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Short Communication

Nintendo Wii Fit-Based Sleepiness Testing is Not Impaired by Contagious Sleepiness

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ABSTRACT

Sleep deprivation may cause accidents, and it has deteriorating effects on health. A measurement of postural steadiness by a portable and affordable Nintendo Wii Fit balance board can be used to quantify a person's alertness. At work, people are under the influence of their environment—often other people—that may affect their alertness. This work investigates whether sleep deprivation among people is "contagious," as quantified by sway measures. We measured 21 volunteers' postural steadiness while alert and sleep deprived. During the measurements, a screen placed in front of the participants showed a footage of either alert or sleep-deprived faces. We found a significant difference between the day time and night time steadiness, but found no effect resulting from watching footage of sleep-deprived people. This finding shows that a posturographic sleepiness tester quantifies physiological sleep deprivation, and is insensitive to the influence of social factors.

1. Introduction

Excessive daytime sleepiness at work is common [1]. Sleepiness may also have negative effects on, e.g., health, mood, and performance, and even cause accidents [1]. A simple and reliable sleepiness tester might reduce the sleepiness-related impairments. However, measuring sleepiness faces challenges because of its complex and ambiguous nature. Time of day and time awake affect a person's state of alertness, but alertness is also affected by many other things. At work places, people tend to commerce with each other. At what level the commonly experienced sleepiness among people influence others is still unsolved.

Because postural steadiness is controlled by the central nervous system, and because sleep deprivation affects the central nervous system, postural steadiness may be used to quantify a person's state of alertness [2–4]. Our research group is creating a simple, portable, and affordable Nintendo Wii Fit-based (WBB) posturographic sleepiness tester [4] that could be used in homes as well as in work places. The use of Nintendo Wii Fit balance board in balance measurements has created some controversy [5,6]. However, during the past years, WBB has successfully been used to study, e.g., Parkinson disease [7], effect of residual anesthetics [8], and the rehabilitation of children with cerebral palsy [9].

We are interested in factors that influence sleepiness and thus influence postural steadiness. Mostly, research concentrates on difficulties in either sensory [3] or sensorimotor integration that accompany sleep deprivation and lead to detrimental effects in postural control. Cognitive factors such as the amount of attention engaged in the task have also been investigated with mixed results [10,11]. We found no studies about the influence of social factors on postural steadiness during sleep deprivation albeit social contagion can produce "sleepy-like" behavior [12]. Inspired by work on the function of yawning that describe it as a "communicative function involved in the transmission of drowsiness, boredom, or mild psychological stress" [13], we conducted a study on the influence of social contagion on postural steadiness during sleep deprivation. We investigated whether people who are sleepy will be even sleepier when they observe someone who is sleep deprived.

The aim of this study was to determine if a sleep-deprived person's state of alertness is affected, as quantified by sway measures, when he/she is subjected to footage of people who are sleep deprived.

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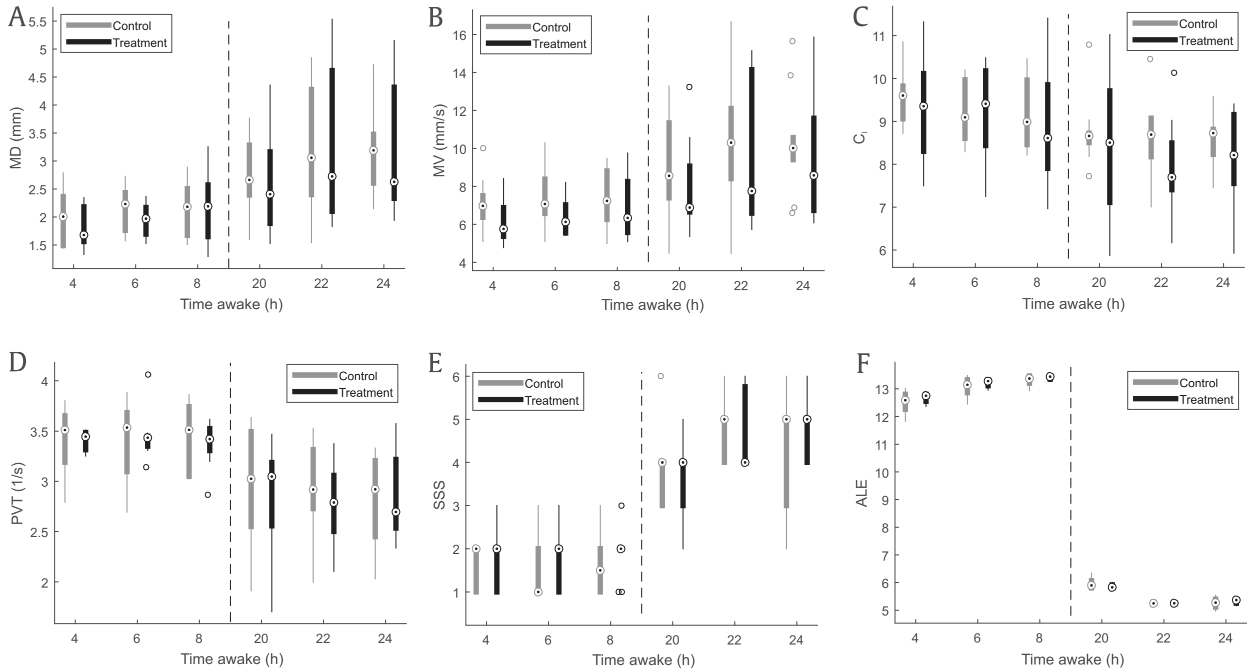

Fig. 1. Boxplots (central mark: median, box: 25th and 75th percentiles, whiskers: most extreme data points, circles: outliers) of (A) MD, (B) MV, (C) C_I, (D) PVT, (E) SSS, and (F) ALE. With all measures, the effect of sleep deprivation was significant ($p < 0.0001$), whereas the difference between control and treatment groups was not. ALE, theoretical alertness; C_I, complexity index; MD, mean distance; MV, mean velocity; PVT, psychomotor vigilance test; SSS, Stanford sleepiness scale.

2. Materials and methods

University of Helsinki Ethical Review Board in humanities and social and behavioral sciences (Statement 29/2015) deemed the study ethical. Written informed consents were collected from the volunteers and the assistants before the study.

Before the measurements, three assistants (2w/1m) were filmed from the neck up for 20 minutes while alert (5 PM–7 PM) and while sleepy (around 4 AM). The assistants were allowed to sleep for 1.5 hours right before the second filming to create sleep inertia. Out of these six (three alert and three sleepy) 20-minute footages, 5-minute sequences (one person per footage) were chosen as study material.

Participants for the study were students in the Department of Physics, University of Helsinki. Twenty-two participants agreed to take part in the study, one discontinued after 10 measurements because of excessive sleepiness. The 21 volunteers (9w/12m, 20–43 years, 151–192 cm, 46–114 kg) were measured with WBB three times during daytime (10 AM–4 PM) and three times during nighttime (2 PM–8 PM). The volunteers went to bed the previous night between 10 PM and 12 AM and woke up between 6 AM and 8 AM, having 8.1 ± 0.3 hours of bedtime. The volunteers had a light meal every second hour. Board games, reading, and computer work were allowed. Sleeping, heavy exercise, and going outdoors were prohibited.

The Nintendo Wii Fit balance board was placed 70 cm in front of a 24″ screen. The WBB was connected wirelessly via Bluetooth to a PC laptop. The measurement software was a custom-made C#-program.[1] Movable walls were placed in front and at the sides of the set up to offer visual separation from the rest of the room. Volunteers stood unshod feet together, arms crossed over their chest, and hearing protectors on their head. They were advised to stand relaxed, but as still as possible, and to keep their focus on the screen. Each stance took 5 minutes.

Volunteers were randomly placed in to two groups: control and treatment. During the daytime measurements, both groups were presented with the same three footages of the three alert assistants. The control group was presented with the same three footages also during nighttime. The treatment group was presented with the three sleepy footages.

For reference, the participants were asked to perform a 10-minute reaction time test, psychomotor vigilance task (PVT) [14], and a self-estimate of sleepiness with a Stanford sleepiness scale [15] (SSS, a score between 1 and 7, that increases with increasing sleepiness). The final PVT score was the average value of the reciprocals of the reaction times, with the first reaction time omitted. Furthermore, the volunteers' theoretical alertness (ALE) was estimated with a three-process model of alertness [16].

Sway signals were sampled at $f_S = 50$ Hz and filtered with a nonlinear empirical mode decomposition (EMD) filter [17]. The EMD filter breaks the signal into several intrinsic mode functions that feature decreasing frequency. We used EMD as a band-pass filter, removing all mode functions, except for those from 4 to 8.

The filtered sway signals were quantified with sway measures. Fuzzy sample entropy (FSE) [18] depicts the regularity of a signal. The decrease in sample entropy measures has been associated with impaired balance and the presence of cognitive control in balancing [4,8,10]. In multiscale scheme, FSE is calculated at each scale τ, after a τ-point moving average filtering along with downsampling by τ points ($\tau = 1{:}10$) [18]. The complexity index, C_I, is the sum of FSEs at different scales. As in Tietäväinen et al [4], the following parameters were used: $m = 3$, $r = 0.1$, $c = 0.01$.

We also calculated the following two conventional sway measures: mean distance (MD) and mean velocity (MV):

$$MD = \frac{1}{n}\sum_{i=1}^{n}|x(i)| \tag{1}$$

[1] https://wiimotelib.codeplex.com/, last accessed 31.11.2016.

$$MV = \frac{1}{n-1}\sum_{i=1}^{n-1}|[x(i+1) - x(i)] \times f_S|, \quad (2)$$

where x is either anterioposterior or mediolateral component of the sway signal of length n. The average sway measure value of anterioposterior and mediolateral signals was used to quantify the sway.

Finally, separate t tests were used to determine if age, height, and weight differed between control and treatment groups. Fisher exact test was used to test the differences in gender between the groups. Mixed two-way multivariate analysis of variance was conducted with C_I, MD, and MV as dependent variables. The group (control and/or treatment) was the between-subject independent variable and alertness (alert and/or sleepy) was the within-subject variable. The three repetitions in alert and sleepy conditions were averaged. Age, height, and weight were taken as covariates after centering their means. Mixed analysis of variances (condition, alertness) were also conducted with PVT, SSS, and ALE as dependent variables.

3. Results

No difference was detected in the anthropometrics between the control and treatment groups. With both groups, sleep deprivation decreased the C_I and PVT scores, and increased the MD, MV, and SSS scores (for all scores, $p < 0.0001$). These results are in accordance with the decreasing ALE ($p < 0.0001$). None of the measured scores showed a difference between the control and treatment groups. The results are presented in Fig. 1A–F.

4. Discussion

All measures detected the sleep deprivation due to wakefulness, but none of them detected evidence of sleepiness contagion. This result is perhaps not surprising; it is hard to find research on social mimicry effects on sleepiness. Nielsen et al [19] mention that a lack of research on sleepiness contagion could be explained by the complexity of the sleepiness influence mechanism. We found only one paper that describes sleep deprivation modulated by transaction between staff and participants, and between participants [20]. Notably, the sleepiness measure in that particular study was subjective; whereas in our study, we measured sleepiness using an objective scale. Theoretically, occupational health could be prone to social effects. Sleepiness at work may increase in the presence of many people in a similar sleepy state. Nevertheless, our results lead to conclusion that objective excessive daytime sleepiness at work originates most probably from an individual's sleep behavior and is not considerably influenced by social contagion factor. Although subjective perception of sleepiness may vary in the presence of other people [20], the objective measure, i.e., posturographic sleepiness tester, remains intact.

The increased MD and MV during sleep deprivation were expected according to other results of amplitude and velocity-related measures [2,3]. The decrease in C_I was in accordance with our previous results [4].

Because of the lack of suitable data, no power calculations for needed sample size was conducted before the study. This prohibits us from determining that no effect of contagious sleepiness affects the Wii-Fit sleepiness testing. However, it can be concluded that if such effect exists, it is negligible when compared with the effect of sleepiness due to sleep deprivation, and does not need to be considered when conducting sleepiness tests. Posturographic sleepiness tester benefits from insensitivity to "contagious sleepiness", because this type of sleepiness is temporary when compared with sleepiness due to sleep deprivation. We conclude that observing sleepy people does not considerably influence objective measurements of one's own sleepiness, i.e., posture steadiness.

Conflicts of interest

All authors have no conflicts of interest to declare.

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