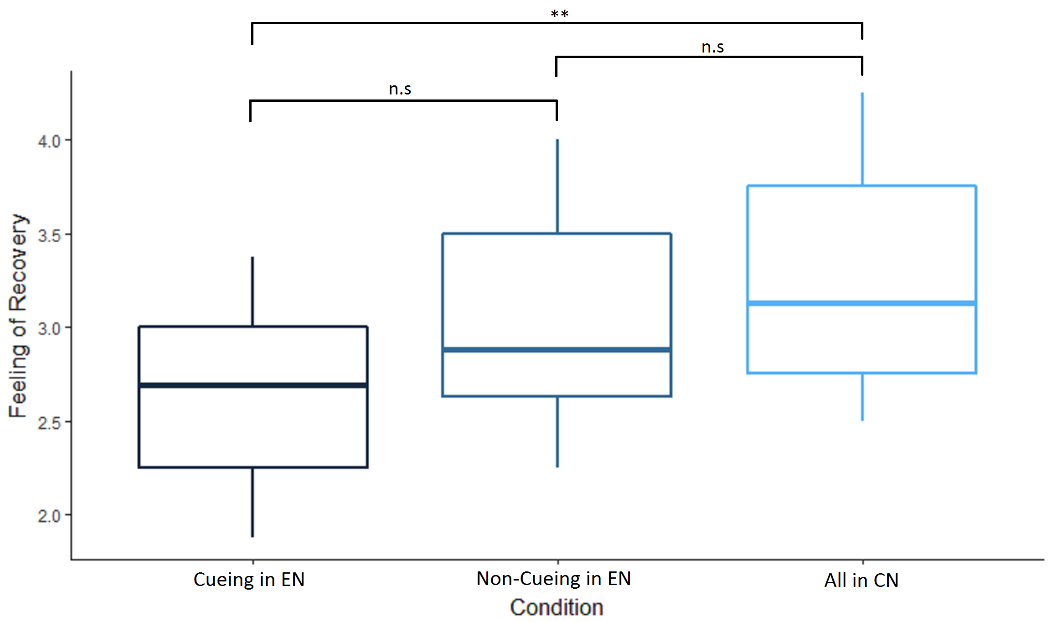

Figure 15: Feeling of recovery the next morning in three different conditions: Cueing group in experimental night (EN), Non-Cueing group in experimental night, all participants in control night (CN). One denotes impaired feeling of recovery, whereas five stands for positive ratings. Comparing the feeling of recovery, participants felt more recovered in the control night than participants in the Cueing group in the experimental night.

3.3.2 Sleep Data Evaluation

On average, each participant assigned to the Cueing group was exposed to 45 stimuli of random intensities during the night, where a sound intensity of zero means inaudible and one means full volume, i.e. room volume. Averaging over the amount of scored reactions and the corresponding auditory intensities for each individual participant and taking the mean of all participants within the Cueing group, no arousal was scored in 74.1% (range: 61.4% - 86.3%; mean sound intensity: 0.42, intensity range: 0.34 - 0.48), an arousal was scored in 23.4% (range: 7.4% - 38.6%, mean sound intensity: 0.64, intensity range: 0.49 - 0.8) and for the remaining 2.5% (range: 0 - 10.9%, mean sound intensity: 0.61, intensity range: 0.47 - 0.82) an arousal was scored just before stimulus onset. For a detailed overview of numbers of arousals and mean auditory intensities of each participant within the Cueing group, a table is attached in the *Appendix*. In order to find out whether the arousals scored just before stimulus onset were random occurrences or due to a mismatch between real stimulus onset and displayed onset, 20 randomly chosen data points were scored equally as the data was scored after stimulus onset. The percentage of random arousals was then compared to the percentage of arousals scored before stimulus onset, not yielding a significant result (random arousals: 4% of all data points, arousals before stimulus onset: 2.6% of all data points). As these unclear arousals could neither be assigned to the *No Reaction*-category, nor to the *Arousal after stimulus onset*-category, they were not included in the subsequent analysis.

Analysing the obtained polysomnographic data confirmed that participants were more often aroused when exposed to louder sounds. A permutation test yielded a significant result with a large effect size ($p < 0.001$, $d = 3.2$), visualized in *Figure 16*. Overall, no correlation between the scored number of arousals and the self-reported awakenings was found. In contrast, a participant for which 17 arousals were scored reported waking up twice during the night and a participant for which 8 arousals were scored reported waking up every 30 minutes. Additionally, neither was a correlation found between the number of arousals and the reported number of heard tones. Testing for correlations between the scored arousals and the sleep quality or the feeling of recovery respectively did not yield significant results. When analysing whether more arousals were scored in the first half of the night (in which N3 is predominate) or the second half of the night (in which REM sleep dominates sleep), no significant results were obtained.

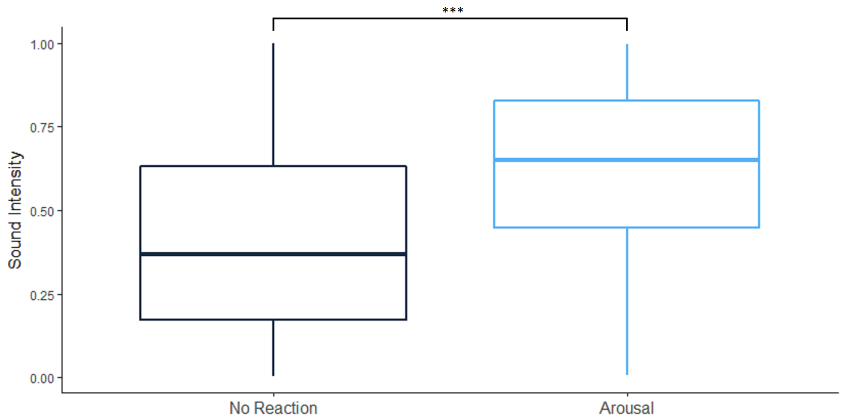

Figure 16: Analysis of the obtained sleep data of the Cueing group in the experimental night showed that more arousals were elicited when the sound intensity was higher.

3.3.3 Dream Content Analysis

In the experimental night, 4 out of 9 participants (44.4%) recalled their dreams in the Non-Cueing group and 11 out of 14 participants (78.6%) exposed to sounds reported dreaming, yielding a total number of 15 recalled dreams (65.1%). Overall, incorporation of the sleep experiment was self-reported in six dreams (40%) - once in the Non-Cueing group and five times in the Cueing group.

The participant in the Non-Cueing group dreamed of lying on a couch and wanting to conduct the experiment. When looking what time it was, some problem occurred, which caused the subject to wake up and being irritated when looking at the real time. Within the Cueing group, one participant reported two false awakenings, in which he already took off the sleep mask. Similarly, a second participant reported dreaming of taking off the sleep mask and being relieved when waking up and realizing that the sleep mask was still in the right place. Two participants likewise dreamed of taking off the electrodes. One of them reported: "I had the same dream over and over again, which was elicited by the sound. For some reason I thought that I ripped off the electrodes and consequently, failed the experiment. The voice from the speaker repeatedly said *'You have failed, the experiment was aborted!'* Then I woke up, examined the electrodes and fall asleep again until it beeped the next time." Another subject dreamed of not being able to fall asleep because he worried that something with the experiment will go wrong. None of the subjects within the Cueing group incorporated sounds into their dreams.

In the control night, 11 participants (47.8 %) remembered their dreams in the morning. None of the participants incorporated the sleep experiment in their dreams.

4 Discussion, Limitations and Future Directions

This study aimed at investigating two main aspects. First, evaluating whether the recently developed portable sleep mask - the *Traumschreiber* - is suitable for conducting home-based sleep experiments. Suitability was evaluated by investigating its usability for participants, the quality of the obtained polysomnographic data, and the impact on sleep when used in an automated field study where participants set up the experiment themselves. The second goal was to evaluate whether a portable monitoring device such as the *Traumschreiber* can be used in an auditory stimulation experiment in order to find the amount of auditory stimulation at which participants are aroused but not woken up.

4.1 Suitability of the *Traumschreiber* for Sleep Experiments

Usability Our data shows that participants neither had difficulties to understand nor to execute the experiment as the given instructions were clear and comprehensible. The verbal instruction during the first meeting, the written experimental schedule as well as the video were sufficient to enable subjects to set up the experiment themselves. Thus, this study proved that using the sleep mask for sleep experiments at participants' homes is generally feasible.

Design In terms of the design of the mask, some issues were noticed which should be improved in order to increase comfortability of sleeping with the *Traumschreiber* for participants before conducting further experiments. To prevent that the sleep mask gets out of place during the night, an adjustable string is needed, such that each participant can fasten the string in the desired strength. Additionally, it would be advantageous if the battery was less heavy as participants were disturbed by its weight and size. Changes in the design for optimizing the collection of data include a covering cap for the switch of the mask to prevent it from being switched off by mistake when turning around in bed or when shifting the mask into a comfortable position. Using some medical tape to fixate the electrodes would be beneficial in order to prevent the electrodes from getting detached during the night, especially the two electrodes at the heart. As the currently used battery needs approximately three hours to charge, a battery which charges faster or alternatively, an exchangeable battery, would facilitate testing participants day after day and ensure that no data is lost because the battery is not fully charged.

Experimental Set-up As all participants were Cognitive Science or Psychology students of the University of Osnabrück, it is not a representative sample of the population. We assume that subjects were not completely new to EEG or sleep experiments, which might have had an impact on understanding the instructions and on the usability and execution of the experiment. Nevertheless, this does not impact our findings on the influence of the sleep mask on sleep, the results of the obtained polysomnographic data, and the analysis of the acoustic stimulation.
As EMG activity was recorded at the chin during this experiment, no good muscle ac-

tivity was obtainable for males wearing a beard. Therefore, future studies either need to measure EMG activity at a different location or should not recruit male subjects with beards. For measuring ECG activity, continuing to use two electrodes at the heart is recommended as these electrodes were most often detached or sometimes either one or the other ECG channel did not transmit a good signal quality during the night.
For future sensory stimulation studies, not starting stimulation directly after the participants went to bed is recommended. In the present experiment, subjects in the Cueing group reported hearing the sounds already before falling asleep, as sounds were played every ten minutes throughout the night. Therefore, it would be of advantage to start playing the sounds when it is most likely that participants are already asleep. During this study, participants needed on average 20 - 30 minutes to fall asleep in the experimental night. Thus, future studies should consider starting sensory stimulation approximately 30 minutes after the participant went to bed.

Questionnaire When evaluating the questionnaire designed by the experimenter, good information on the usability and the comfortability of the sleep mask was obtained. Nevertheless, some interesting questions were left unanswered, as they were not included in the questionnaire. Adding the following questions to the *Fragebogen zum Gebrauch des Traumschreibers* is therefore recommended for future studies:

- How helpful was watching the video previously to executing the steps described in the experimental schedule? *To clarify the importance of the video for the understanding of the participants.*
- How helpful were the verbal instructions given via the speakers of the minicomputer? *To clarify the importance of the verbal instructions for the understanding of the participants.*
- How deep is your sleep normally? Do you wake up often in general? *To check if the number of arousals correlates with self-assessment of depth of sleep.*
- How long did the whole procedure - from watching the video until going to bed - take in the evening? *The question: "How long did it take to attach the electrodes in the evening?" seemed to be unclear to participants, as a time range between 3 and 30 minutes was reported. In order to prevent confusion of attaching the electrodes and the duration of the whole procedure in the evening, adding this question is recommended.*
- What is your motivation for participating in the experiment? *Motivated participants might put more effort in attaching the electrodes, which could result in better polysomnographic data.*
- How excited were you in the evening before going to bed? *Excitement could influence the time to fall asleep and the number of awakenings during the night.*
- How do you like the design of the sleep mask? How would you improve it? *Studies showed that objects which are more attractive to the user are easier to use, even if they have the same functions (Norman, 2004).*

Influence on Sleep Regarding the influence of sleeping with the *Traumschreiber*, our findings confirm the prior hypothesis that sleep is disturbed when wearing the sleep mask (longer time needed to fall asleep, more awakenings and worse sleep quality in the experimental night). When participants were additionally exposed to auditory stimulation during the night, sleep was even more affected. Especially for memory consolidation experiments, researchers need to be careful to prevent fragmentation of sleep by sensory stimulation, as the continuity of sleep is important for memory consolidation functions (Diekelmann et al., 2009). Usually, polysomnography aims at accurately recording brain activity with minimal discomfort to subjects as not to disturb the continuity of sleep (Smolley et al., 2013). Unfortunately, the current study shows that this is not the case. Even for participants that were not exposed to auditory stimulation in the experimental night, sleep quality was decreased immensely compared to the control night. We assume that the origin of worse sleep quality is multifactorial and includes the unfamiliar feeling of sleeping with the electrodes, the cables, and the sleep mask. Additionally, influencing factors can be the limitation of movements and the feeling of being supervised. Previous research found similar factors that influence sleep in the first night when sleeping in a laboratory environment, calling it the first-night effect (Agnew et al., 1966; Le Bon et al., 2001). Concerning the environmental influence on sleep quality which was also mentioned as a possible factor of the first-night effect by Le Bon et al. (2001), previous research compared the influence of polysomnography on sleep quality of patients with obstructive sleep apnea when either sleeping at home or sleeping in the laboratory (Kingshott et al., 2000). They found that patients slept better at home, with more slow wave, more REM sleep, and less sleep fragmentation. Likewise, Bruyneel et al. (2011) found that polysomnography at home is associated with better sleep efficiency than in the laboratory. Nevertheless, both studies only tested patients with sleep disorders and therefore, future research is needed to clarify the role of sleeping in the laboratory compared to sleeping at home for healthy participants when using the *Traumschreiber* for polysomnography. Such an experiment would also clarify whether the first-night effect is as present in home-based experiments as in experiments taking place in a laboratory environment. Another question that should be answered is whether participants adapt to sleeping with the sleep mask when tested in multiple nights, which could lead to an increase of sleep quality. In summary, although we showed that sleep quality is decreased when wearing the *Traumschreiber*, we think that experiments at home provide more natural environmental conditions than experiments taking place in the laboratory.

Regarding the relationship between scored numbers of arousals during the night and sleep quality, we expected to find a correlation, such that higher numbers of arousals would correlate with worse sleep quality. Although Bonnet et al. (1978) found that for participants with lower arousal thresholds, sleep quality was significantly worse than for participants with higher arousal thresholds, we were not able to replicate their findings. Unexpectedly, neither was a correlation found between self-reported number of awakenings and scored arousals. These results could be due to a low number of participants, as not all subjects assigned to the Cueing group could be analysed because the obtained polysomnographic

data did partly provide a bad signal quality. The fact that scoring of arousals was done by only one person which additionally had only a few experiences in scoring sleep data could also have influenced the results. Another reason why no correlation between the number of awakenings and arousals was found could be that arousals do not necessarily lead to awakenings and that awakenings are quickly forgotten (Halász, 1998; Halász et al., 2004). This could, for example, explain why one participant for whom 17 arousals were scored only reported waking up twice during the night.
Concerning the arousals scored just before stimulus onset, we assume that they were due to spontaneous arousals. Schieber et al. (1971) were the first to mention these "phases d'activation transitoire spontanées" (phases of spontaneous transitory activation), later called micro-arousals. They occur every 4-5 minutes, 50-100 times during the night with a duration between some seconds to more than ten seconds (Halász, 1998). Halász et al. (2004) reported that these spontaneous arousals show similar activation patterns as arousals elicited by external stimuli. Therefore, we speculate that the arousals scored just before stimulus onset were micro-arousals and not due to a mismatch of timing.

Obtained Sleep Data Evaluation of the obtained sleep data revealed that data collection needs to be improved for future studies to enable precise analysis of polysomnographic data and scoring of sleep stages. Issues that occurred during the study in terms of data collection will now be discussed.
One problem faced was that the two cables collecting EMG activity got detached after testing eight participants. In took three days until the defect was fixed, in which no muscle activity was collected in the three subsequent nights. For all three participants, only less than 20 minutes of data was collected. Therefore, we assume that the bad collection of data in the three experimental nights was due to the missing cables. In three different nights, only less than three hours of data was collected. For one night, the participant reported that the mask was turned off in the morning. He hypothesized that he could have turned it off by mistake when turning around in bed. Reasons for the short collection of data in the remaining two nights might have been a disruption of the bluetooth connection because the participants either went to the bathroom, lay on the transmitter of sleep mask which disturbed the transmission of data, or the Raspberry Pi being placed too far away from the bed. Another reason for termination of the connection might have been a discharged battery of the sleep mask which prevented the data to be sent.
If data was transmitted, the analysis of the sampling rate showed that data transmission was bad in two nights. Reasons could be a low battery or a bad bluetooth connection. Unfortunately, many channels did not transmit a good signal quality. One possible explanation is that most participants were completely new to attaching the electrodes themselves and thus, did not attach them accurately. Other reasons could have been that the cables were either bent or had a defective contact, or the electrodes lost contact to the skin during the night (e.g. when participants turned around in bed). Surprisingly, the signal quality of one of the EEG channels (EEG2) was especially bad. It transmitted a bad signal in almost half of the experimental nights, which could be due to a defective cable. In summary, in a quarter of all nights, data transmission was stopped already before three

hours of data collection. During five different nights, the data was not good enough that accurate scoring of sleep stages would be guaranteed - two nights the sampling rate was bad and three nights no good signal quality of the channels was obtained. Taken together, in only half of the experimental nights a good signal quality of sleep data was recorded that would enable experienced experimenters to analyse the polysomnographic data. In the remaining 50% of the nights, the data would not suffice to analyse sleep data and score sleep stages. For future studies, this could be a major issue when using the *Traumschreiber* for polysomnography. To improve data collection in subsequent experiments, it will be important that the Raspberry Pi can automatically re-establish a bluetooth connection to the sleep mask after it is lost. Moreover, a better preparation of participants is recommended, e.g. including a training session for attaching the electrodes or emphasizing the necessity of attaching the electrodes correctly. Additionally, future studies need to find a way to prevent bending of the cables during the night to ensure good recording of polysomnographic data.

Dream Content The dream reports indicate that participants within the Cueing group remembered more dreams than participants within the Non-Cueing group. Since dreams are generally quickly forgotten if not woken up, we speculate that higher dream recall within the Cueing group is due to higher awakening rates. Although 40% of all dreams included the sleep experiment, none of the participants incorporated the acoustic stimuli into their dreams. Similarly, Rahimi et al. (2015) reported that in studies that used a pure tone stimuli, the sound was only incorporated in 5% of all dreams and Dement et al. (1958) reported incorporation of a 1000Hz tone in 9% of dreams.
A possible explanation for high incorporation rates of the sleep experiment in our study could be that participants did not include the experiment because of the acoustic stimulation but because of the tactile stimulus of wearing the sleep mask. When looking at incorporation rates in previous studies, Paul et al. (2014) reported incorporation of tactile stimuli in 45% of dreams and Koulack (1969) reported incorporation in 42% of recalled dreams, similar to the incorporation rates in our study. Nevertheless, the feeling of wearing the sleep mask is not comparable to the direct application of tactile stimulation in the named studies. A more plausible explanation for why participants incorporated the sleep experiment into their dreams could be the experimental setting. In his review, Schredl (2003) reported that in 38.4% of 1753 analysed dreams of participants that slept in the laboratory, the experimental setting was incorporated, which almost perfectly matches our findings.
Analysing the content of dreams that incorporated the experimental setting, 4 out of 6 participants reported dreaming of either taking off the sleep mask or the electrodes. This could indicate that participants were either afraid to do something wrong as taking off the electrodes or the sleep mask by mistake, or that they wished to finish the experiment - maybe because sleeping with the mask was not perceived as comfortable or the electrodes or the cables were sensed as disturbing. In summary, incorporation of the sleep experiment into the dream content could either be due to wearing the sleep mask or simply because of the experimental set-up.

4.2 Portable Monitoring Devices for Auditory Stimulation Experiments

Originally, we aimed at finding a model of auditory threshold for each individual participant which takes into account the different sleep stages as previous research found that the arousal threshold differs between different stages (Ermis et al., 2010; Rechtschaffen et al.,1966). For three reasons, this was not done. First, not enough data points were obtained per person as only one night was observed. Second, the obtained data was not good enough in almost half of the nights such that accurate scoring of sleep stages would not be guaranteed. And third, accurately scoring sleep stages and changes of sleep stages after auditory stimulation would have exceeded the scope of this thesis. Therefore, a follow up study is recommended that tests participants in multiple nights with auditory stimulation and then accurately scores sleep stages in order to obtain a model of arousal threshold for the entire night.

Nevertheless, we were able to obtain a general arousal threshold for each participant, irrespectively of the sleep stage and the time of the night. The results confirm that more arousals were elicited to louder sounds than to quiet ones. Moreover, the data suggests that different participants have different awakening thresholds, as some participants that were exposed to sounds during the night did not wake up once while others reported waking up every 30 minutes. Yet, we need to consider that this could also be due to different environmental conditions, e.g. the speakers being placed at different distances, different acoustic surroundings, different background noise level, or different body position (directed towards or away from speakers). All these factors can have an influence on how one perceives the sounds and therefore, we cannot conclude absolute arousal thresholds from our data, i.e. we cannot infer that participant A has a higher arousal threshold than participant B.

Although the sleep stages were not taken into account for calculating arousal thresholds in this study, we were able to obtain a constant intensity of acoustic stimulation for each participant to which arousals are likely in the respective environmental surroundings. However, we need to keep two things in mind: First, if we use this constant arousal threshold in subsequent experiments, we risk to wake up participants in light sleep and achieve no reaction in deep sleep. Second, even if we are able to determine an individual arousal threshold for each participant and every sleep stage, subsequent experiments using this threshold need to be executed at participants' homes as well. If we would later use this threshold in the laboratory for the same participant, he might react differently, as the acoustic surroundings differ and the participant sleeps in an unfamiliar environment. Unfortunately, in order to conduct fully automated experiments at participants' homes that aim at specifically investigating one field of research (e.g. memory consolidation or induction of lucid dreams) techniques that can automatically score sleep stages are needed, as mostly only one sleep stage is of interest for each field of research and therefore, sensory stimulation in only one sleep stage is desired. Therefore, future research needs to focus on reliable, automatic scoring of sleep stages in order to enable automated home-based sleep experiments that use sensory stimulation in different sleep stages. If automatic scoring of sleep stages is possible in real time, portable monitoring devices such as the *Traum-*

schreiber can enable fully automated sensory stimulation experiments - from finding the arousal threshold during one night and stimulating specific sleep stages in subsequent nights.

4.3 Concluding Remarks

The present field study proved that the *Traumschreiber* is generally suitable for home-based experiments. The main issue that needs to be solved is to ensure good data collection. This can be achieved if the Raspberry Pi is able to re-establish a bluetooth connection after it was lost and if the signal quality of measured activity can be improved. If these issues can be resolved, portable monitoring devices such as the *Traumschreiber* can be used for different home-based automated sleep experiments, enabling researchers to gain higher numbers of experimental nights for different research purposes. Summarizing the findings of the auditory stimulation experiment, we were able to obtain a constant arousal threshold for each individual participant. For the nights in which a good signal quality of polysomnographic data was obtained, the data will allow experienced sleep researchers to score sleep stages and therewith, determine an arousal threshold for every sleep stage. In order to conduct fully automated home-based sensory stimulation experiments, the next step research needs to achieve is to enable automatic real-time scoring of sleep stages, such that only specific sleep stages can be stimulated in a home-based setting. Then, researchers can use portable monitoring devices such as the *Traumschreiber* for conducting all sorts of automated sensory stimulation experiments in order to further explore the processes that occur during the night. The results of these studies will deepen our understanding of memory consolidation functions, neurophysiological sleep patterns, dreaming, and might even be used for practical applications such as for fear extinction or light exposure therapies.

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Appendix A: Informed Consent

Versions-Datum: 11.01.2017

Einverständniserklärung

a) zum Verbleib beim Probanden und
b) zum Verbleib bei der Versuchsleitung

nach Information und Aufklärung über die Studiendurchführung und mögliche Folgen und Schäden sowie über den Umgang und die Verwendung der damit zusammenhängenden personenbezogenen Daten.

Titel der Studie:	**Stimulation des Schlafes mittels einer mobilen Hightech-Schlafmaske**
Name und Adresse der Projektleitung:	**Professor Dr. Gordon Pipa, Kristoffer Appel** **Institut für Kognitionswissenschaft,** **Universität Osnabrück** **Wachsbleiche 27, 49090 Osnabrück**

Sehr geehrte Studienteilnehmerin,
sehr geehrter Studienteilnehmer,

hiermit bitten wir Sie um Ihr Einverständnis zur Teilnahme an dem oben genannten Forschungsvorhaben und zur Nutzung Ihrer personenbezogenen Daten, wie sie Ihnen in der Versuchspersoneninformation/-aufklärung erläutert wurden.

I. Allgemeines

Hiermit erkläre ich,____, geboren am ______________________,
*(Name, Vorname)**

** bitte in Druckbuchstaben*

dass ich durch die Projektleitung mündlich und schriftlich über das Wesen, die Bedeutung, die Risiken und Folgen der wissenschaftlichen Untersuchungen im Rahmen der o.g. Studie informiert und aufgeklärt wurde und ausreichend Gelegenheit hatte, meine Fragen mit der Projektleitung zu klären.

Mir ist bekannt, dass im Rahmen dieser Studie keine medizinischen Befunde erhoben werden.

Mir ist bekannt, dass ich das Recht habe, mein Einverständnis jederzeit ohne Angabe von Gründen und ohne nachteilige Folgen für mich zurückzuziehen und einer Weiterverarbeitung meiner Daten und Proben widersprechen und ihre Vernichtung verlangen kann.

Ich habe eine Kopie der schriftlichen Versuchspersoneninformation/-aufklärung und der Einverständniserklärung mit Versionsdatum 11.01.2017 erhalten.

Ich erkläre, dass ich freiwillig bereit bin, an der wissenschaftlichen Studie teilzunehmen.

Seite 1/3

Ich erkläre mich damit einverstanden,

1. dass meine für den Zweck der o.g. Studie nötigen personenbezogenen Daten durch die Studienleitung erhoben und pseudonymisiert aufgezeichnet und verarbeitet werden, auch auf elektronischen Datenträgern, und gegebenenfalls auch nachts;
2. dass folgende Personen Zugang zu den erhobenen Daten zum Zweck der Durchführung und wissenschaftlichen Verwertung der Studie haben:

- Prof. Dr. Gordon Pipa
- Kristoffer Appel
- die aktuellen und zukünftigen Mitarbeiter der Neuroinformatik-Gruppe am Institut für Kognitionswissenschaft
- Personen, die im Rahmen dieser Studie ihre Bachelor- oder Masterarbeit anfertigen

3. dass die Daten acht Jahre aufbewahrt und danach vernichtet werden;

4. dass die Studienergebnisse in anonymisierter Form, die keinen Rückschluss auf meine Person zulässt, veröffentlicht werden. Die Veröffentlichung kann in einer wissenschaftlichen Zeitschrift erfolgen oder im Internet;

5. dass polysomnografische Aufnahmen meines Schlafes mit Hilfe der Hightech-Schlafmaske angefertigt werden und Schlaf-Experimente (siehe Punkt 6) durchgeführt werden, die eine verminderte Schlafqualität verursachen können und so zu stärkerer Müdigkeit am Morgen des Experimentes führen können. Dadurch kann meine Konzentrationsfähigkeit, Aufmerksamkeit und Fahrtüchtigkeit (Auto) beeinträchtigt sein. Die polysomnografischen Aufnahmen umfassen:

- EEG. Ziel der Messung von EEG (Elektroenzephalographie) ist die Erfassung der elektrischen Spannung, die durch das Gehirn erzeugt wird. Um dies zu ermöglichen, verwenden wir mit dem EEG eine vollkommen ungefährliche Methode, bei der wir die Spannung an der Kopfhaut messen. Zur Messung werden Sie Messsensoren auf Ihre Stirn kleben.

- EOG. Bei dieser Methode werden Ihre Augenbewegungen erfasst. Dazu werden Sie Messsensoren in Ihrem Gesicht befestigen.

- EMG. Bei dieser Methode wird Ihre Muskelanspannung erfasst. Dazu werden Sie Messsensoren an Ihrem Kinn befestigen.

- EKG. Bei dieser Methode wird die Aktivität Ihres Herzes erfasst. Dazu werden Sie Messsensoren auf Ihrem Oberkörper befestigen.

- Fragebögen. Wir werden Sie im Rahmen dieser Untersuchung bitten, eine Reihe von Fragen zu beantworten. Die Befragungsdauer beträgt insgesamt etwa 45 Minuten;

6. dass mir zu allen Zeitpunkten des Experimentes akustische Reize vorgespielt werden können, auch nachts.

II. Ausschlusskriterien, Verhaltensregeln

II.1 Ausschlusskriterien

Hiermit bestätige ich, dass folgende Ausschlusskriterien bei mir nicht vorliegen:

Ich bin nicht jünger als 18 Jahre.

Ich habe keine gesundheitlichen Probleme, welche die Teilnahme an der Studie nicht ratsam erscheinen lassen, bzw. durch die Studie negativ beeinflusst werden könnten. Dies betrifft insbesondere neurologische Störungen und Störungen des Herz/Kreislaufsystems.

Ich bin nicht schwanger und stille nicht.

Ich leide nicht an psychischen oder psychosomatischen Erkrankungen.

Ich leide nicht unter Halluzinationen und befinde mich nicht in psychiatrischer Behandlung.

Ich nehme keine Schlafmittel, keine Psychopharmaka, keine Schmerzmittel und keine Antihistaminika.

Ich leide nicht an Schlafstörungen, insbesondere nicht an: Insomnie (Ein- und Durchschlafstörungen), Störungen des Schlaf-Wach-Rhythmus', schlafbezogenen Atmungsstörungen, Hypersomnie oder Narkolepsie, Schlafwandeln, regelmäßige Alpträume (mehr als ein Alptraum pro Woche) oder schlafbezogenen Bewegungsstörungen.

II.2 Zustimmung zur Einhaltung von Verhaltensregeln

Ich erkläre, dass ich über die Verhaltensregeln informiert bin, die ich ab 24 Stunden vor Beginn der einzelnen Untersuchungen einhalten muss (siehe Versuchspersoneninformation/-aufklärung) und sichere zu, dass ich diese Verhaltensregeln eingehalten habe / einhalten werde.

III. Datenschutzrechtliche Einwilligungserklärung

Einblick in die pseudonymisierten Daten durch Dritte

- entfällt -

IV. Aufwandsentschädigung

Für meine Teilnahme an dieser Studie erhalte ich keine finanzielle Aufwandsentschädigung. Mir werden jedoch 3 Versuchspersonenstunden gutgeschrieben.

V. Unterschrift

Ich erkläre hiermit, dass ich freiwillig und unter Kenntnis der oben genannten Punkte teilnehme.

Osnabrück, ______________________________ ______________________________________

*(Unterschrift **Versuchsperson**)*

Osnabrück, ______________________________ ______________________________________

*(Unterschrift **Projektleitung**)*

Appendix B: Experimental Information and Schedule

Versionsdatum: 11.01.2017

Versuchspersoneninformation-/aufklärung

Titel der Studie:	**Stimulation des Schlafes mittels einer mobilen Hightech-Schlafmaske**
Name und Adresse der Projektleitung:	**Professor Dr. Gordon Pipa, Kristoffer Appel Institut für Kognitionswissenschaft, Universität Osnabrück Wachsbleiche 27, 49090 Osnabrück**

Studieninhalt

In diesem Experiment geht es darum, Ihren Schlaf mit einer neuartigen Hightech-Schlafmaske (Name: „Traumschreiber“) zu vermessen (siehe Abschnitt „Aufzeichnungen“) sowie mittels akustischer Reize zu stimulieren. Dies dient dazu, wissenschaftliche Erkenntnisse z. B. über den Einfluss einer solcher Stimulation auf das Traumerleben oder auf Gedächtnisprozesse herauszufinden, oder um herauszufinden, wie groß individuelle Unterschiede bzgl. der nötigen Lautstärke zum Aufwecken sind. Außerdem möchten wir mit dieser Studie mehr über die grundsätzliche Eignung des Traumschreibers für solche Experimente erfahren.

Zu diesem Zweck werden Sie eine Nacht lang eine batteriebetriebene Hightech-Schlafmaske tragen, die über Einweg-Klebeelektroden Ihren Schlaf messen kann. Außerdem wird Ihnen im Laufe der Nacht mehrfach pro Stunde ein kurzer Ton oder Knacklaut in verschiedenen Lautstärken präsentiert (von unhörbar bis Zimmerlautstärke). In einer zweiten Nacht werden Sie gebeten, wie gewohnt (ohne Schlafmaske) zu schlafen und am Morgen Fragebögen auszufüllen.

Es werden im Rahmen dieser Studie keine medizinischen Befunde erhoben.

Ihre Aufgaben

Das Experiment ist detailliert im Ablaufplan beschrieben. Zusammengefasst machen sich wie gewöhnlich bettfertig, kleben die Elektroden an und starten das Experiment auf dem beigefügten Minicomputer. Anschließend setzen Sie die Schlafmaske auf und gehen schlafen. Morgens füllen Sie drei Fragebögen zu möglichen Trauminhalten, ihrem Schlafverhalten und der Hightech-Schlafmaske aus und nehmen die Schlafmaske ab. Anschließend geben Sie die Ihnen ausgehändigten Instrumente und Fragebögen an die Experimentleitung zurück. Eine Woche später gehen Sie wie gewohnt schlafen und füllen am darauffolgenden Morgen zwei Fragebögen zu möglichen Trauminhalten und ihrem Schlafverhalten aus. Diese lassen Sie der Projektleitung in den folgenden Tagen zukommen.

Vergütung

Ihnen werden für die Teilnahme an dieser Studie 3 VP-Stunden gutgeschrieben.

Aufzeichnungen

Mithilfe des Traumschreibers ist es möglich, Ihren Schlaf in Ihrer gewohnten Schlafumgebung aufzuzeichnen und dies später auszuwerten. Dies beinhaltet folgende Methoden:

- **EEG** (Elektroenzephalografie): Ziel der Messung von EEG ist die Erfassung der elektrischen Spannung, die durch das Gehirn erzeugt wird. Um dies zu ermöglichen, verwenden wir mit dem EEG eine vollkommen ungefährliche Methode, bei der wir die Spannung an der Kopfhaut messen. Zur Messung werden Sie Messsensoren auf Ihre Stirn kleben.
- **EOG** (Elektrookulografie): Bei dieser Methode werden Ihre Augenbewegungen erfasst. Dazu werden Sie Messsensoren in Ihrem Gesicht befestigen.
- **EMG** (Elektromyografie): Bei dieser Methode wird Ihre Muskelspannung erfasst. Dazu werden Sie Messsensoren an Ihrem Kinn befestigen.
- **EKG** (Elektrokardiografie): Bei dieser Methode wird die Aktivität Ihres Herzens erfasst. Dazu werden Sie Messsensoren auf Ihrem Oberkörper befestigen.

Genauere Informationen zur Anbringung der Messsensoren finden Sie im Ablaufplan (s.u.).

Risiken

Es kann wegen des Experimentes (Tragen der Hightech-Schlafmaske und der Einweg-Elektroden, akustische Stimulation während des Schlafes) dazu kommen, dass Sie öfter als gewöhnlich nachts aufwachen und somit die Schlafqualität vermindert ist. Das bedeutet u. U. auch, dass Ihre Konzentrationsfähigkeit, Aufmerksamkeit und Fahrtüchtigkeit (Auto) am Morgen wegen Müdigkeit eingeschränkt sein kann.

Im Rahmen der EEG-, EOG-, EMG-, und EKG-Aufzeichnungen kann es zu Hautrötungen kommen.

Vorzeitiger Experimentabbruch

Sie haben jederzeit das Recht, das Experiment ohne Angabe von Gründen abzubrechen.

Verhaltensregeln

- Trinken Sie in den letzten 24 Stunden vor dem Experiment bitte **keinen Alkohol**
- Führen Sie bitte **keinen Mittagsschlaf** an den Tagen der Experimente durch – auch nicht wenn Sie dies normalerweise machen
- Schlafen Sie gewöhnlich lange in den Nächten vor dem Experiment (**kein Schlafmangel**)
- Gehen Sie bitte vorsichtig mit den Ihnen zur Verfügung gestellten Materialien um.

Name und Adresse der Projektleitung

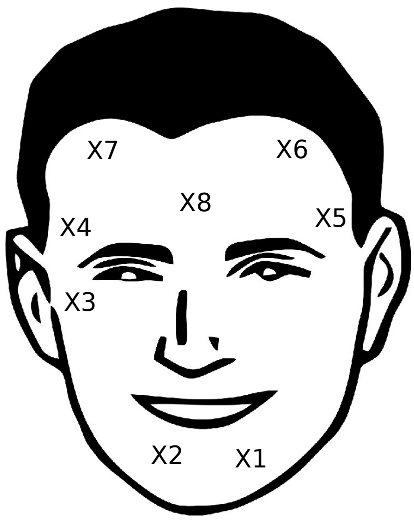
Professor Dr. Gordon Pipa und Kristoffer Appel, Institut für Kognitionswissenschaft, Universität Osnabrück, Wachsbleiche 27, 49090 Osnabrück.

Bei Fragen wenden Sie sich gerne an Laura Mandt, die im Rahmen ihrer Bachelorarbeit mit der operativen Durchführung dieser Studie betraut ist, unter lmandt@uos.de

Versionsdatum: 11.01.2017

Ablaufplan / Anleitung

- **Am Abend:**
  - Schauen Sie sich zunächst das Video an, in dem die Anbringung der Schlafmaske beschrieben wird.
  - Lesen Sie den Ablaufplan nun bis zum Ende durch (auch „Am Morgen“).
  - Machen Sie sich wie gewöhnlich zu Ihrer normalen Schlafenszeit bettfertig.
  - Falls vorhanden, entfernen Sie bitte sorgfältig Ihr Make-up.
  - Waschen Sie Ihr Gesicht mit einer gewöhnlichen Seife und trocknen Sie es ab.
  - Legen Sie die Fragebögen „Traumbericht“, „Schlaf-Fragebogen A“, „Fragebogen zum Gebrauch des Traumschreibers“ und einen Stift auf Ihren Nachttisch / in Bettnähe ab.
  - Kleben Sie die Einweg-Klebelektroden wie folgt an Ihren Körper / Kopf (ziehen Sie sie dazu von der Plastikfolie ab):
    - **X9** und **X10**: an den linken seitlichen Brustkorb auf die Rippen, im Abstand von etwa 10 cm
    - acht Elektroden gemäß folgender Zeichnung in Ihr Gesicht:



X1 und **X2**: zwischen Kinn und Lippen
X3: etwa 1 cm außerhalb und 1 cm unterhalb des rechten äußeren Augenwinkels
X4: etwa 1 cm außerhalb und 1 cm oberhalb des rechten äußeren Augenwinkels (nicht auf die Augenbraue)
X5: etwa 1 cm außerhalb und 1 cm oberhalb des linken äußeren Augenwinkels (nicht auf die Augenbraue)
X6: möglichst weit in die linke „Geheimratsecke“, d.h. möglichst dicht an den Haaransatz (aber nicht ins Haar)
X7: möglichst weit in die rechte „Geheimratsecke“, d.h. möglichst dicht an den Haaransatz (aber nicht ins Haar)
X8: zentral auf die Stirn

- Falls die Elektroden nicht gut halten, versuchen Sie es bitte noch einmal mit neuen Ersatzelektroden und fixieren Sie die Elektroden zusätzlich mit dem Medi-Tape (Klebeband).
- Stellen Sie den Minicomputer in etwa zwei Meter Entfernung zu Ihrem Kopfkissen auf.
- Schließen Sie den Minicomputer an das Stromnetz an, indem Sie den Netzstecker mit dem Minicomputer und einer Steckdose verbinden. Er fährt nun automatisch hoch.
- Warten Sie etwa 30 Sekunden, bis der Minicomputer hochgefahren ist. Dies erkennen Sie daran, dass sich ein Fenster mit einem großen grauen Button "Experiment starten" öffnet. Wenn dies nicht der Fall sein sollte, trennen Sie den Minicomputer bitte nochmal vom Stromnetz. Achten Sie darauf, dass die Kabel des Lautsprechers nicht mit dem Minicomputer verbunden sind, und versuchen Sie erneut, den Minicomputer hochzufahren.
- Schließen Sie erst jetzt die Lautsprecher an, indem Sie das Audiokabel mit dem Minicomputer verbinden und den Netzstecker an das Stromnetz anschließen. Stellen Sie die Lautsprecher in etwa zwei Meter Entfernung und in Richtung ihres Kopfkissens auf.
- Folgen Sie den mündlichen Anweisungen des Minicomputers.
- Wenn Sie dazu aufgefordert werden, starten Sie die Aufnahme, in dem Sie (am besten mit dem Fingernagel) auf dem Touchscreen das Feld „Experiment starten!“ drücken.
- Wenn Sie dazu aufgefordert werden, schalten Sie dann die Hightech-Schlafmaske ein, indem Sie den Schalter in die mit Punkt markierte Stellung kippen.
- Wenn Sie dazu aufgefordert werden, setzen Sie bitte die Schlafmaske auf und verbinden Sie die Elektrodenkabel gemäß ihrer Beschriftung („X1“, „X2“, …, „X10“) mit den Elektroden in Ihrem Gesicht und an Ihrem Oberkörper. Dabei ist es egal, welche der beiden Oberkörper-Elektroden Sie mit welchem der beiden Kabel „X9“ und „X10“ verbinden.
- Sollten technische Probleme mit dem Minicomputer oder mit der Schlafmaske auftreten, schalten sie bitte beides komplett aus (über den Kippschalter an der Schlafmaske und durch Ziehen des Netzsteckers des Minicomputers. Schalten sie anschließend die Geräte wieder wie oben beschrieben ein.
- Versuchen Sie wie gewohnt einzuschlafen und schlafen Sie solange, wie Sie möchten.

- **In der Nacht:**
  - Im Laufe der Nacht wird Ihnen vollautomatisch mehrfach pro Stunde ein kurzer Ton oder Knacklaut in verschiedenen Lautstärken präsentiert (von unhörbar bis Zimmerlautstärke)
  - Falls Sie dadurch aufwachen sollten, versuchen Sie entspannt wieder einzuschlafen.

- **Am Morgen:**
  - Bitte füllen Sie zunächst den Fragebogen „Traumbericht“ aus.
  - Füllen Sie anschließend die beiden weiteren Fragebögen „Schlaf-Fragebogen A“ und „Fragebogen zum Gebrauch des Traumschreibers“ aus.
  - Nehmen Sie nun die Schlafmaske ab, indem Sie zunächst die Elektrodenkabel von den Einweg-Klebeelektroden abklippen.
  - Schalten Sie die Schlafmaske am Kippschalter aus.
  - Nehmen Sie die Einweg-Klebeelektroden ab und entsorgen Sie diese im Restmüll.

- Schalten Sie den Minicomputer aus, indem Sie den Stecker aus der Steckdose ziehen.
- Verpacken Sie alle Experimentutensilien und bringen Sie sie zum abgesprochenen Treffpunkt zurück.

- **Eine Woche später:**
    - Machen Sie sich wie gewohnt zu Ihrer normalen Schlafenszeit bettfertig.
    - Legen Sie die Fragebögen „Traumbericht“, „Schlaf-Fragebogen A“ und einen Stift auf Ihren Nachttisch / in Bettnähe ab.
    - Versuchen Sie (dieses Mal ohne Schlafmaske) wie gewohnt einzuschlafen und schlafen Sie solange, wie Sie möchten.
    - Nach dem Erwachen füllen Sie bitte zunächst den Fragebogen „Traumbericht“ und anschließend den „Schlaf-Fragebogen A“ aus.
    - Die ausgefüllten Fragebögen lassen Sie mir bitte in den folgenden Tagen zukommen. Alternativ können Sie die Fragebögen auch im Büro von Kristoffer Appel (Wachsbleiche 27, R.50/214) oder von Professor Dr. Gordon Pipa (Wachsbleiche 27, R.50/218) abgeben.

LISST

Landecker **I**nventar zur Erfassung von **S**chlaf**st**örungen

Schlafzentrum Pfalzklinik Landeck, Weinstr. 100, 76889 Klingenmünster

Angaben zur Versuchsperson:

VP-Nr.: ______

Alter: __________________

augenblickliches Gewicht (in kg) ☐ kg

Körpergröße (in cm) ☐ cm

Geschlecht: männlich ☐ weiblich ☐

Zum Ausfüllen dieses Fragebogens:
Sehr geehrte Versuchsperson,
bitte füllen Sie diesen Fragebogen sorgfältig aus.
Sie tun dies am besten ohne langes Grübeln; das, was Ihnen als Erstes zu einer der Fragen einfällt, ist meistens richtig.
Bitte bedenken Sie, daß sich die folgenden Fragen auf die ***letzten vier Wochen*** beziehen.
Die meisten Fragen sind einfache Feststellungen. Sie beantworten sie, indem Sie die zutreffende Nummer ankreuzen.
Wenn Sie eine Aussage stark verneinen bzw. diese niemals auf Sie zutraf, antworten Sie bitte mit ① **.** Wenn eine Aussage „immer“ oder „ganz genau“ zutrifft, antworten Sie mit ⑥ **.** Ansonsten können Sie zwischen ② = „selten“, ③ = „gelegentlich“, ④ = „häufig“ oder ⑤ = „meistens“ auswählen.
Zur Erinnerung ist dieser Antwortschlüssel am Fußende jeder Seite noch einmal abgedruckt.
Bitte beantworten Sie alle Fragen!

Hier ein Beispiel, wie Sie Ihre Antwort markieren können:

Ich wache plötzlich nach Luft ringend auf, unfähig zu atmen. ① ~~②~~ ③ ④ ⑤ ⑥

Wenn diese Feststellung nicht auf Sie zutrifft und Sie niemals nachts aufwachen und nach Luft ringen, dann kreuzen Sie die ① = „nie“ an. Wenn Sie jedoch jede Nacht mehrmals mit Atemschwierigkeiten wach werden, so kreuzen Sie bitte die ⑥ = „immer, trifft voll und ganz zu“ an.

Es ist wichtig, daß Sie alle Fragen beantworten.

(Bitte beachten Sie, daß die Antwort ① bedeutet, daß diese Frage zu *keiner Zeit* in den letzten vier Wochen auf Sie zutraf.)

1) Ich bin abends viel früher oder später müde als andere. ① ② ③ ④ ⑤ ⑥

2) Beim Zubettgehen fühle ich mich traurig oder niedergedrückt. ① ② ③ ④ ⑤ ⑥

3) Beim Einschlafen oder während der Nacht habe ich unruhige Beine. ① ② ③ ④ ⑤ ⑥

4) Ich kann nicht so viel schlafen wie andere. ① ② ③ ④ ⑤ ⑥

5) Ich habe Alpträume. ① ② ③ ④ ⑤ ⑥

6) Mein Schlaf wird durch Traurigkeit oder Niedergeschlagenheit beeinträchtigt. ① ② ③ ④ ⑤ ⑥

①	②	③	④	⑤	⑥
„nie“	„selten“	„gelegentlich“	„häufig“	„meistens“	„immer“
„trifft überhaupt nicht zu“	„trifft nicht zu“	„trifft eher nicht zu“	„trifft etwas zu“	„trifft zu“	„trifft voll und ganz zu“

7)	Ich bin tagsüber oft sehr müde und kann mich. nur schwer auf meine Arbeit konzentrieren.	① ② ③ ④ ⑤ ⑥
8)	Ich oder mein(e) Partner(in) bemerken, dass ich mich im Schlaf aufrichte und die Bettdecke zupfe, im Zimmer umhergehe oder den Raum verlasse.	① ② ③ ④ ⑤ ⑥
9)	Wenn ich nicht alleine schlafe, störe ich andere mit meinem Schnarchen.	① ② ③ ④ ⑤ ⑥
10)	Wenn ich morgens aufwache, gelingt es mir nicht immer, mich zu bewegen, obwohl ich schon wach bin.	① ② ③ ④ ⑤ ⑥
11)	Beim Einschlafen oder während der Nacht habe ich ein Kribbelgefühl in den Beinen oder Armen.	① ② ③ ④ ⑤ ⑥
12)	Ich leide an Schlaflosigkeit.	① ② ③ ④ ⑤ ⑥
13)	Beim Einschlafen bewege ich meinen Kopf rhythmisch auf dem Kissen hin und her.	① ② ③ ④ ⑤ ⑥
14)	Durch Schuldgefühle werde ich am Schlafen gehindert.	① ② ③ ④ ⑤ ⑥
15)	Ich gehe früher oder später als andere zu Bett.	① ② ③ ④ ⑤ ⑥
16)	Es wurde mir schon gesagt, dass ich während des Schlafes aufhöre zu atmen.	① ② ③ ④ ⑤ ⑥
17)	Ich habe Schwierigkeiten einzuschlafen.	① ② ③ ④ ⑤ ⑥
18)	Ich bin häufig so müde, dass ich Schwierigkeiten habe, meine Arbeit zu verrichten.	① ② ③ ④ ⑤ ⑥
19)	Wenn ich lache, mich ärgere oder andere, heftigere Empfindungen habe, habe ich manchmal das Gefühl, dass alle Kraft aus meinen Muskeln schwindet oder ich mich nicht mehr bewegen kann.	① ② ③ ④ ⑤ ⑥
20)	Beim Zubettgehen drängt sich eine Fülle von Gedanken in meinen Kopf.	① ② ③ ④ ⑤ ⑥

①	②	③	④	⑤	⑥
„nie“ „trifft überhaupt nicht zu“	„selten“ „trifft nicht zu“	„gelegentlich“ „trifft eher nicht zu“	„häufig“ „trifft etwas zu“	„meistens“ „trifft zu“	„immer“ „trifft voll und ganz zu“

21)	Ich mache im Schlaf wiegende und/oder schaukelnde Bewegungen.	① ② ③ ④ ⑤ ⑥
22)	Wenn ich auf dem Rücken schlafe, ist mein Schnarchen besonders ausgeprägt.	① ② ③ ④ ⑤ ⑥
23)	Ich spreche im Schlaf.	① ② ③ ④ ⑤ ⑥
24)	In monotonen und langweiligen Situationen, z.B. beim Fernsehen, im Kino bzw. Theater, oder als Beifahrer, beim Lesen usw., fällt es mir schwer, wach zu bleiben.	① ② ③ ④ ⑤ ⑥
25)	In der Nacht liege ich wach und denke über meine derzeitigen Angelegenheiten nach.	① ② ③ ④ ⑤ ⑥
26)	Morgens brauche ich sehr lange, bis ich richtig wach werde.	① ② ③ ④ ⑤ ⑥
27)	Beim Einschlafen oder während der Nacht muss ich immer wieder meine Arme und/oder Beine bewegen.	① ② ③ ④ ⑤ ⑥
28)	Meine Zubettgehzeiten unterscheiden sich von einem Tag auf den anderen um mehr als drei Stunden.	① ② ③ ④ ⑤ ⑥
29)	Nachts wache ich immer wieder auf.	① ② ③ ④ ⑤ ⑥
30)	Ich knirsche im Schlaf mit den Zähnen.	① ② ③ ④ ⑤ ⑥
31)	Ich habe Schwierigkeiten, mich lange richtig auf etwas zu konzentrieren.	① ② ③ ④ ⑤ ⑥
32)	Ich habe einen sehr oberflächlichen Schlaf.	① ② ③ ④ ⑤ ⑥
33)	Nach dem Aufwachen habe ich ein Spannungsgefühl im Mund- oder Kieferbereich oder sogar Kieferschmerzen.	① ② ③ ④ ⑤ ⑥
34)	Es fällt mir oft schwer, meine Beine im Bett ruhig zu halten.	① ② ③ ④ ⑤ ⑥

①	②	③	④	⑤	⑥
„nie“ „trifft überhaupt nicht zu“	„selten“ „trifft nicht zu“	„gelegentlich“ „trifft eher nicht zu“	„häufig“ „trifft etwas zu“	„meistens“ „trifft zu“	„immer“ „trifft voll und ganz zu“

35)	In Rückenlage habe ich häufiger Atemaussetzer.	① ② ③ ④ ⑤ ⑥
36)	Beim Einschlafen oder während der Nacht schmerzen meine Beine oder Arme.	① ② ③ ④ ⑤ ⑥
37)	Nachts stehe ich auf, weil ich nicht mehr schlafen kann.	① ② ③ ④ ⑤ ⑥
38)	Es kommt vor, dass ich mit einem lauten Schrei auf wache, dabei schwitze, Herzrasen habe und längere Zeit benötige, um die Orientierung wiederzufinden.	① ② ③ ④ ⑤ ⑥
39)	Im Bett gelingt es mir nur schwer, belastende Gedanken aus meinem Kopf zu vertreiben.	① ② ③ ④ ⑤ ⑥
40)	Beim Zubettgehen oder Aufwachen kann ich mich nicht bewegen, obwohl ich wach bin.	① ② ③ ④ ⑤ ⑥
41)	Man sagt mir, dass ich im Schlaf komische Bewegungen mache oder um mich schlage.	① ② ③ ④ ⑤ ⑥
42)	Ich gehe zu deutlich anderen Zeiten ins Bett, als sich dies mit meinen täglichen Anforderungen verträgt.	① ② ③ ④ ⑤ ⑥
43)	Mein Schlafrhythmus ist sehr wechselhaft.	① ② ③ ④ ⑤ ⑥
44)	Es kommt vor, dass ich im Schlaf eine schmerzhafte Erektion habe.	① ② ③ ④ ⑤ ⑥
45)	Ich wache morgens früher auf und kann nicht mehr schlafen.	① ② ③ ④ ⑤ ⑥
46)	Mein Schlafrhythmus ist anders als bei anderen Menschen.	① ② ③ ④ ⑤ ⑥
47)	Es kommt vor, dass ich nachts von Alpträumen geweckt werde. In der Regel kann ich mich an den Alptraum kaum erinnern.	① ② ③ ④ ⑤ ⑥
48)	Nachts liege ich wach und kann nicht schlafen.	① ② ③ ④ ⑤ ⑥

①	②	③	④	⑤	⑥
„nie“ „trifft überhaupt nicht zu“	„selten“ „trifft nicht zu“	„gelegentlich“ „trifft eher nicht zu“	„häufig“ „trifft etwas zu“	„meistens“ „trifft zu“	„immer“ „trifft voll und ganz zu“

49) Ich ermüde rasch. ① ② ③ ④ ⑤ ⑥

50) Ich habe ganz andere Schlafzeiten als mein Partner. ① ② ③ ④ ⑤ ⑥

50a) Wie oft erinnern Sie sich in letzter Zeit (einige Monate) an ihre Träume?

O fast jeden Morgen
O mehrmals die Woche
O etwa einmal die Woche
O 2-3mal im Monat
O etwa einmal im Monat
O weniger als einmal im Monat
O gar nicht

①	②	③	④	⑤	⑥
„nie“ „trifft überhaupt nicht zu“	„selten“ „trifft nicht zu“	„gelegentlich“ „trifft eher nicht zu“	„häufig“ „trifft etwas zu“	„meistens“ „trifft zu“	„immer“ „trifft voll und ganz zu“

51)	Ich leide unter Bluthochdruck.	① ② ③ ④
52)	Ich habe Übergewicht.	① ③ ④
53)	Ich habe mit dem Herzen Schwierigkeiten.	① ② ③ ④
54)	Ich habe eine Schilddrüsenerkrankung.	① ③ ④
55)	Ich habe Wadenkrämpfe.	① ② ③ ④
56)	Ich leide an Asthma oder einer anderen Erkrankung der Lunge.	① ③ ④
57)	Ich habe Allergien.	① ③ ④
58)	Ich habe chronischen Schnupfen oder Beschwerden mit den Nasen-Nebenhöhlen.	① ③ ④
59)	Ich habe Kopfschmerzen oder Migräne.	① ② ③ ④
60)	Ich habe Beschwerden im Magen-Darm-Bereich.	① ② ③ ④
61)	Ich habe Muskel- oder Gelenkschmerzen.	① ② ③ ④
62)	Nachts muss ich häufiger als früher aufstehen und zur Toilette gehen.	① ② ③ ④
63)	Ich leide an einer Erkrankung mit mehr oder weniger chronischen Schmerzen oder Beschwerden, die bisher noch nicht genannt wurden, und zwar an: ______________________________	① ② ③ ④

①	②	③	④
„nein“	„gelegentlich“	„ja“	„weiß nicht genau“

64) Ich nehme Schlafmittel. ① ② ③ ④ ⑤ ⑥

65) Ich nehme Medikamente wegen Herzbeschwerden. ① ② ③ ④ ⑤ ⑥

66) Ich nehme Medikamente gegen Bluthochdruck. ① ② ③ ④ ⑤ ⑥

67) Ich nehme Medikamente wegen einer Erkrankung an der Lunge. ① ② ③ ④ ⑤ ⑥

68) Ich nehme Medikamente wegen einer Allergie. ① ② ③ ④ ⑤ ⑥

69) Ich nehme Schmerzmittel. ① ② ③ ④ ⑤ ⑥

70) Ich nehme Medikamente, die meine Stimmung verbessern sollen. ① ② ③ ④ ⑤ ⑥

71) Ich nehme Medikamente wegen Schilddrüsen-problemen. ① ② ③ ④ ⑤ ⑥

72) Ich nehme Medikamente wegen Magen-Darm-Beschwerden. ① ② ③ ④ ⑤ ⑥

73) Ich nehme Hormonpräparate (außer der „Pille")? ① ② ③ ④ ⑤ ⑥

Da Alkohol ähnliche Auswirkungen auf den Schlaf haben kann wie Medikamente, beantworten Sie bitte noch folgende zwei Fragen:

74) Ich trinke Alkohol:

O nie
O selten/nur bei besonderen Anlässen
O 1 bis 2 Mal pro Woche
O 3 bis 4 Mal pro Woche
O 5 bis 6 Mal pro Woche
O täglich

75) Wenn ich Alkohol trinke, dann durchschnittlich:
(Geben Sie bitte Ihren durchschnittlichen Getränkekonsum pro Gelegenheit an) Falls Sie pro Gelegenheit mehr als einen alkoholischen Getränketyp zu sich nehmen, geben Sie bitte die Zusammensetzung an.

☐ Gläser Bier (0,3 l)
☐ Gläser Wein (0,25 l)
☐ Gläser Spirituosen (0,02 l)

①	②	③	④	⑤	⑥
„nie"	„selten"	„gelegentlich"	„häufig"	„meistens"	„immer"
„trifft überhaupt nicht zu"	„trifft nicht zu"	„trifft eher nicht zu"	„trifft etwas zu"	„trifft zu"	„trifft voll und ganz zu"

VP-Nr. ________

Datum ________

Uhrzeit ________

Traumberichtsbogen

Haben Sie letzte Nacht geträumt?

O Ja

O Nein

Wenn ja, schreiben Sie bitte den erlebten Traum auf. Falls Sie mehrere Träume hatten, geben Sie bitte alle Träume vollständig wieder. Versuchen Sie sich an möglichst viele Details zu erinnern. **Geben Sie bitte jedem Traumbericht einen Titel.**

Schlaf-Fragebogen A

VP-Nummer:
~~Name:~~ Alter: Datum:

Anleitung:

Die folgenden Fragen beziehen sich darauf, wie sie in der **letzten Nacht** geschlafen haben.

Kreuzen Sie bitte die Antworten an, die für Sie am **ehesten** zutreffen! Gehen Sie bei der Beantwortung der Fragen zügig vor und lassen Sie **keine** Frage aus.
Bitte sofort nach dem Aufwachen morgens ausfüllen!

1) Wann haben Sie sich gestern Abend schlafen gelegt (Licht gelöscht)?

Bitte die Uhrzeit angeben: ____ : ____ z. B. 22 : 15

2) Wie lange hat es gestern Abend nach dem Lichtlöschen gedauert, bis Sie eingeschlafen waren?

Weniger als 5 min.	[1]
5 bis 10 min.	[2]
10 bis 20 min.	[3]
20 bis 30 min.	[4]
30 min. bis 1 Stunde	[5]
mehr als eine Stunde	[6]

3) Woran hat es Ihrer Meinung nach gelegen, wenn Sie nicht gleich einschlafen konnten? (Mehrfachnennungen möglich)

persönliche/berufliche Probleme	[1]
Geräusche im Zimmer oder von draußen	[2]
Beschäftigung mit Tagesereignissen	[3]
ungewohnte Schlafumgebung	[4]
sonstige: ____________________________	[5]

4) In der Einschlafphase hat man hin und wieder plötzlich deutliche Bildeindrücke. War dies gestern Abend bei Ihnen so?

nein	[1]
bin nicht sicher	[2]
ja, sehr deutlich	[3]

5) Hatten Sie in der Einschlafphase Muskelzuckungen in den Armen oder Beinen?

nein	[1]
leicht	[2]
stark	[3]

6) Hatten Sie gestern Nacht ein Stechen in der Herzgegend oder ein Ziehen im linken Arm verspürt?

nein	[1]
leicht	[2]
stark	[3]

7) Sind Sie gestern, nach dem Einschlafen, nachts wieder aufgewacht?

nein	[1]
ja, einmal	[2]
ja, zweimal	[3]
ja, dreimal	[4]
ja, mehr als dreimal	[5]

8) Woran hat es Ihrer Meinung nach gelegen, wenn Sie nachts wach wurden? (Mehrfachnennungen möglich)

persönliche/berufliche Probleme	[1]
Geräusche im Zimmer oder von draußen	[2]
Ich mußte zur Toilette.	[3]
Ich hatte geträumt.	[4]
sonstige: ____________________________	[5]

9) Falls Sie in der Nacht aufgewacht sind, wie lange waren Sie wach? (Falls Sie keine genauen Angaben machen können, schätzen Sie bitte!)

1. Aufwachen:	_____ min. (Dauer)
2. Aufwachen:	_____ min. (Dauer)
3. Aufwachen:	_____ min. (Dauer)
4. Aufwachen:	_____ min. (Dauer)

10) Können Sie sich erinnern, ob Sie heute Nacht geträumt haben?

Nein, ich kann mich nicht erinnern, geträumt zu haben.	[1]
Ja, ich habe geträumt, kann mich aber nicht an den Trauminhalt erinnern.	[2]
Ja, ich habe geträumt und kann mich an den Trauminhalt erinnern.	[3]

11) Falls Sie sich an Ihre Träume erinnern können: Welche Gefühle hatten Sie während des Träumens? (Mehrfachnennungen möglich)

angenehme Gefühle	[1]
neutrale Gefühle	[2]
unangenehme Gefühle	[3]

12) Haben Sie in der letzten Nacht geschwitzt?

nein	[1]
leicht	[2]
stark	[3]

13) Wann sind Sie heute Morgen aufgewacht?

Bitte die Uhrzeit angeben: ____ : ____ z. B. 07 : 00

14) Sind Sie heute morgen geweckt worden (Radio-Wecker, Radio, Personen etc.) oder wurden Sie von allein wach?

Ich wurde von allein wach.	[1]
Ich wurde aus dem Halbschlaf geweckt.	[2]
Ich wurde aus dem Tiefschlaf geweckt.	[3]

15) Haben Sie heute Morgen Kopfschmerzen?

nein	[1]
leicht	[2]
stark	[3]

16) Haben Sie gestern Abend nach dem Abendessen Alkohol (Bier, Wein, Schnaps) getrunken?

Nein	[1]
Ja, über den Abend verteilt	[2]
Ja, unmittelbar vor dem Schlafengehen	[3]

17) Haben Sie gestern Abend ein Schlafmittel benutzt?

Nein	[1]
Ja	[2]

18) Wenn ja, welches Präparat / welche Präparate?

____

____

19) War der gestrige Tag für Sie sehr anstrengend?

nein	[1]
ein wenig	[2]
sehr	[3]

Anleitung:

Auf dieser Seite finden Sie einige Wörter, mit denen Sie beschreiben können, wie Sie sich gestern Abend, vor dem Schlafengehen, fühlten, wie Sie heute Nacht geschlafen haben und wie Sie sich heute Morgen fühlen.

Kreuzen sie hinter **jedem** Wort an, in welchem Ausmaß es für Sie zutrifft!

Bitte antworten Sie zügig und **lassen Sie keine Zeile aus**!

		nicht	wenig	mittel	ziemlich	sehr
20. Wie haben Sie in der vergangenen Nacht geschlafen?	gleichmäßig	[1]	[2]	[3]	[4]	[5]
	tief	[1]	[2]	[3]	[4]	[5]
	unruhig	[1]	[2]	[3]	[4]	[5]
	entspannt	[1]	[2]	[3]	[4]	[5]
	ungestört	[1]	[2]	[3]	[4]	[5]
	gut	[1]	[2]	[3]	[4]	[5]
	ausgiebig	[1]	[2]	[3]	[4]	[5]
21. Wie fühlten Sie sich gestern Abend vor dem Schlafengehen?	sorglos	[1]	[2]	[3]	[4]	[5]
	erschöpft	[1]	[2]	[3]	[4]	[5]
	schlafbedürftig	[1]	[2]	[3]	[4]	[5]
	überfordert	[1]	[2]	[3]	[4]	[5]
	ausgeglichen	[1]	[2]	[3]	[4]	[5]
	ruhig	[1]	[2]	[3]	[4]	[5]
	müde	[1]	[2]	[3]	[4]	[5]
	entspannt	[1]	[2]	[3]	[4]	[5]
22. Wie fühlen Sie sich heute morgen?	ausgeglichen	[1]	[2]	[3]	[4]	[5]
	dösig	[1]	[2]	[3]	[4]	[5]
	tatkräftig	[1]	[2]	[3]	[4]	[5]
	munter	[1]	[2]	[3]	[4]	[5]
	frisch	[1]	[2]	[3]	[4]	[5]
	ausgeschlafen	[1]	[2]	[3]	[4]	[5]
	entspannt	[1]	[2]	[3]	[4]	[5]

VP-Nr. ________

Datum ________

Uhrzeit ________

Fragebogen zum Gebrauch des Traumschreibers

		leicht				schwer
1)	War es leicht oder schwer, die Messsensoren anzubringen?	1	2	3	4	5
2)	Waren die Anweisungen leicht oder schwer verständlich?	1	2	3	4	5
3)	Wie lang hat es ungefähr gedauert, die Messsensoren anzubringen?	________________				
4)	War es leicht oder schwer, die Messsensoren morgens abzunehmen?	1	2	3	4	5
5)	Wie lang hat es ungefähr gedauert, die Messsensoren abzunehmen?	________________				
6)	Hatten Sie Probleme, den Minicomputer oder das Experiment zu starten?	O Ja				O Nein
7)	Hatten Sie sonst technische Probleme? Wenn ja, welche?	O Ja				O Nein

____

____

____

____

8)	Haben Sie die Schlafmaske die gesamte Nacht getragen?	O Ja	O Nein

Wenn nicht, wieso?

____

____

____

9) Haben Sie **alle** Messsensoren die gesamte Nacht getragen? O Ja O Nein

Wenn nicht:

a. Sind die Messsensoren abgefallen? O Ja, ______Stück O Nein

b. Sind Sie an den Kabeln der Messsensoren hängen geblieben? O Ja O Nein

c. Haben Sie die Messsensoren absichtlich abgenommen? O Ja O Nein
Wenn ja, wieso?

____

____

d. Andere Gründe

____

____

10) Wie sehr hat die Schlafmaske Sie beim Einschlafen gestört?

O gar nicht
O etwas
O ziemlich
O extrem

11) Wie sehr haben dich die Kabel der Schlafmaske beim Einschlafen gestört?

O gar nicht
O etwas
O ziemlich
O extrem

12) Wie hat es sich insgesamt angefühlt, mit der Schlafmaske zu schlafen?

O sehr angenehm
O angenehm
O okay
O eher unangenehm
O sehr unangenehm

13) Wie hat sich das Material der Schlafmaske angefühlt?

O sehr angenehm
O angenehm
O okay
O eher unangenehm
O sehr unangenehm

14) Haben Sie unter der Schlafmaske geschwitzt?

O Ja
O Etwas
O Nein

15) Auf welcher Seite schlafen Sie normal?

O auf der Seite
O am Bauch
O am Rücken

16) Hat die Schlafmaske Sie daran gehindert, in dieser Position einzuschlafen?

O Ja
O Etwas
O Nein

17) Wie oft sind Sie ungefähr aufgewacht?

O drei Mal oder weniger
O jede Stunde einmal
O jede halbe Stunde
O alle 15 Minuten

18) Haben Sie nachts einen Ton gehört? O Ja O Nein

a. Wenn ja, wie oft? ________________

b. Was war es für ein Ton? ________________

c. Wann haben Sie ihn gehört?

O eher zu Beginn der Nacht
O eher am Ende der Nacht
O an verschiedenen Zeitpunkten in der Nacht
O ich weiß es nicht

19) Haben Sie sich beobachtet gefühlt?

O Ja
O ein bisschen
O Nein

20) Sonstige Anmerkungen

Appendix D: Figures of Sampling Rates

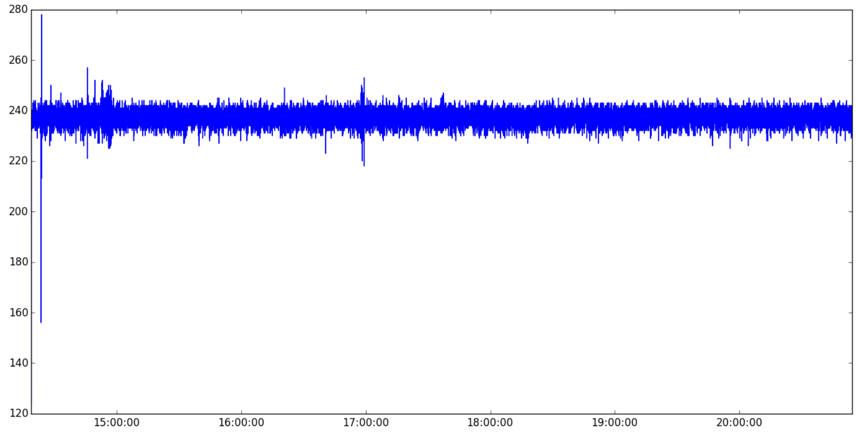


Figure 1: VP01

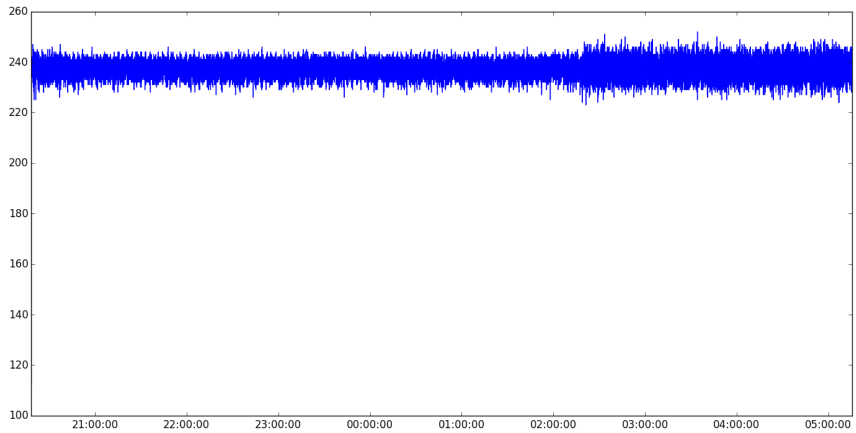


Figure 2: VP02

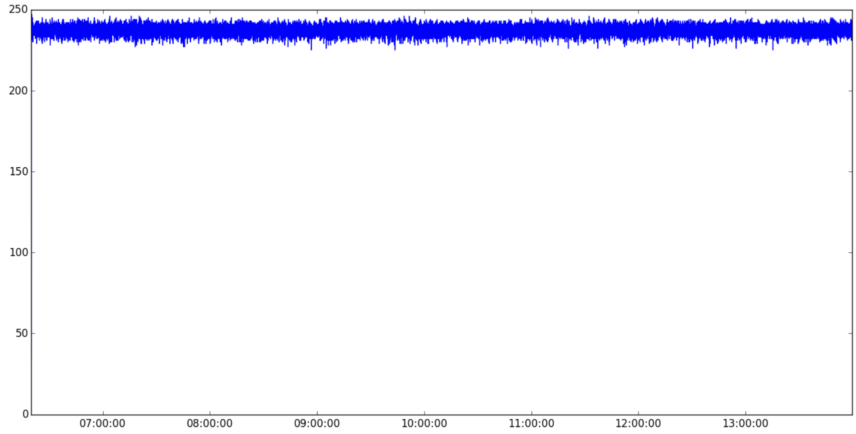


Figure 3: VP04

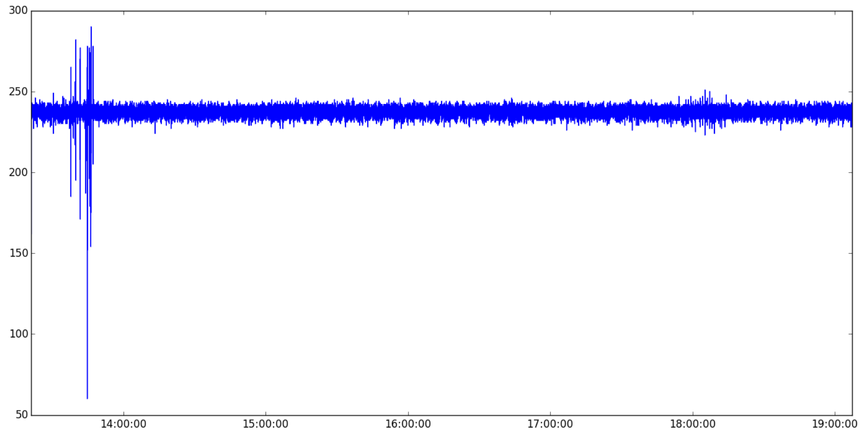


Figure 4: VP05

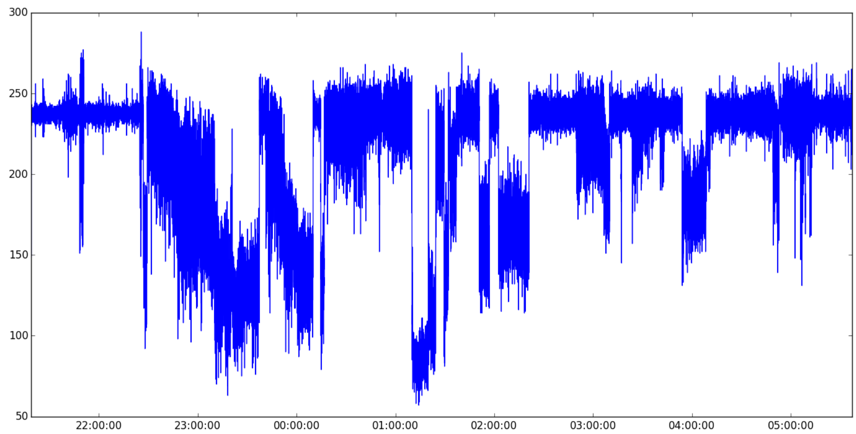


Figure 5: VP06

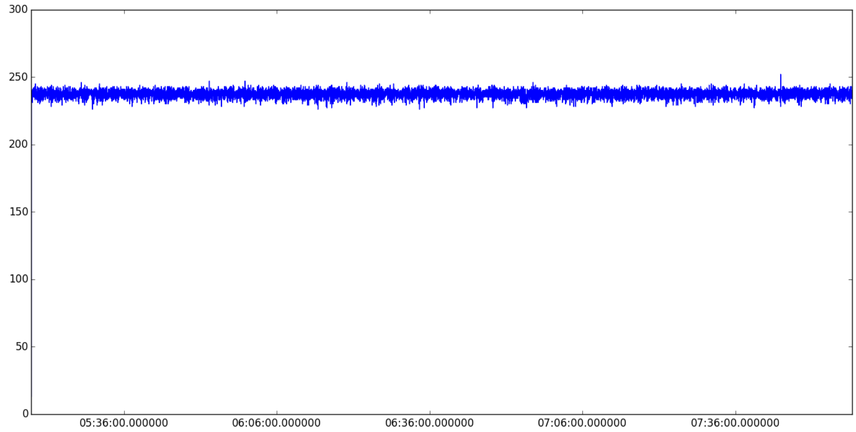


Figure 6: VP07

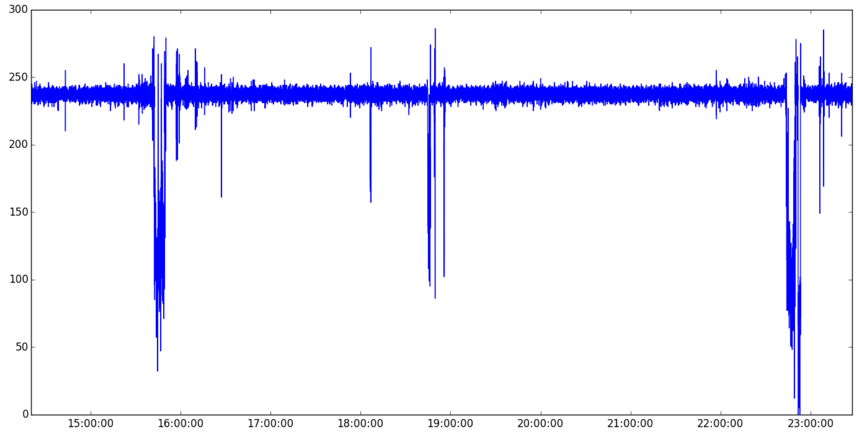


Figure 7: VP08

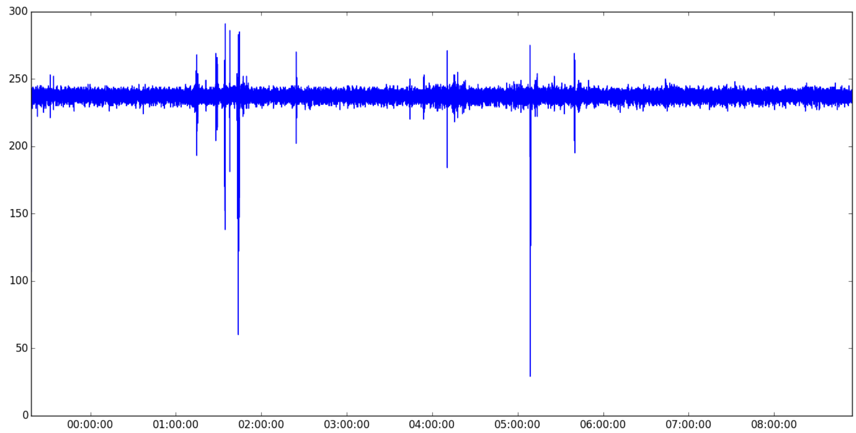


Figure 8: VP09

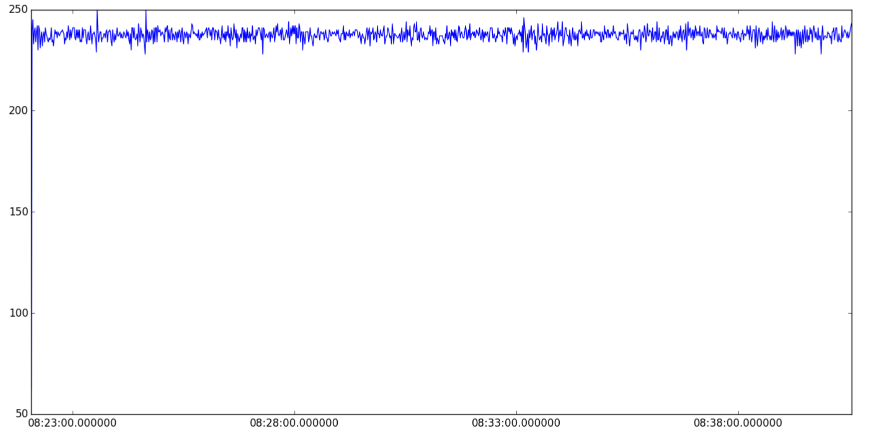


Figure 9: VP10

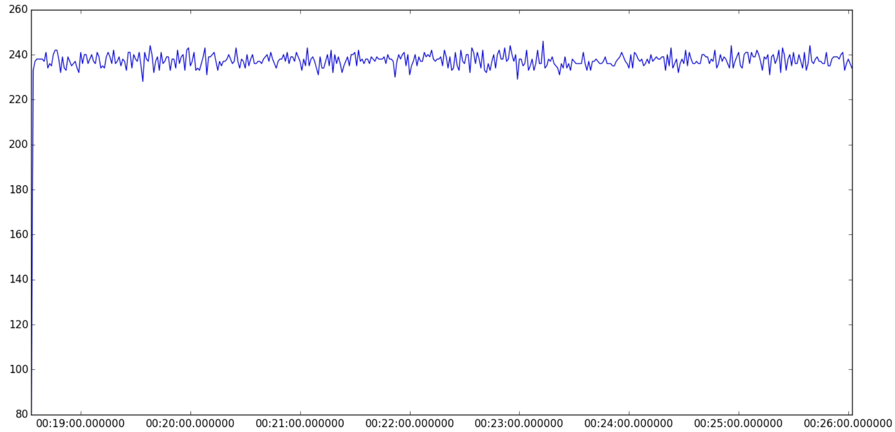


Figure 10: VP12

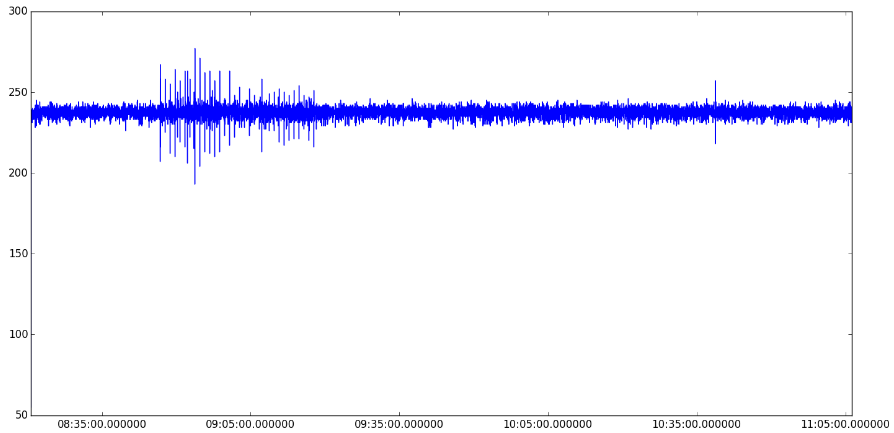


Figure 11: VP13

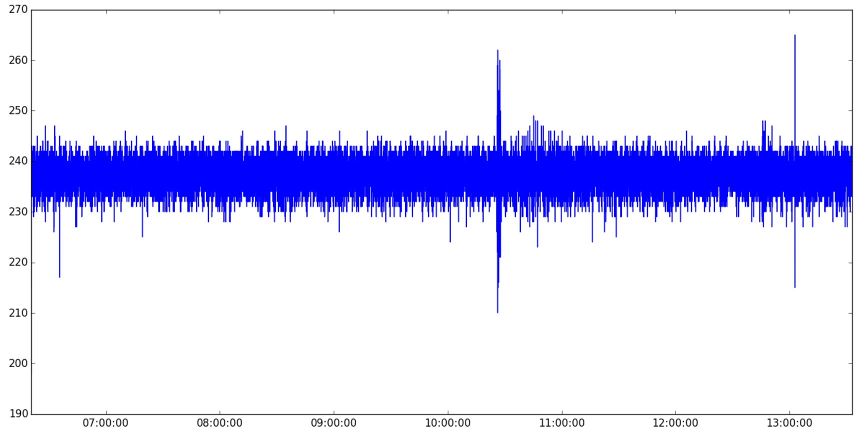


Figure 12: VP14

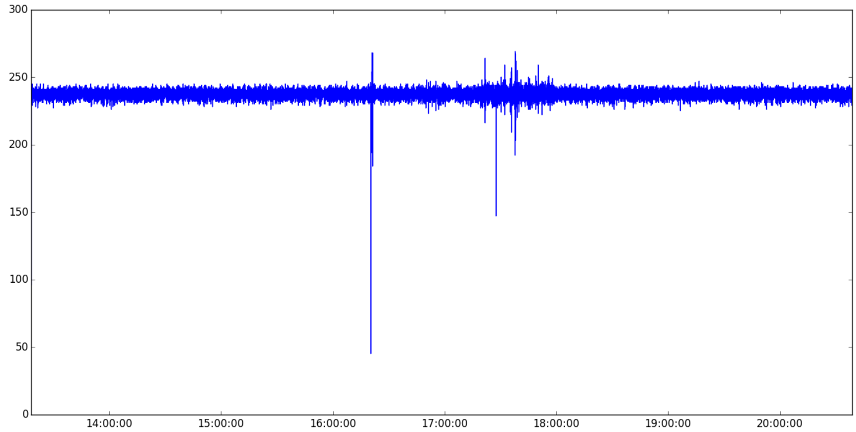


Figure 13: VP15

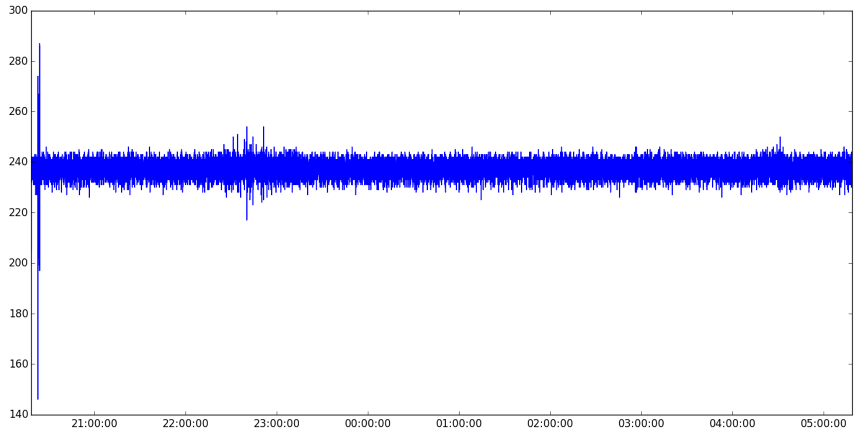


Figure 14: VP16

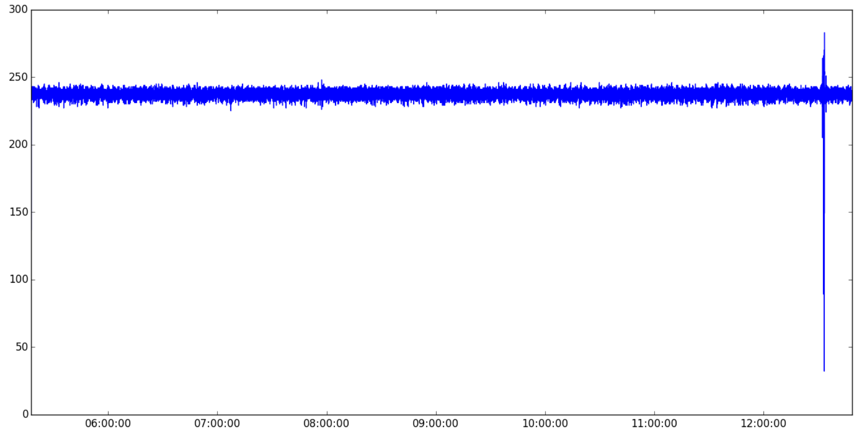


Figure 15: VP17

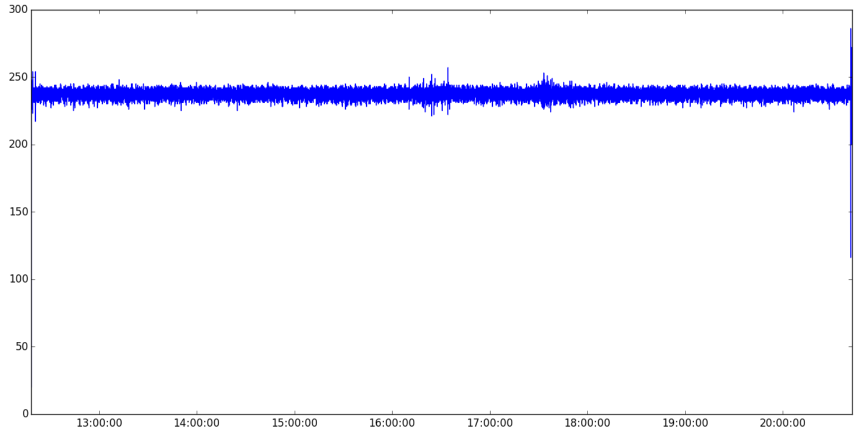


Figure 16: VP18

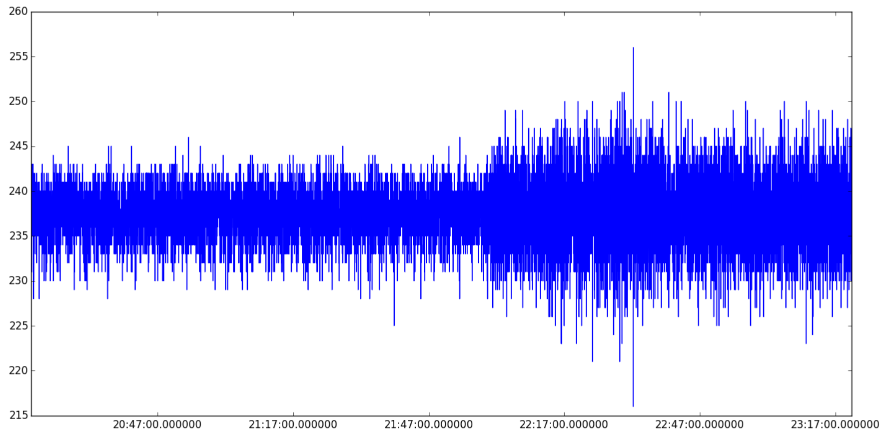


Figure 17: VP19

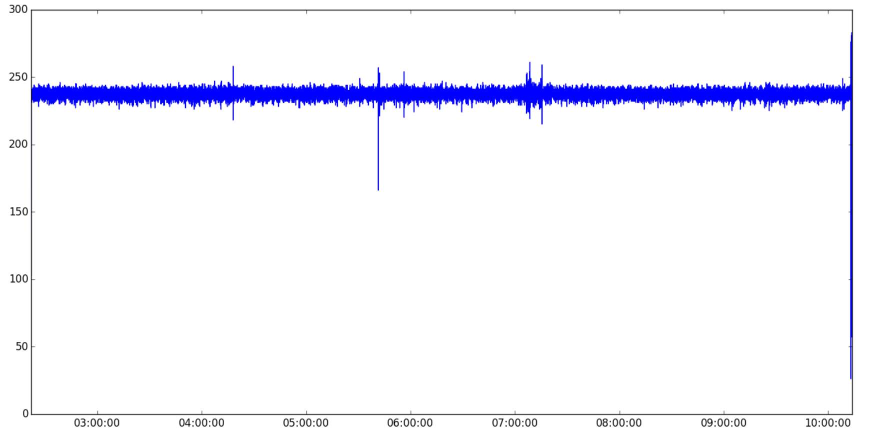


Figure 18: VP20

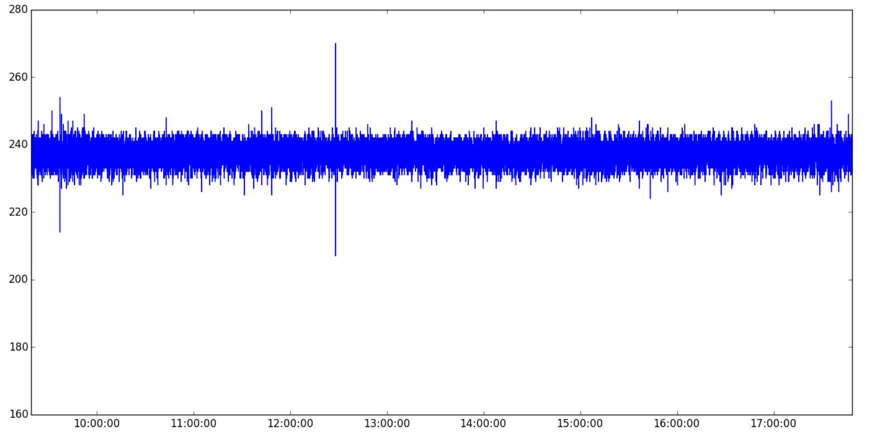


Figure 19: VP21

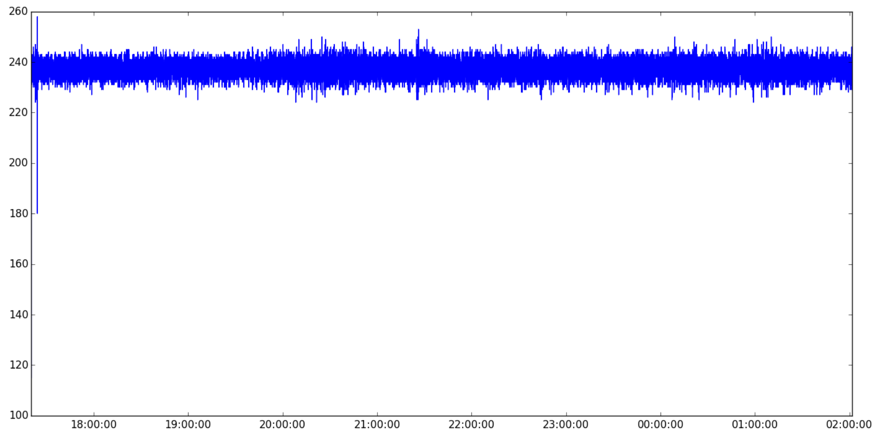


Figure 20: VP22

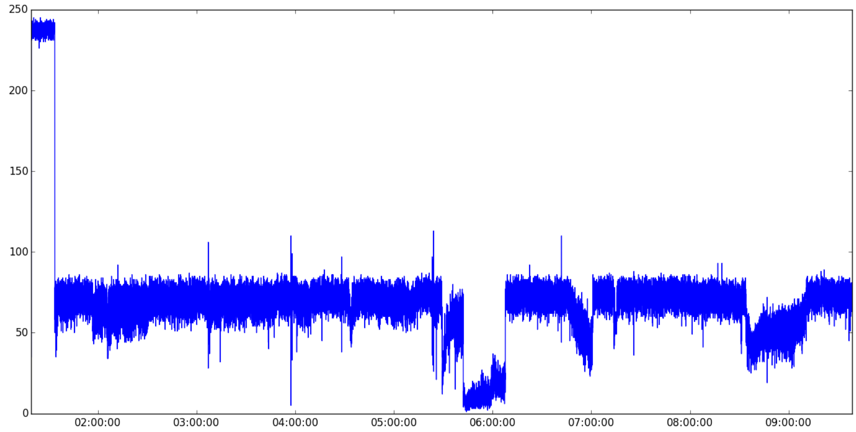


Figure 21: VP23

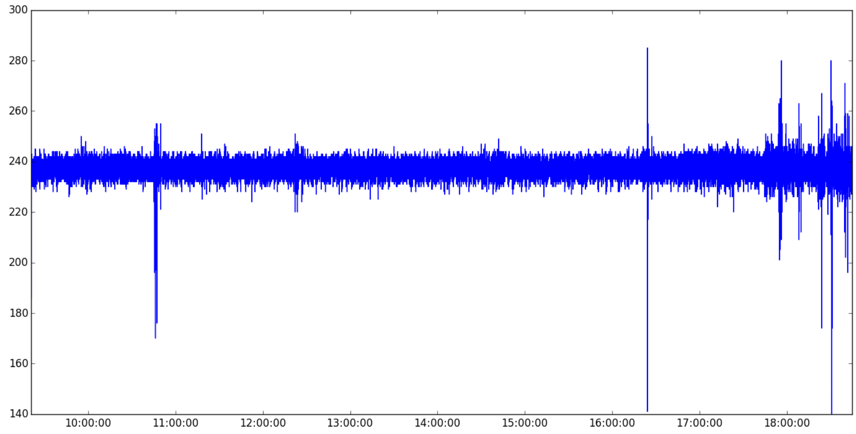


Figure 22: VP24

Appendix E: Tables

Table 1: Percentages of time (100% = entire night) in which a bad signal quality was obtained for each channel and every participant respectively. If no percentages are specified (-), the signal quality was good during the entire night for the respective channel.

ID	VEOG	HEOG/EEG1	EEG2	EEG3	EMG	ECG1	ECG2
1	100%	8%	80%	80%	-	-	-
2	-	-	-	-	-	50%	40%
4	-	-	12%	-	5%	5%	-
5	-	-	40%	-	-	-	-
6	-	-	60%	-	-	10%	-
7	-	-	-	-	-	-	-
8	-	10%	100%	-	-	-	-
9	-	-	-	-	-	25%	15%
10	-	-	-	-	100%	-	-
12	-	-	-	-	100%	-	-
13	90%	-	-	-	-	-	-
14	-	100%	100%	40%	-	-	75%
15	15%	-	50%	-	90%	-	-
16	-	-	-	-	-	-	-
17	-	-	-	10%	-	-	-
18	-	-	100%	-	-	-	-
19	80%	80%	100%	-	-	10%	-
20	-	-	-	-	-	50%	-
21	-	-	-	30%	-	75%	
22	-	-	-	-	-	-	-
23	-	-	-	-	-	-	-
24	60%	-	10%	-	-	-	-

Table 2: Reactions to auditory stimuli for all participants within the Cueing group in percentages and the respective intensities of auditory stimulation (0: inaudible, 1: room volume). Arousals were overall caused by louder sounds.

ID	No Reaction		Unclear		Arousal	
	Stimuli	Intensity	Stimuli	Intensity	Stimuli	Intensity
6	75%	0.44	2.1%	0.82	22.9%	0.66
8	85.2%	0.48	7.4%	0.47	7.4%	0.8
13	66.7%	0.37	-	-	33.3%	0.64
15	63.6%	0.41	4.5%	0.62	31.8%	0.49
17	61.4%	0.34	-	-	38.6%	0.65
18	79.6%	0.39	-	-	20.4%	0.67
20	71.7%	0.38	10.9%	0.54	17.4%	0.65
22	86.3%	0.46	-	-	13.7%	0.71
23	85.1%	0.42	-	-	14.9%	0.56
24	66%	0.45	-	-	34%	0.58