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Unilateral visual stimulation results in increased subjective sleepiness

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Introduction

Sleep is hypothesized to play an important role in brain recovery. The necessity to recover is thought to be use dependent. Longer use by elongated waking results in intensified sleep, as can be measured by higher slow wave activity in the NREM sleep EEG. Furthermore, increased use of specific brain areas results in locally intensified sleep in those specific brain areas (Kattler et al. 1994).

Sleep deprivation leads to increased subjective sleepiness (Strijkstra et al. 2003). Whereas sleep deprivation influences the entire brain, it is unclear whether localized use of certain specific brain areas leads to higher sleepiness.

The visual cortex in the occipital lobe can be specifically influenced by visual stimuli. The visual cortex is known to be able to increase its metabolism up to 40% with specific checkerboard stimulation (Fox & Raichle 1984). We used checkerboard stimulation to investigate the effects of enhanced visual cortex activity on subjective sleepiness.

Methods

The study was carried out with 12 healthy young male (6) and female (6) subjects (18-25 years). The subjects did not smoke nor use drugs, and refrained from consuming alcohol and coffee throughout the experiment.

Subjects scored as normal chronotypes. Subjects signed an informed consent. The study was approved by the Medical Ethics Committee of the Academic hospital of the University of Groningen.

Subjects were asked to schedule their sleep between 00:00 and 08:00 3 days before the experimental procedure in the lab. Subjects were habituated to the lab and the procedures on day 1 by performing 2 test sessions prior to sleeping at 22:00 and 23:00 hours. A test session consisted of several performance tasks, wake EEG measurements, a control procedure without visual stimulation by checkerboard (see below) and 3 subjective sleepiness questionnaires. Subjects were subsequently scheduled to sleep in the lab from 00:00 to 08:00. On day 2, subjects performed 4 test series, at 09:00, 10:00, 22:00 and 23:00. These test sessions were used as baseline data for comparison with the later experimental data. On day 3, test sessions were performed every hour from 09:00 to 23:00. During these sessions, the visual stimulation procedure was included in all test sessions (see below). On day 4, two more control test sessions were performed at 9:00 and 10:00, to monitor recovery from the experimental manipulation by the recovery sleep.

Visual stimulation was carried out by means of an inverting checkerboard on either the left or right half of a 17 inch computer monitor, aiming for stimulation of the visual cortex of the contralateral brain hemisphere.

Subjects were positioned at 35 cm from the screen, corresponding to an angular exposure of ~24°. Subjects were

asked to focus on a plus sign in the centre of the screen. A checkerboard inverting 4 times per second was presented on either the left (6 subjects) or the right (6 subjects) half of the screen. During part of the visual stimulation, subjects performed an ‘oddball’ task procedure. During this task, letters would occur at 5 cm adjacent to the plus sign in the middle of the screen. Subjects were asked to remember a specific letter prior to the letter exposures. During the letter exposures, subjects were asked to push a specific button if the remembered letter was shown at 5 cm either left or right of the central plus sign (25% of cases), and another button if any other letter (75% of cases) was shown. This test was implemented to maximize the effect of the checkerboard presentation, due to the effort associated with the required attention. The stimulation time amounted to 12 minutes per test session.

To monitor subjective sleepiness, 3 different scales were used: Karolinska Sleepiness Scale (KSS), visual analog scale for fatigue (VAS-f) and the fatigue component of the Profile Of Mood Scale (POMS). The resulting data were standardized to a standard normal distribution (z-scores) within a subject before averaging between subjects.

Results and discussion

The three subjective sleepiness scales showed similar patterns throughout the experiment (see Figure 1). Subjective sleepiness was similar at the start and the end of the day (i.e. at 09:00 and 23:00) during the baseline day. At the start of the experimental day 3, subjective sleepiness was also similar to the start of the previous baseline day. Subjective sleepiness was indeed statistically indistinguishable (paired-t test baseline vs. experimental day at 09:00; KSS: $p=0.58$, VAS-f: $p=0.44$, POMS-f: $p=0.31$). During the experimental day 3, subjective sleepiness increased. After 20:00 near the end of the day, a strong increase in subjective sleepiness was observed. To some extent, this increase is also reflected in the increase in sleepiness from 22:00 to 23:00 during the baseline day, i.e. at 22:00 and 23:00. However, the increase in subjective sleepiness on the experimental day was larger compared to the baseline day 2 (paired t-test; baseline vs. experimental day at 22:00; KSS: $p=0.011$, VAS-f: $p=0.0001$, POMS-f: $p=0.0021$; baseline vs. experimental day at 23:00; KSS: $p=0.028$, VAS-f: $p=0.0010$, POMS-f: $p=0.0017$). After the recovery night, subjective sleepiness was again similar to the morning levels of the baseline day 2 and the experimental day 3.

Thus, we find a higher level of subjective sleepiness in experimental conditions with intense unilateral visual stimulation as compared to a normal day with ordinary activities. Obviously, this can be due to any difference between baseline and experimental conditions. For example, between 11:00 and 20:00 during the baseline situation, subjects were not in the lab doing tests, which may make a difference. However, subjective sleepiness in our lab under very similar conditions without checkerboard stimulation (Strijkstra et al. 2003) showed similar subjective sleepiness levels in the morning at 09:00 and in the evening on the same day at 23:00. This indicates that in our hands a normal daily routine followed by tests in the lab, i.e., the baseline situation of the present experiment, results in similar levels of subjective sleepiness as a day with several test sessions in lab conditions. We thus conclude that our visual stimulation procedure induced sleepiness on top of the normal daily level of sleepiness in our subjects.

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Figure 1

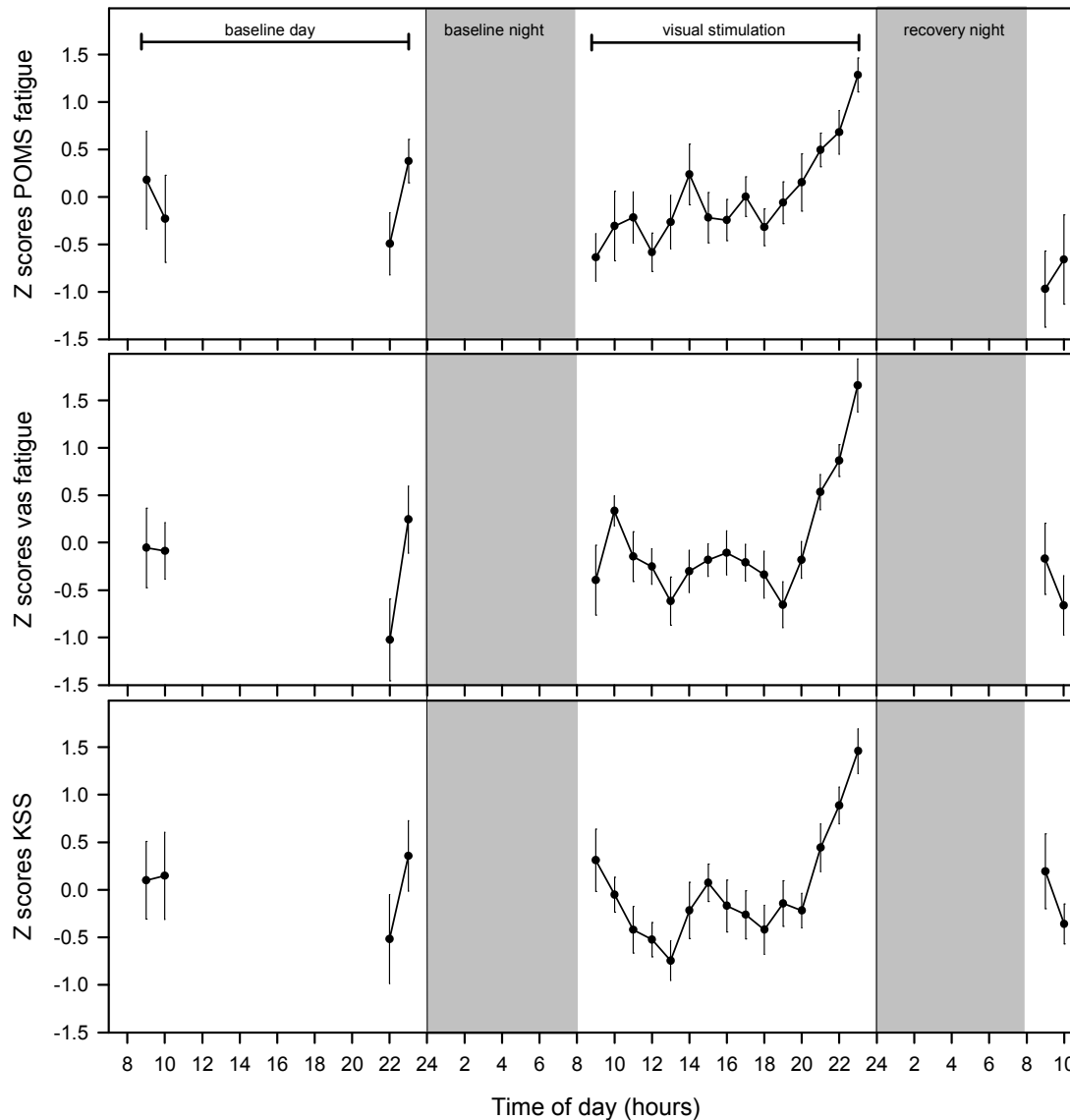


Figure 1. The average Z-scores and SEM of the three subjective sleepiness scales (POMS-f, VAS-f, KSS) at all time points during the experiment. Data are Z-transformed to standard normal distribution within subjects and subsequently averaged between subjects. Data of three consecutive days are shown: 1) the baseline day with morning and evening test sessions, 2) after the baseline night (grey area) the experimental day with the visual stimulation procedure during the test sessions, and 3) the two test sessions after the recovery night. Please note a) the similarity of the patterns of the three subjective sleepiness measures, b) the similarity of the sleepiness levels of the early morning sessions, and c) the difference in subjective sleepiness between the baseline day and visual stimulation day during the late evening sessions.