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How to quantify sleepiness during an attempt to sleep?

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Abstract

Background. Sleepiness assessment tools were mostly developed for detection of an elevated sleepiness level in the condition of sleep deprivation and several medical conditions. However, sleepiness occurs in various other conditions including the transition from wakefulness to sleep during an everyday attempt to get sleep. *Objective*. We examined whether objective sleepiness indexes can be implicated in detection of fluctuations in sleepiness level during the polysomnographically-monitored attempt to sleep, i.e. in the absence of self-reports on perceived sleepiness level throughout such an attempt. *Approach*. The polysomnographic signals were recorded in the afternoon throughout 106 90 min napping attempts of 53 university students (28 females). To calculate two objective sleepiness indexes, the electroencephalographic (EEG) spectra were averaged on 30 s epochs of each record, assigned to one of 5 sleep–wake stages, and scored using either the frequency weighting curve for sleepiness substate of wake state or loadings of each frequency on the 2nd principal component of variation in the EEG spectrum (either sleepiness score or PC2 score, respectively). *Main results*. We showed that statistically significant fluctuations in these two objective sleepiness indexes during epochs assigned to wake stage can be described in terms of the changes in verbally anchored levels of subjective sleepiness assessed by scoring on the 9-step Karolinska Sleepiness Scale. *Significance*. The results afford new opportunities to elaborate importance of intermediate substates between wake and sleep states for sleep–wake dynamics in healthy individuals and patients with disturbed sleep.

1. Introduction

Sleepiness plays a key role in the regulation of the sleep–wake cycle, especially in the triggering of sleep onset at an individual's usual bedtime or during sleep deprivation (Taillard *et al* 2024). The diverse approaches to evaluation of sleepiness were developed (Baiardi and Mondini 2020, Johnson and Gurubhagavatula 2023). As many as 99 sleepiness assessment tools were identified in one of recent literature reviews (Martin *et al* 2023). These tools were mostly designed to detect an elevated sleepiness level in the condition of sleep deprivation or in several medical conditions such as narcolepsy, hypersomnolence, and excessive daytime sleepiness (Ohayon *et al* 2012, Baiardi and Mondini 2020, Taillard *et al* 2024).

However, sleepiness occurs not only in the inappropriate situations of prolonged wakefulness and sleep insufficiency or in the conditions characterized by its abnormally high duration and frequency. Most often, it almost inevitably precedes the event of sleep onset during an everyday attempt of getting sleep (Taillard *et al* 2024).

Measurements of brain activity from the scalp during such an attempt of getting sleep allow the applying conventional physiological criteria known as scoring rules for determination of five stages of vigilance, one stage of wake state and 4 stages of sleep state. Time-series data on discrete 30 s epochs of the polysomnographic records obtained using the methods of electroencephalography (EEG), electromyography (EMG), and electrooculography (EOG) can be scored either as W that is the only wake stage or as R that is the stage of rapid eye movement (REM) sleep, or as non-rapid eye movement (NREM) sleep with further subdivision into stages N1, N2, and N3 (Berry *et al*, https://aasm.org/clinical-resources/scoring-manual/). Stage N1 represents the transient state between wakefulness and sleep and the transition from W to N1 occurs in a graded and staged fashion (Andrillon *et al* 2024).

However, these scoring rules cannot be directly applied in detecting sleepiness that can be classified as a substate of the wake state preceding to the sleep state. By contrast, gradual changes in alertness prior to falling asleep can be easily staged by interpreting a self-assessed sensation of drowsiness. For instance, the 9-step Karolinska sleepiness scale (KSS) can be used for self-reporting as many as 9 alertness-sleepiness stages preceding the transition to sleep, from feeling extremely alert to feeling very sleepy (Åkerstedt and Gillberg 1990).

While such subjective feelings can be easily self-reported before the EEG-, EMG- and EOG-monitored nap or night sleep, they cannot be self-reported during the following attempt to relax and to try to sleep. Therefore, the question arises: how to measure the fluctuations in sleepiness level during such a polysomnographically recorded nap or night sleep? Invention of these measures can offer a new approach to describing sleepiness as intermediate substate between wake and sleep states in healthy individuals and patients with disturbed sleep.

It is well-known that, during relaxed wakefulness in the eyes closed condition, alpha rhythm (9 Hz–12 Hz) is dominated in the EEG, and that an increase in level of sleepiness in this condition leads to a decrease of spectral EEG power density in the high-frequency rage, including the alpha frequencies. In contrast, a change in the opposite direction occurs in the low-frequency range, i.e. the theta (5 Hz–8 Hz) and delta waves (1 Hz–4 Hz) become larger in response to increase in subjective level of sleepiness (Lorenzo *et al* 1995, Leproult *et al* 2003, Strijkstra *et al* 2003, Marzano *et al* 2007, Putilov and Donskaya 2014). Therefore, the EEG spectrum of the sleepy brain can be used for objective quantification of the alertness-sleepiness continuum into the stages of drowsiness (Olbrich *et al* 2009) and objective (spectral EEG) sleepiness scores assigned to KSS scores (Putilov *et al* 2012, Putilov and Donskaya 2013, 2019).

Consequently, the aim of the present study was to examine whether the objective indexes of sleepiness can be implicated in detecting fluctuations in sleepiness level in the absence of any self-reports about subjective feelings during the EEG-monitored attempt to sleep.

2. Methods

2.1. Participants of the nap study and study protocol

Unpaid volunteers of the nap study were 25 male and 28 female university students with mean age $\pm$ standard deviation of 20.4 $\pm$ 1.6 and 20.3 $\pm$ 1.1 years, respectively. The structured interview with a sleep researcher preceded the invitation to participate in the study and to choose the dates of three afternoon naps. The interview was focused on the following exclusion criteria. Age either younger than 18 or older than 23 years, recollections on history of mental or sleep disorder, any complaints about poor physical condition and functioning, current mild cold and missing classes due to any kind of sickness in two previous weeks, involvement in shift or night work and crossing several time zones in the previous month, irregular sleep–wake schedule characterized by more than 1 h difference in weekday bedtimes and frequent sleep reduction including, at least, one night of partial sleep deprivation in the previous week. Female participants, the exclusion criteria additionally included pregnancy or breastfeeding. These participants were also asked about the day of last menstruation and usual length of the cycle.

The study participants attended classes before and after their visit to a sleep laboratory located in the same university building. Each student participated in three 90 min napping attempts during one-month period with the intervals between naps varying from three days to three weeks. The same afternoon hour (not earlier than 12:30 and not later than 15:30) was chosen for the visits of participant to the sleep laboratory. The first napping attempt was regarded an adaptation nap, while, for the current study, the analysis was performed for the polysomnographic records obtained during the 2nd and 3rd naps.

Before each polysomnographic recording, a short questionnaire was administered for subjective sleepiness scoring on (1) the 9-step KSS designed for self-reporting current levels of sleepiness and (2) the 8-item Epworth Sleepiness Scale (ESS) designed to determine daytime sleepiness levels experienced in everyday life events. The KSS (Åkerstedt and Gillberg 1990) is verbally anchored Likert scale with 9 levels of alertness-sleepiness: 1- extremely alert, 2- very alert, 3- alert, 4- rather alert, 5- neither alert nor sleepy,

6- some signs of sleepiness, 7- sleepiness, but no effort to keep awake, 8- sleepiness, but some effort to keep awake, 9- very sleepy, great effort to keep awake, fighting sleep. The ESS (Johns 1991) quantifies the likelihood to fall asleep in each of 8 different daily life situations with a scale ranging from 0 to 3, where 0 corresponds to none and 3 to the situation when dozing off is the most likely. The total score ranges from 0 to 24.

2.2. Polysomnographic recordings and sleep scoring

During the preparation to polysomnographic recordings, the study participants were instructed to try to relax and to sleep for 90 min after light off. For these recordings, the Neurovisor BMM-36 (Medical Computer Systems LLC, Moscow), the MCScap Sleep electrode helmet, and the NeoRec 1.4 software were used. The electrodes were applied in accord with the standard monitoring montage known as the International 10–20 system of electrode placement. The EEG signals were obtained from 19 channels connected by a monopolar 10–20 scheme with two reference electrodes on the mastoid bones. Other than EEG polysomnographic signals included the signals recorded from two EMG channels, one EOG channel, and one electrocardiogram channel. The signals were conditioned by the high-pass, low-pass, and notch filters (0.5 Hz, 35 Hz, and 50 Hz frequencies, respectively), and the sampling frequency was equal to 1000 Hz.

Visual scoring on 30 s epochs of each record was performed independently by two experienced scorers in accord with the conventional scoring procedure (Berry *et al*, https://aasm.org/clinical-resources/scoring-manual/). Depending upon a stage, the initial disagreement between the initial scoring results varied from 8% (N1) to 1% (N3). The scorers reexamined together all intervals with discrepant scores to produce final consensus scores. The 30 s epochs were classified into 5 sleep–wake stages: one wake stage (W), three stages of NREM sleep (N1, N2, N3), and one stage of REM sleep (R).

2.3. Spectral analysis of the EEG signals

The spectral EEG power densities were calculated from the EEG signals recorded from electrodes placed at 5 derivations (Fz, F4, Cz, Pz, and O2 referenced to the ear mastoid sites, M1/M2). We analyzed data from these several derivations to decrease the impact of topographic variation in spectral EEG (Bartsch *et al* 2015), such as, for example, a more rapid buildup of low-frequency activity in frontal than occipital cortical area during transition from N1 to N2 (Finelli *et al* 2001, Putilov *et al* 2013, Putilov 2014). To remove all epochs containing artifacts from further analysis, the records of the signals from each of these 5 derivations were visually inspected on 1 s epochs. Spectral power densities for the artifact-free 1 s epochs were computed using the Fastest Fourier Transform in the West package (Frigo and Johnson 2005; see also www.fftw.org for more detail).

Further analysis of spectra for 1 s epochs was limited to the first 16 single-Hz frequency bandwidths (1 Hz–16 Hz), i.e. 0.50–1.49 Hz for 1 Hz, 1.50–2.49 Hz for 2 Hz, 2.50–3.49 Hz for 3 Hz, …, 15.50–16.49 Hz for 16 Hz). Averaging within each of 30 s intervals of EEG records (i.e. the sleep scoring intervals) provided the sets of 16 single-Hz power densities that, for further analysis, were ln-transformed and assigned to sleep–wake stages.

2.4. Calculation of two objective (spectral EEG) indexes of sleepiness

The $SPSS_{23.0}$ statistical software package (IBM, Armonk, NY, USA) was applied for principal component analysis of the sets of 16 ln-transformed single-Hz power densities (1 Hz–16 Hz) from each of 5 derivations. Scores on the 1st and 2nd principal components of variation in the EEG power spectra were calculated in the same way as in Putilov *et al* (2012). Score on the 2nd principal component named 'PC2 score' was used for further analysis.

Another index of objective sleepiness named 'sleepiness score' was calculated in a similar manner as PC2 score. Instead of using the loadings of 16 single-Hz powers on the 2nd principal component for their weighting, the differences between powers obtained for KSS scores 5 (Alert) and 3 (Neither alert nor sleepy) in Putilov *et al* (2019) were used for such weighting (the so-called 'frequency weighting curve'). In other words, we used either 16 loadings of frequencies on the 2nd principal component of variation in the EEG spectrum or 16 single-Hz differences between powers for KSS = 5 and KSS = 3 that is the frequency weighting curve derived in Putilov *et al* (2019) (see the equation for summing weighted powers in supplementary). Figure S1 illustrates these frequency weighting curves obtained by calculation of principal component loadings and differences between spectral powers for two KSS scores.

2.5. Statistical analysis

For statistical analysis, objective sleepiness scores calculated for 5 derivations were averaged. Such derivation-averaged scores were further averaged within each stage on subintervals of each record and the deviations from these mean scores were additionally calculated for W. Objective sleepiness scores obtained for each record were finally averaged within each of study participants (i.e. over two napping attempts).

The significance of differences between scores for two epochs on the first 10 min interval of napping attempt or the significance of such differences between scores averaged over 10 min intervals on the whole 90 min interval of nap were examined using paired student t-test with Bonferroni adjustment for multiple comparisons. Additionally, Pearson coefficient of correlation was computed to measure correlations of objective indexes of sleepiness with subjective sleepiness scores and latency to N1.

2.6. Simulation of subjective sleepiness score from an objective index of sleepiness

The sample-averaged KSS score that study participants self-reported prior to napping attempts was assigned to a sample-averaged objective sleepiness score obtained for the 1st 6 min of the polysomnographic records preceding to the first occurrence of N1 at the 10th min. The final KSS score for this 1st occurrence of N1 was suggested to be equal to the maximal KSS score 9 (i.e. very sleepy, great effort to keep awake, fighting sleep). Each of KSS scores for the 2nd and the following epochs of W preceding to N1 at the 10th min as well as each of KSS scores for 10 min intervals of the 90-napping attempts was determined by relating it to these objective sleepiness scores obtained for the 1st 6 min of the polysomnographic record and to the final objective scores for the 1st occurrence of N1 (see the regression equation in supplementary). When simulated for stage W, such transformation of two objective sleepiness scores into KSS scores allowed the anchoring these objective sleepiness indexes (i.e. the EEG-based sleepiness scores) to the verbally described alertness-sleepiness levels of the 9-step KSS (i.e. 4- Rather alert, 5- Neither alert nor sleepy, 6- Some signs of sleepiness, 7- Sleepiness, but no effort to keep awake, and 8- Sleepiness, but some effort to keep awake).

3. Results

Figure 1 illustrates that any of two objective sleepiness indexes (sleepiness score and PC2 score) calculated for W can be easily distinguished from the remaining scores calculated for any of sleep stages (N1, N2, N3, and R). While sleepiness score for sleep stages fluctuates in close proximity to zero, this score for W is almost always much lower than zero (figures 1(A) and (C)). PC2 score for sleep stages is almost always below zero, while this score for W fluctuates around 1 (unit) (figures 1(A) and (C)).

Moreover, figure 1 illustrates the expected tendency of sleepiness and PC2 scores to increase and decrease, respectively, with progression of napping attempt. The scores for W calculated for the 1st epoch of the 90 min napping attempts differed from scores for W obtained 5 min later, i.e. for the 10th epoch ($t = -3.6$ and $t = 2.8$ for sleepiness and PC2 score, $p/10$ for 10 comparisons on the interval of the 1st f10-epoch of the EEG records was equal to 0.01 and 0.08, respectively). The scores for W calculated for the 1st 10 min interval of napping attempts differed from scores for W obtained for the next 10 min interval ($t = -3.5$ and $t = 4.2$ for sleepiness and PC2 score, $p/8$ for 8 comparisons of 9 10 min intervals of the EEG records was equal to 0.08 and was lower than 0.001, respectively). Similar differences from scores calculated for the 1st 10 min interval were also found for the following scores, i.e. calculated for the 5th–7th 10 min intervals, characterized by high prevalence of stages N3 and R (figure 2(A)).

As it is shown in figure 3(A), such trends became much clearer after expressing objective sleepiness scores as deviations from mean score obtained by averaging over 20 epochs of the first 10 min interval of 90 min napping attempts and over 9 10 min intervals of such attempts. Consequently, the level of significance of the differences between the earlier and later relative scores became much higher (figure 3(A)).

The most drastic differences were revealed in the comparisons of relative scores for 1–4 min prior to the 1st occurrence of N1 during the 1st 20 min of napping attempts (figures 2(C) and 3(C)). For instance, there were significant differences between the 5th and 1st min preceding the 1st occurrence of N1 ($t = -4.9$ and $t = 4.5$ for sleepiness and PC2 score, respectively, $p/4$ for 4 comparisons of these 5 epochs of the EEG records was always lower than 0.001).

In contrast, such differences between objective sleepiness scores calculated for the first 10 min interval of nap were found to be mostly non-significant (figure 3(B), left) in the records with latencies to N1 exceeding 20 min (figure 2(B)). In such records, objective sleepiness score was reduced during wakefulness in the beginning of a napping attempt and it did not reach its maximal level during the epochs with W occurring in the middle of the attempt, e.g. during the 5th and 6th 10 min intervals of the 90 min napping attempt. Instead, it declined during these intervals to the scores observed in the very beginning of this attempt (figure 3(B), right). This decline suggests that, when sleep onset latencies were long, the study participants were not sleepy not only in the beginning but also in the middle of their napping attempts (i.e. compare figures 3(B) and (C), right, illustrating the time course of objective sleepiness scores in the records with long and short sleep onset latencies, respectively).

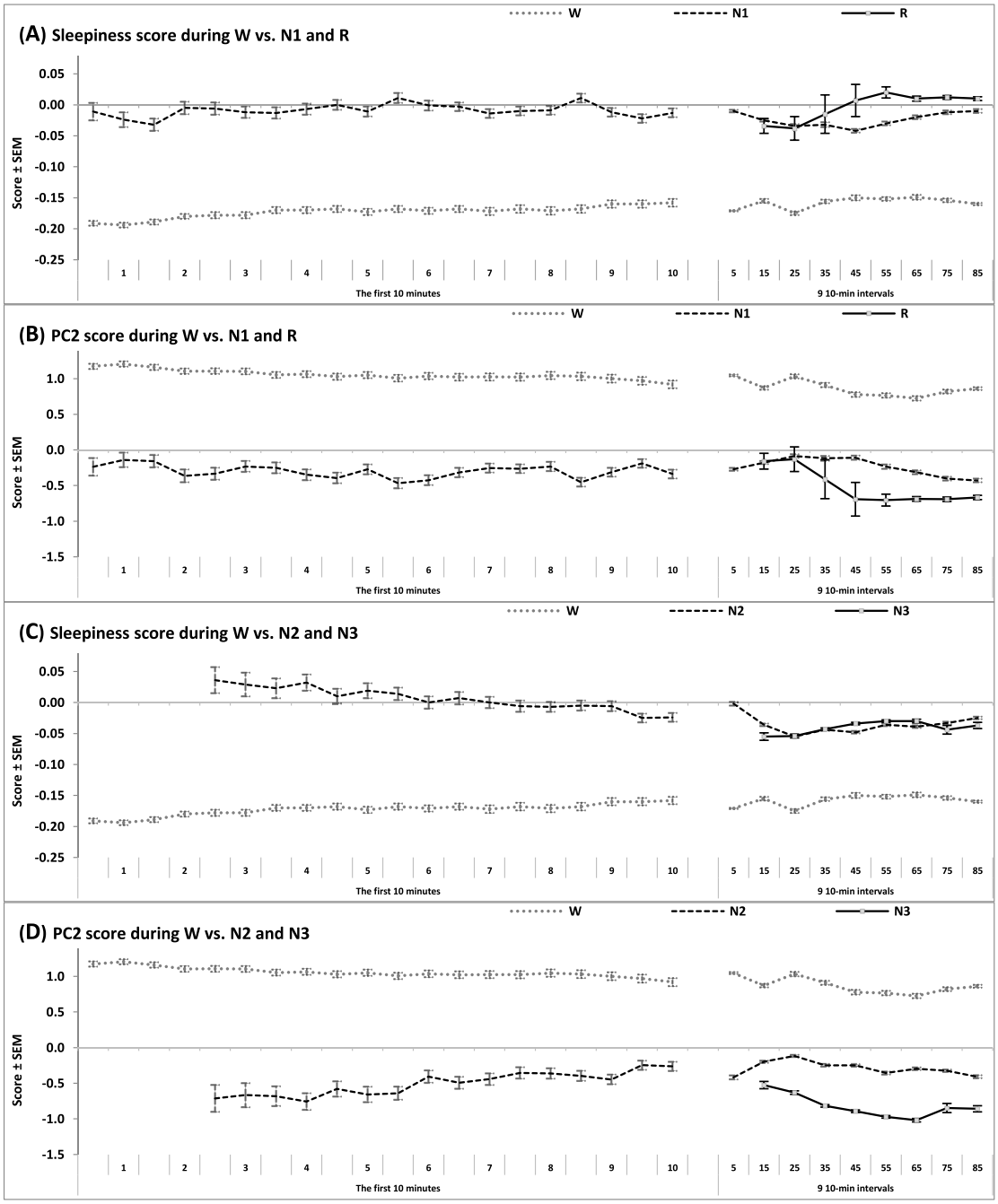

Figure 1. Comparison of sleepiness and PC2 scores for wake stage with scores for sleep stages. (A) and (C) Sleepiness score. (B) and (D) PC2 score. (A) and (B) Comparison of W with N1 and R. (C) and (D) Comparison of W with N2 and N3.

Consequently, latency to N1 significantly correlated with mean objective scores preceding the 1st occurrence of N1 on the 1st 20 min interval of napping attempts (figure S2). Moreover, objective sleepiness scores averaged over the 1st 20 min interval of napping attempts significantly correlated both with this latency and with KSS score reported prior to napping attempts (figure S3).

Figure 4 illustrates a possible approach to transform objective sleepiness scores in verbally anchored steps of the KSS, i.e. as fluctuations in subjective sleepiness in the range from score 4 through scores 5, 7, and 8 to score 9 (i.e. from rather alert through some signs of sleepiness, sleepiness, but no effort to keep awake, sleepiness, but some effort to keep awake to very sleepy, great effort to keep awake, fighting sleep, respectively).

As it is shown in figure 4 (right graphs), sleepiness level for W on the vast majority of 20 min intervals of polysomnographic records fluctuated in the range from 5 to 7, i.e. from neither alert nor sleepy to sleepiness, but no effort to keep awake, respectively. Moreover, as it is shown in figure 4 (left graphs), sleepiness level for W remains relatively low, slightly above 5, till the 5th min prior to N1 and rapidly rises thereafter reaching

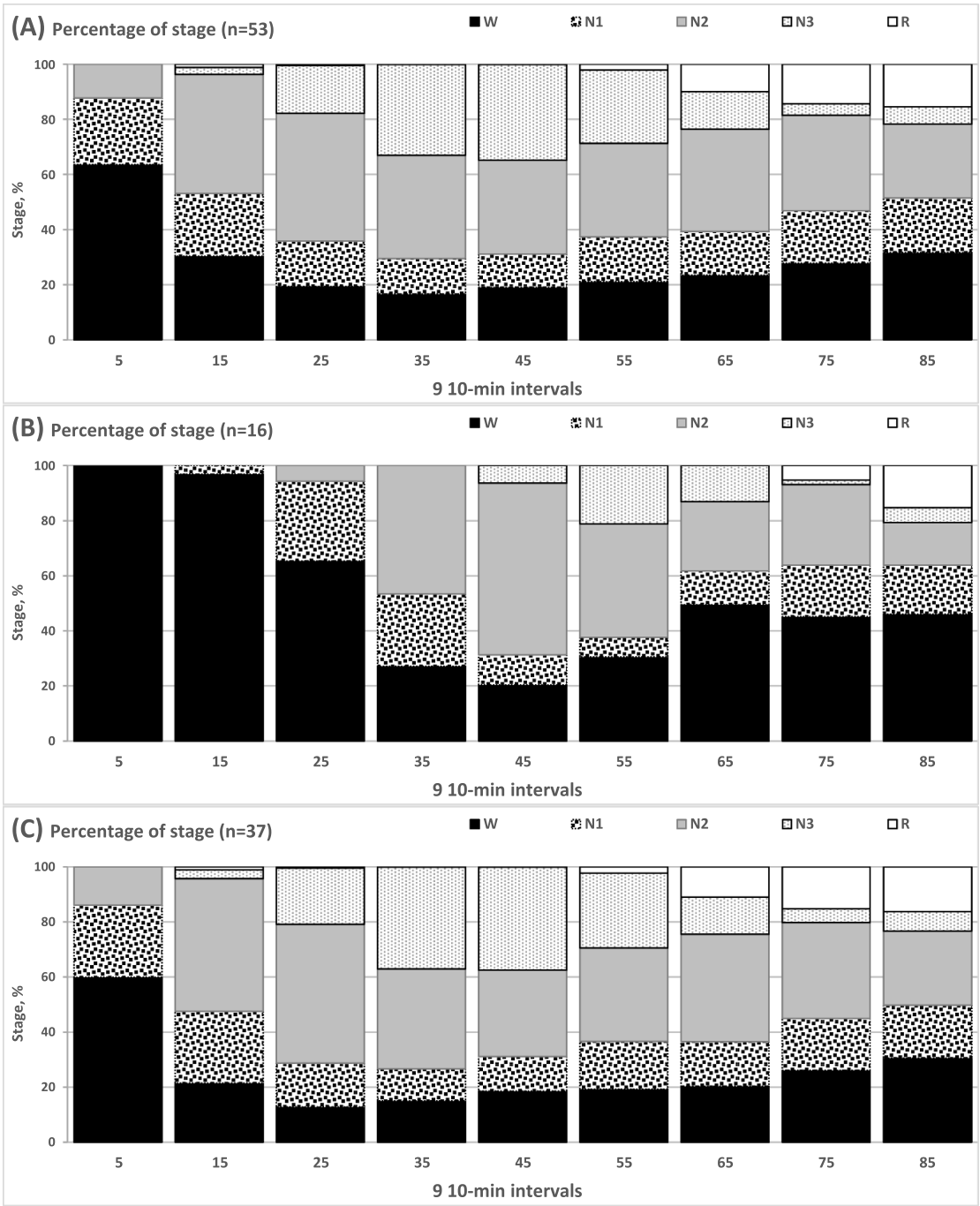

Figure 2. Distribution of sleep–wake stages on 9 10 min intervals of napping attempts. (A) Distribution for the whole sample. (B) Distribution for the subsample with, at least, one record characterized by longer than 20 min latency to N1. (C) Distribution for the remaining subsample with both records characterized by latency to N1 shorter or equal to 20 min.

score 7 during the 1st min prior to N1. Figure S4 illustrates the results of transformation of sleepiness scores into KSS scores for male and female study participants who showed significant difference in pre-nap KSS score (4.5 ± 0.3 and 5.4 ± 0.2, respectively, independent t-test $t_{51} = -2.5$, $p = 0.016$).

4. Discussion

Sleepiness assessment tools were mostly designed to detect an elevated level of sleepiness in the condition of sleep deprivation and some of medical conditions (Ohayon *et al* 2012, Baiardi and Mondini 2020, Taillard *et al* 2024). However, sleepiness occurs in various other conditions including the transition from wake to sleep states in everyday attempts of getting sleep. In the present study, we used two objective indexes of sleepiness that were previously proposed in sleep deprivation studies (Putilov *et al* 2012, 2019) to examine whether, in the absence of any self-reports about subjective sleepiness level, these indexes can be implicated

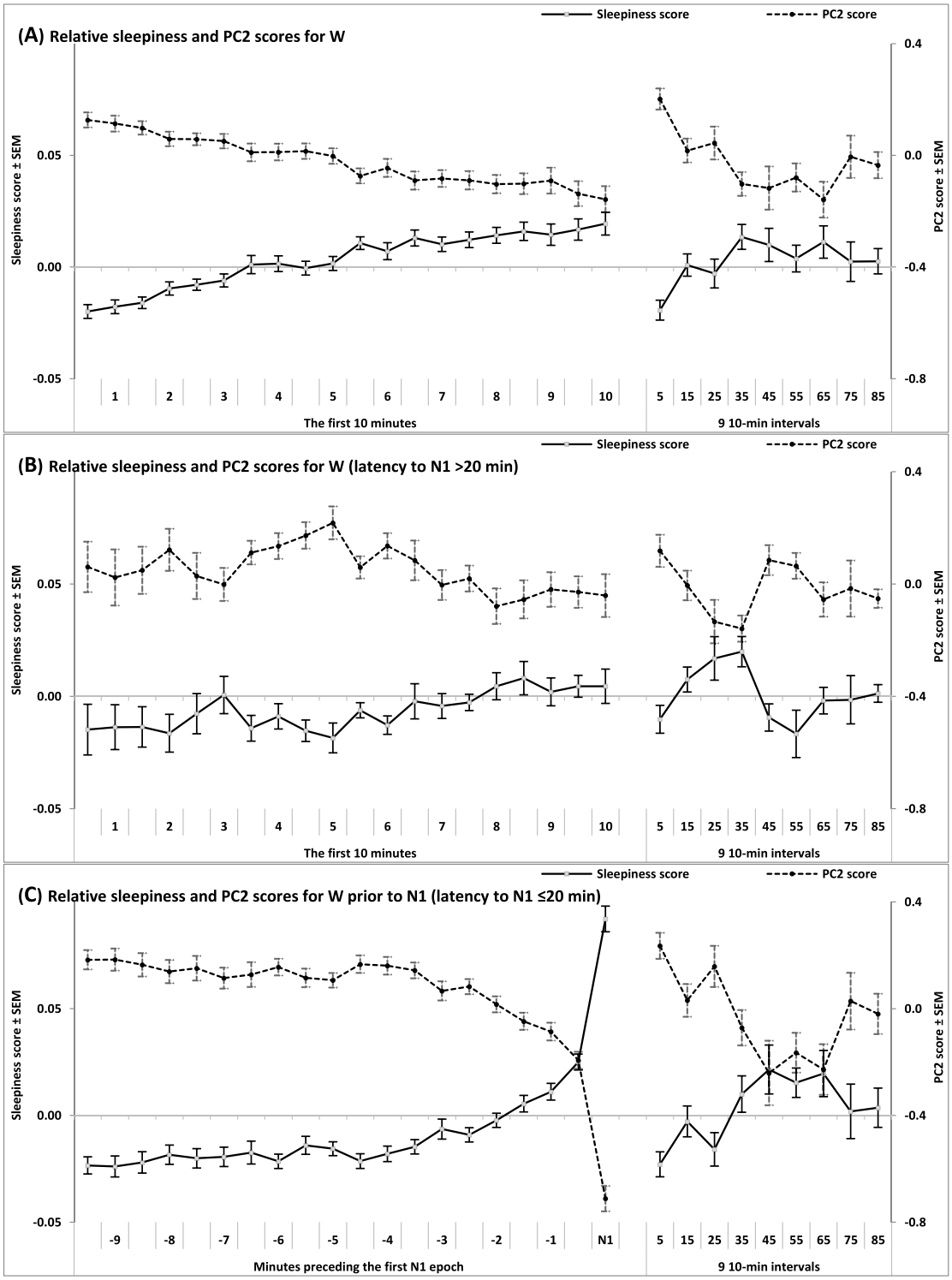

Figure 3. Time courses of relative objective sleepiness and PC2 scores for wake stage. (A) and (B) Each score was expressed as the deviation from mean score obtained for W by averaging either over the 1st 10 min interval of each 90 min record or over 9 10 min intervals of this record. (A) The whole sample. (B) The subset of subjects having the records with latency to N1 longer than 20 min (data were averaged within an individual in the case of two records with such a long latency). (C) When latency to N1 was shorter or equal to 20 min, each score on the 1st 20 min interval of such 90 min record was expressed as the deviation from mean score obtained for 19 or less epochs with W prior to the 1st N1 epoch (left graphs). The averaging over 9 10 min intervals of each 90 min record on the right graphs was similar to that in (A) and (B). Left *y*-axis: objective sleepiness score. Right *y*-axis: subjective (KSS) score.

in detecting fluctuations in sleepiness level during the EEG-monitored attempt to sleep. To calculate these indexes, sleepiness score and PC2 score, the EEG spectra were averaged on 30 s epochs of each record, assigned to 5 sleep–wake stages, and scored using the frequency weighting curve for sleepiness substate of wake state and loadings of each frequency on the 2nd principal component of variation in the EEG

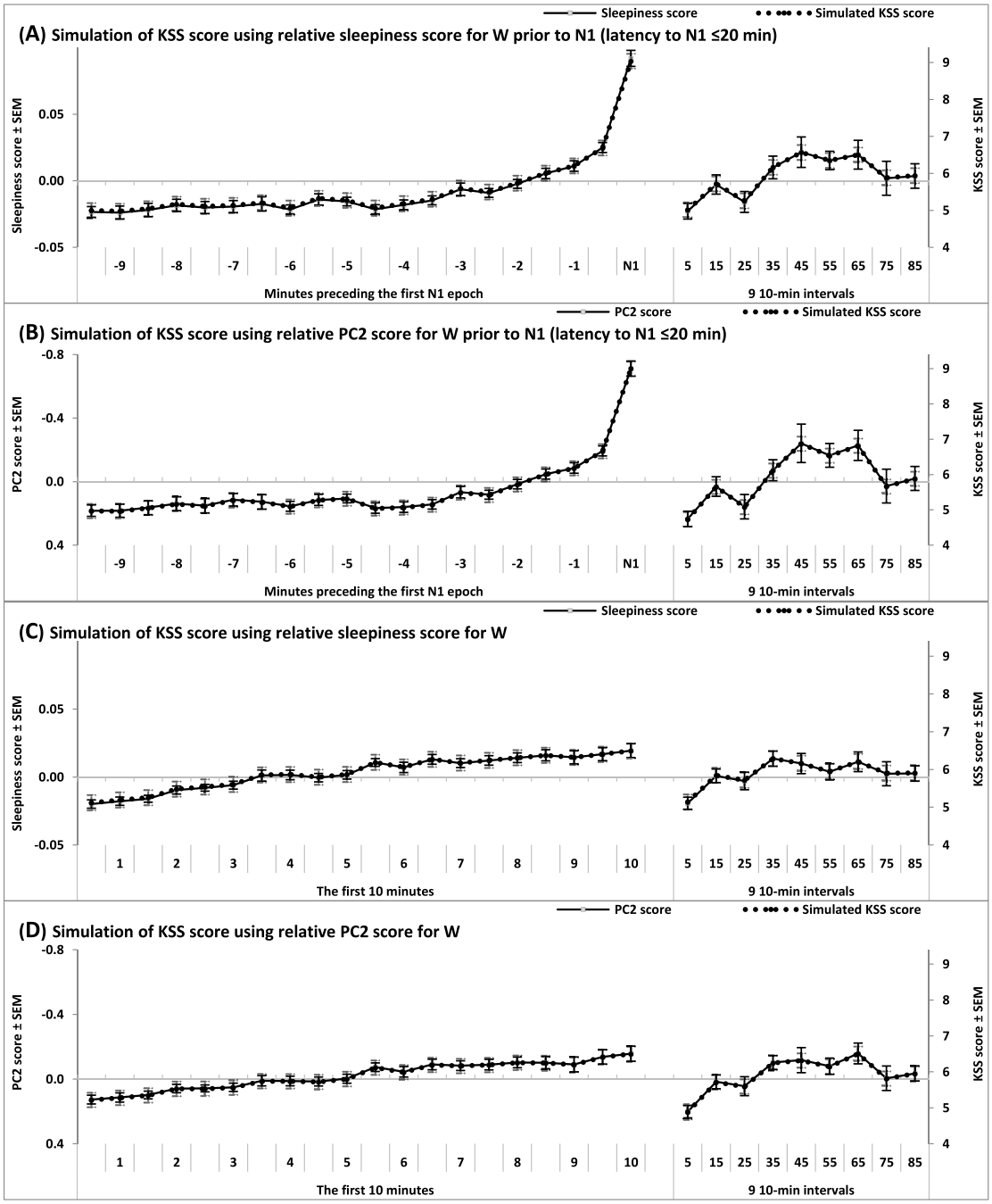

Figure 4. Simulated time courses of subjective (KSS) score. The sample-averaged KSS score self-reported by study participants prior to napping attempts (5.1 ± 0.2) was assigned to an objective sleepiness score obtained for the 1st 6 min of the polysomnographic records in accord to the formula (1). (A) Simulation is based on objective sleepiness score. (B) Simulation is based on PC2 score. The objective scores used for simulations are also shown in figure 3(C). (C) and (D) Simulation of KSS score using objective scores from figure 3(A). Left *y*-axis: objective (relative sleepiness) score. Right *y*-axis: objective (PC2) score of sleepiness.

spectrum, respectively. On the example of the statistically significant fluctuations in these two objective indexes of sleepiness, we demonstrated a plausibility of assignment of these fluctuations to the changes in verbally anchored levels of subjective sleepiness self-assessed with the 9-step KSS.

The proposed approach to quantification of substates of wake state during the EEG-monitored attempt to sleep is in line with approaches suggested in some other recent studies aimed on the development of polysomnography-based methods of description of intermediate vigilance states (e.g. Brodersen *et al* 2024). Results of such studies afford new opportunities to elaborate the importance of intermediate substates between the states of wake and sleep for normal and pathological sleep–wake dynamics. In particular, the objective indexes of sleepiness can be implemented in the detection of unsuccessful attempts to switch between wake and sleep states during a nap or night sleep episode (Brodersen *et al* 2024). Although

sleepiness and transition from wakefulness to sleep frequently co-occur, an individual can feel sleepy, or drowsy, without actually falling asleep (Andrillon *et al* 2024). Consequently, a research based on the proposed objective indexes of sleepiness can provide a better understanding of sleep–wake dysregulations underlying insomnia, excessive daytime sleepiness, and other conditions characterized by disturbed sleep and wakefulness.

It was previously proposed that brief arousals and wake states are an integral part of the normal process of sleep regulation, and they are generated by the mechanism controlling the typical sequences of sleep-stage transitions observed during short naps or all-night sleep episodes (Lo *et al* 2013, Bartsch *et al* 2015). Our results on sleepiness level within the epochs with W observed in the 90 min napping attempts suggested the profound difference in the time course of this level between the records with normal and delayed transition from wake to sleep states. In the case of delayed sleep onset, the normal transition from lower to higher sleepiness levels was not detected. Therefore, the proposed here method of quantification of sleepiness in W can provide an additional objective criterion for diagnostic of reduced daytime sleepability.

Previously, Guo *et al* (2020) introduced a threshold parameter for light sleep that distinguishes between shallow and deeper light sleep, N1 and N2, respectively, and they showed that this parameter correlates with severity of obstructive sleep apnea in children and that, after treatment of this condition, it returns back to normal values (i.e. that are similar to those detected for healthy children). Therefore, we expect that the proposed here method of quantification of sleepiness in W can also help to reveal significant differences in levels of sleepiness and light sleep between normal sleepers and patients with some of sleep disorders in untreated and treated conditions. Such methods can be applied, for instance, for comparison of sleepiness and light sleep during all-night sleep episode recorded before treatment for diagnostic purposes and after treatment for evaluation of treatment benefits. Moreover, since clinical sleep researchers also utilize multiple sleep latency test for correct diagnosis, treatment, prognosis and innovative research of sleep disorders (Kayabekir 2019), the proposed method of quantification of sleepiness during W preceding sleep onset can be used as an additional approach that can help to achieve these purposes by means of this test.

5. Conclusions

Sleepiness assessment tools were mostly designed to detect an elevated sleepiness level in the condition of sleep deprivation and some of medical conditions, but sleepiness occurs in various other conditions including the most often occurring transition from wake to sleep states in our everyday attempts of getting sleep. We examined whether, in the absence of any self-reports about subjective sleepiness level, two objective indexes of sleepiness that were previously proposed in sleep deprivation studies can be implicated in detecting fluctuations in sleepiness level during the EEG-monitored attempts to sleep. The results suggested a possibility to assign the statistically significant fluctuations in these two objective indexes of sleepiness to the changes in verbally anchored levels of subjective sleepiness. Such results afford new opportunities to elaborate the importance of intermediate substates between the states of wake and sleep for normal and pathological sleep–wake dynamics.

Data availability statement

The data cannot be made publicly available upon publication because they are owned by a third party and the terms of use prevent public distribution. The data that support the findings of this study are available upon reasonable request from the authors.

Acknowledgment

Not applicable.

Conflict of interest

The authors declare that they have no conflicts of interest.

Ethical approval and informed consent

All procedures performed in these studies were conducted in accordance with the principles embodied in the Declaration of Helsinki. The protocols for the experimental sleep deprivation studies were approved by the Ethics Committee of the Institute of Higher Nervous Activity and Neurophysiology in June 2019 (Approval#12402-02-7112). Informed written consent to participate in the study was obtained from all individual participants included in the nap study.

Authors' contributions

A A P, A N P, D E S, V B D, and O G D designed and performed the nap study; D S S, E B Y, O V M, A N P, D E S, E O G, A O T, and N V L contributed equally to the collection of experimental data; A A P, O G D, E O G, A N P, D E S, and V B D contributed equally to the analysis of experimental data; and A A P wrote the paper.

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