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Research report

Psychomotor vigilance task performance during total sleep deprivation in young and postmenopausal women

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Abstract

The objective of this study was to investigate the effects of age on women's performance in the psychomotor vigilance task (PVT) during total sleep deprivation (SD). A total of 46 healthy women volunteered. They belonged to two age groups: young ($n = 34$; age range 19–30 years; 12 without, and 22 with oral contraceptives (OC); early phase of the menstrual cycle) and older ($n = 12$; age range 60–68; postmenopausal; without hormone therapy). During a 40-h total SD, the subjects performed the PVT and the Stanford Sleepiness Scale (SSS) at 2-h intervals. At baseline, the reaction speed of the young women was faster as compared to the older women (Mann–Whitney *U*-test $p < 0.01$). During SD, all the PVT measures as well as the SSS scores changed similarly in the two age groups, when the baseline performance difference in favour of the young women was taken into account (area under curve analyses, Mann–Whitney *U*-tests n.s.). No age difference in the time course of the SD-related deterioration in PVT performance or subjective sleepiness was observed. OC use had no effects on any of the measures during SD. After recovery sleep, young women had higher subjective sleepiness scores than older women, the sleepiness scores being highest in young women not taking OCs. In conclusion, in women, aging has no effects on the amount or the time course of the decline in PVT performance caused by total SD. OC use does not significantly affect young women's PVT performance during SD in the early phase of the menstrual cycle.

Keywords: Sleep deprivation; Psychomotor vigilance; Subjective sleepiness; Aging; Oral contraceptives; Women

1. Introduction

Sleep deprivation is a common phenomenon in modern society, where people tend to work prolonged hours and engage in late night social program at the expense of a good nights' sleep. Loss of sleep leads to decreased alertness and a severe impairment of neurobehavioral performance [1–3]. It also compromises safety [4,5] and decreases productivity at work [6]. One of the most widely used neurobehavioral tests to assess arousal and sustained attention during sleep deprivation is the psychomotor vigilance task (PVT) [7], which has been shown to be very sensitive to sleep loss [3,8–9].

Besides the challenge of sleep loss, many western societies are also faced with remarkable aging of the population and workforce. In normal alert conditions, aging has been shown to have an adverse effect on PVT performance [10,11]. The combined effects of aging and sleep deprivation on PVT performance have received less attention, and the results are somewhat inconsistent. Recently, Adam et al. [10] reported that older men performed better than young men after one night without sleep, while Blatter et al. [11] reported similar performance in young and aged subjects of both genders after 16 h of wakefulness using a 5-min PVT task.

Despite the female predominance in the older age groups, the studies on aging women's performance during total sleep deprivation still remain scarce [12]. In particular, to our knowledge, no previous report has assessed aging women's performance in the standard 10-min PVT task during total sleep deprivation. Women's brain function may be influenced by several gender-specific factors. These include, in particular, hormonal

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fluctuations, which can be associated, e.g. with the menopause, or with the use of oral contraceptives (OC) in the samples of young, gender-matched controls.

The aim of our study was to assess the effects of aging on women's PVT performance during a 40-h total sleep deprivation period. In addition, we investigated the effects of OC use on performance of young women during the SD period.

2. Materials and methods

The study was performed in cooperation between the sleep research units of the University of Brussels, Belgium, and the University of Helsinki, Finland. The data were collected as part of a more extensive study "Sleep in Aging Women". Subsets of the data have been previously described [13,14], but no comprehensive report focusing on the PVT measures has been published.

2.1. Subjects

A total of 46 women gave informed consent to participate in the study, which was approved by the Ethics Committee of the Helsinki University Central Hospital (Helsinki) and the Ethics Committee of the Vésale Hospital (Brussels). Ten young subjects not taking OCs were studied at the University of Brussels and the rest of the subjects at the University of Helsinki. The conditions in the two laboratories were carefully matched, and a strict common timetable was planned before the experiments to ensure comparability of the data. All subjects were financially compensated for their attendance.

The women were divided into two groups according to their age. The first group (group 1) consisted of young women (mean age 23; age range 19–30; BMI $22.5 \pm 3.1\,kg/m^2$; mean ± S.D.). The second group (group 2) consisted of postmenopausal women (mean age 63 years, age range 60–68; BMI $26.0 \pm 2.5\,kg/m^2$; no menstruation since on average 12 years, range 5–21 years; $n = 12$), who had not used any hormone therapy for at least one year prior to the study.

Group 1 was further divided into two subgroups according to oral contraceptive use: group 1a consisted of young women with no use of oral contraceptives for at least one month (average 9 months) prior to and during the study (mean age 25 years; age range 20–30 years; BMI $23.6 \pm 3.1\,kg/m^2$; $n = 12$; self-reported regular menstrual cycle), and group 1b consisted of regular users of oral contraceptives (mean age 22, age range 19–30; BMI $21.9 \pm 2.9\,kg/m^2$; $n = 22$; oral contraceptive use for at least 6 months prior to the study). During the study, the subjects in group 1b were using oral contraceptives with a constant low dose of ethinylestradiol (20 μg) combined with a third generation progestin (either desogestrel 0,15 mg; $n = 16$; Mercilon®; Organon; Roseland, NJ, U.S.A.; or gestoden 75 μg; $n = 6$; Meliane®; Schering; Berlin, Germany). The subjects used the OCs according to the conventional regimen with 21 days of OCs followed by 7 days without OCs. All the young women were studied during the early phase of their menstrual cycle (days 1–10). Thus, the women in group 1b were either on the OC-free interval or taking the very first OCs of the cycle.

All subjects were non-smoking and drug-free. Subjects with endocrinological, cardiovascular, pulmonary, gastroenterological, neurological or other somatic illnesses as well as psychiatric and sleep disorders or extreme chronotypes were excluded by thorough interview, physical examination, blood tests and questionnaires (Beck Depression Inventory, Beck Anxiety Inventory, Basic Nordic Sleep Questionnaire (Helsinki), the Pittsburg Sleep Quality Index (Brussels)). Hormone measurements (HCG, FSH, estradiol) were performed at the beginning of the study, and they verified the postmenopausal status of the older women and excluded pregnancy in group 1a.

For one week prior to the sleep deprivation, the subjects were instructed to follow regular sleep-wake hours (sleep between 10 pm and 7 am) and a nutrition schedule (regular meal hours and balanced energy intake; for details, see [14]). The subjects had to abstain from caffeine and alcohol containing drinks as well as all medication, except for oral contraceptives in group 1b. During this period, the subjects wore actigraphs (Actiwatch-L, Cambridge Neurotechnology Ltd.) and filled in sleep diaries. The average sleep onset time during this week was $11{:}08 \pm 0{:}37$ pm (mean ± S.D.; $n = 33$) for the young versus $10{:}39 \pm 0{:}22$ pm ($n = 12$) for the older women (Actiwatch Sleep Analysis Software). Respectively, the average wake up time was $07{:}09 \pm 0{:}46$ versus $06{:}24 \pm 0{:}26$ am, and total sleep time $7{:}51 \pm 0{:}34$ versus $07{:}44 \pm 0{:}36$ h. Because of technical failure, actigraphy data could not be obtained from one young subject in group 1a. To exclude sleep disorders and to get familiar with the sleep laboratory surroundings, the subjects spent two consecutive nights in the sleep laboratory with polysomnographic recordings immediately prior to SD.

2.2. Sleep deprivation

The subjects had to stay awake from 6/7 am on day I until 10/11 pm on day II ($n = 25/21$), resulting in 40 h of total sleep deprivation. EEG, EOG and EMG were recorded continuously with an ambulatory device (Embla, Flaga hf. Medical Devices (Helsinki) or Medatec Pamela (Brussels)), except during short showers and tests requiring EEG removal. During the SD period, in addition to the PVT and subjective sleepiness measurements, the subjects underwent either magnetic resonance imaging (MRI) with working memory tasks, or more extensive cognitive tests without MRI (test results not included in this report). At all times, the subjects were under close supervision of the sleep laboratory staff to ensure wakefulness. In addition to the meal schedule of the adaptation week, controlled light snacks were allowed during the sleep deprivation night. Caffeine and medication use remained prohibited. EEG was scored manually according to standard criteria [15].

2.3. PVT measurements and self-rating of sleepiness

The psychomotor vigilance task (PVT) [7] was performed with a PVT-192 unit (Ambulatory Monitoring, Inc. of Ardsley, NY). In the 10-min task a digital millisecond counter starts to scroll on a small computer screen at random intervals of 2–10 s, and the subjects have to respond by pressing a button as quickly as possible to stop the counter. After each press, immediate feedback on performance is displayed on the screen. During SD, the subjects performed 19 measurements at 2-h intervals. The first measurement was performed between 2 and 2.5 h of wakefulness. In the morning after 8 h of recovery sleep, the PVT measurement was repeated once (minimum 15 min of wakefulness prior to PVT).

The subjects rated their sleepiness at 2-h intervals with the Finnish or the French version of the Stanford Sleepiness Scale (SSS) [16]. In the SSS, the subjects are asked to rate their alertness on a 7-point scale, ranging from 1 "feeling active and vital; alert; wide awake" to 7 "almost in reverie; sleep onset soon; lost struggle to remain awake".

2.4. Data analyses and statistics

The default PVT performance metrics were delivered by standard software (PVTcommW version 2.71/REACT version 1.1.03). Mean reaction speed (1/mean reaction time (RT), 1/s), 10th to 90th percentile range (the difference between the fastest 10% and the slowest 10% RTs, s; reflecting performance variability), number of lapses (i.e. RTs ≥ 500 ms), number of false starts, and SSS scores were analysed. Measurements performed outside the specified time range (2–2.5 h after onset of SD and at 2-h intervals thereafter) were excluded from analysis, and the missing values (131 out of 920 trials; ∼14%) were substituted individually for each subject with the average of the two surrounding measurements. Most of the missing values (83/131) were from the first 24 h of the wakefulness period when the subjects participated in other tests.

SPSS 12.0.1 statistical software (SPSS, Chicago, Illinois) and Sigma Stat (SPSS, Chicago, Illinois) were used for statistical analyses. Because of non-normal distribution of the data, which was resistant to transformations (e.g. $(\sqrt{x} + \sqrt{x+1})$; logarithmic and square root transformations), parametric tests like repeated measures ANOVA, or mixed model regression analysis could not be performed. Instead, non-parametric tests were used. For these analyses, the experimental period was divided into three separate phases (baseline, sleep deprivation, after recovery sleep), which were analysed separately as follows.

At *baseline*, the differences between the groups (group 1 versus group 2; group 1a versus group 1b) were assessed by Mann–Whitney *U*-tests. As the baseline value, the average of the first three measurements was used.