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Effects of Sleep on Brain Activity and Concentration Performance

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Abstract

Background: Sleep is essential for maintaining physical health and cognitive function; sleep deprivation impairs attention, memory, academic performance, and decision-making. The prevalence of sleep disorders is increasing; however, the underlying mechanisms remain unclear, and their effects on cognitive function remain obscure. Herein, we examined the influence of sleep on concentration tasks from a neuroscientific perspective using electroencephalography (EEG). **Methods:** This study enrolled 17 healthy young adults (3 women, 14 men; age: 20.9 ± 0.66 years). Participants completed a "sleep diary" using a free smartphone application to measure sleep quality from the previous night through the morning. Subsequently, they were instructed to perform a concentration task comprising a calculation problem based on the Uchida-Kraepelin test (a psychological test also termed the work inspection test). During the task, cerebral activation was measured using EEG. Task performance was calculated as the number of tasks and incorrect answers. Spearman's rank correlation coefficient was applied to analyze correlations between sleep diary entries, Uchida-Kraepelin test, and EEG. **Results:** No significant correlation among sleep duration, number of tasks, and number of incorrect answers was observed. Significant correlations were observed in left frontal β and γ waves and right frontal α and γ waves ($p < 0.05$). β and γ waves showed changes in the left frontal lobe and were positively correlated, and incorrect answers increased as EEG power levels increased. Similarly, α and γ waves in the right frontal lobe were positively correlated, and incorrect answers increased as EEG power levels increased. No significant correlation was found between sleep and concentration the following morning. A significant correlation was found between frontal lobe α, β, and γ waves. **Conclusion:** The increased power of these waves leads to a higher number of errors during concentration tasks, indicating that performance on concentration tasks depends on frontal lobe activity, regardless of sleep quality.

Keywords

Sleep, Concentration, Electroencephalography, Brain Function, Neuroimaging

1. Introduction

Sleep is crucial for maintaining physical and cognitive function in everyday life. However, the prevalence of sleep disorders has increased (Lee et al., 2019). Insomnia is reported to affect one-fifth to one-half of the general population, and one-fifth of those affected develop chronic insomnia (Morin et al., 2020). Shortened sleep duration negatively affects memory formation. A systematic review revealed that individuals who did not sleep for 36 h immediately before the memory task had a memory retention rate of only 40%, compared to those who slept normally (Seoane et al., 2020). Brain imaging studies have shown that impaired memory encoding following sleep deprivation is associated with abnormal patterns of cortical activation. This pattern is thought to occur because of overcompensation in the prefrontal lobe and loss of normal connections to the temporal lobe (Seoane et al., 2020). Decreased hippocampal growth factor levels have also been observed following sleep deprivation, which may underline reversible changes in brain function related to sleep and memory (Seoane et al., 2020).

A study of 491 medical students reported a correlation between sleep duration and academic performance, where lack of nighttime sleep, late bedtime, and daytime sleepiness negatively impacted their academic performance (Jalali et al., 2020). Additionally, sleep deprivation impairs attention and working memory, further impacting other functions such as long-term memory and decision-making. Partial sleep deprivation particularly impairs attention (Alhola & Polo-Kantola, 2007; Zhai et al., 2024). Specifically, the concurrent engagement of exogenous attention interferes with endogenous attention processes. Specifically, changes in α-band activity mediate the relationship between endogenous attention and its effect on task performance; the interference of exogenous attention occurs via the moderation of this indirect effect. Altogether, these results substantiate a model of attention in which endogenous and exogenous attentional processes involve the same neurophysiological resources (Landry et al., 2024). Conversely, the association between sleep fragmentation and cognitive performance did not differ according to race or sex. Objective sleep duration and subjective sleep quality were not associated with cognition in midlife (Leng et al., 2024).

Although sleep deprivation effects have been reported, their underlying mechanisms remain largely unknown (Alhola & Polo-Kantola, 2007). Therefore, in this study, we focused on the effects of sleep quality on cognitive function, specifically concentration skills. Additionally, we aimed to examine the influence of sleep on concentration tasks from a neuroscientific perspective using the electroencephalogram (EEG).

2. Materials and Methods

2.1. Participants

This study enrolled 17 healthy young adults (3 women and 14 men; age: 20.9 ± 0.66 years). They received a comprehensive explanation of the study's safety protocols and were assured of confidentiality. Written informed consent was received from the participants. None of the participants had major physical disorders, including neurological illnesses, brain injuries, or psychiatric disorders. This study was approved by the Ethics Committee of Nishikyushu University (approval no. 24ULJ22) and conformed to the principles of the Declaration of Helsinki and its subsequent amendments.

2.2. Experimental Protocol

Prior to the experiment, participants were asked to answer a "sleep diary" using a free smartphone application (NEC Solution Innovators, Ltd., Tokyo, Japan) to measure their sleep quality from the previous night through the morning (**Table 1**). This application is a simple tool designed to record sleep duration and daytime vitality, serving as the foundation for "Cognitive Behavioral Therapy for Insomnia (BTI)". In follow-up BTI surveys conducted 1 - 3 months later using the application intervention for 752 workers in NEC solution Innovators, Ltd., the severity of insomnia was significantly reduced in both the insomnia group and the comorbidity group, and depressive symptoms were significantly reduced in the comorbidity group compared with pre-BTI (Okajima et al., 2025). The application allows individuals to easily track and understand their sleep status. Details are provided at: https://play.google.com/store/apps/details?id=jp.co.nec_solutioninnovators.isd.cbti.

Table 1. Sleep diary results.

	Question contents	Answers
Question 1	What time did you wake up? (time)	7:50
Question 2	What time did you get out of bed? (minutes)	14.7 ± 12.4
Question 3	Did you wake up during your sleep? (yes/no)	4/13
Question 4	What time did you go to bed? (time)	2:58
Question 5	How long did it take to fall asleep? (minutes)	22.4 ± 15.9
Question 6	What did you do before going to bed?	—
Question 7	Did you take a nap during the day? (yes/no)	1/16
Question 8	Did you think of something?	—
Question 9	What was your daytime vitality? (%)	68 ± 19
Question 10	Did you take caffeine before going to sleep? (yes/no)	2/15

( ) indicate how the questions are answered.

All data were recorded after waking up and before daily activities (work or lectures) commenced, typically at 10:00 a.m. Participants were seated in a quiet room on a chair with a backrest. They performed a concentration task consisting of a calculation problem based on the Uchida-Kraepelin test (Japan Psychological Technology Research Institute Co., Ltd., Tokyo, Japan), a psychological test commonly used in work test inspections. Details are provided on the web page: https://www.nsgk.co.jp/uk/whatis. The task involved continuous single-digit addition, with rows changing every minute for a total duration of 30 min (15 min per session, separated by a short break). Task performance was evaluated based on the number of completed tasks and the number of incorrect answers.

Participants were instructed to perform the tasks without any additional movements and maintain a steady posture. Brain activity was recorded using a portable EEG device (Polymate Pro MP6100; Miyuki Giken Co., Ltd., Tokyo, Japan). Before electrode placement, the scalp was cleansed with alcohol, and electrodes were affixed to an elastic cap using a holder. Nineteen gold-coated active electrodes were positioned according to the international 10/20 EEG placement system placed at the following cortical locations: Fp1 and Fp2 (left and right frontal pole), F3 and F4 (left and right frontal), Fz (middle frontal), F7 and F8 (left and right inferior frontal), C3 and C4 (left and right central), Cz (middle central), P3 and P4 (left and right parietal), Pz (middle parietal), O1 and O2 (left and right occipital), T3 and T4 (left and right mid temporal), T5 and T6 (left and right posterior temporal).

2.3. Data Analysis

EEG data were sampled at a rate of 1000 Hz and filtered within the 1–60 Hz range using a bandpass filter. Artefacts caused by blinking or muscle movements were excluded. The power spectrum analysis was conducted using an electromagnetic source estimation data editor (Cortech Solutions, Wilmington, NC, USA). The EEG power was analyzed in absolute μV2 units. The nine regions of interest (ROI) were set as L-frontal (Fp1, F3, F7, and Fz), R-frontal (Fp2, F4, F8, and Fz), L-temporal (T3 and T5), R-temporal (T4 and T6), central (C3, C4, and Cz), L-parietal (P3 and Pz), R-parietal (P4 and Pz), L-occipital (O1), and R-occipital (O2). EEG rhythms were categorized into six wave bands according to their frequency ranges: δ (1 - 4 Hz), θ (4 - 8 Hz), α (8 - 13 Hz), β (13 - 30 Hz), and γ waves (30 - 50 Hz) based on the previous study (Gao et al., 2023). The mean power level of each waveband was calculated for each task.

2.4. Statistical Analysis

Spearman's rank correlation coefficient was used to analyze the correlation between the sleep diary, Uchida-Kraepelin test, and EEG. IBM SPSS Statistics (version 29.0; IBM Corp., Armonk, NY, USA) was used for all the statistical analyses. Statistical significance was set at $p < 0.05$.

3. Results

Table 1 shows the results of the sleep diary questions. For questions 6 and 8, the answers were content-specific; therefore, these questions were excluded from the analysis. Regarding the answers to Question 6, the most common answer was "consumption of tobacco, alcohol, and caffeine". Additionally, for question 8, a large percentage of people answered, "I don't think anything of it", but there were also a certain number of people who mentioned "not getting enough sleep". Figure 1 shows the results of the EEG power levels. Figure 1 shows the EEG power levels for each brain region. The numbers within the bars indicate the average values for each EEG power level. Table 2 shows a summary of sleep and concentration performance results. The total sleep duration was calculated as the difference between question 1 and (question 4 - 5) in Table 1**,** the total duration in bed was calculated as the difference between question 2 and 4 in Table 1, and the sleep efficiency was calculated as (total sleep duration)/(total duration in bed) × 100.

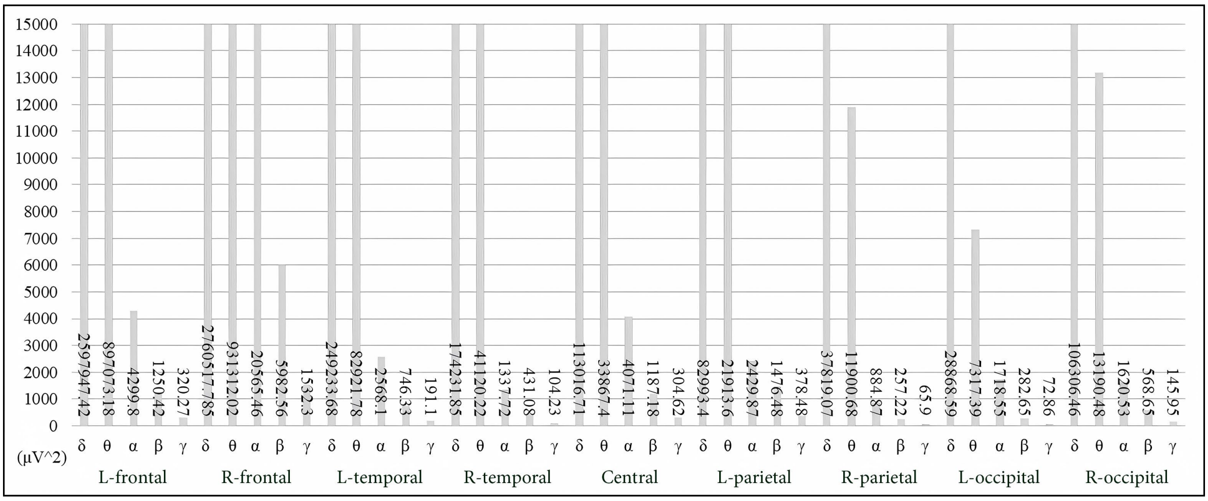

Figure 1. EEG power level results.

Table 2. Summary of sleep and concentration performance results.

Variables	Answers
Total Sleep duration (hours)	**5.81 ± 1.47**
Total duration on the bed (hours)	**6.47 ± 1.47**
Sleep efficiency (%)	**89.84 ± 8.30**
Amount of task (numbers)	**44.68 ± 11.85**
Number of incorrect answers	**2.30 ± 6.40**

Table 3 shows the correlation between the sleep diary and the Uchida-Kraepelin test. There was no significant correlation between sleep duration, the number of tasks, and the number of incorrect answers. Table 4 shows the correlation between the Uchida-Kraepelin test and EEG power levels. Significant correlations were observed in four areas (left frontal β and γ waves, right frontal α and γ waves) ($p < 0.05$). β and γ waves, which showed changes in brain activity in the left frontal lobe, were positively correlated, and the number of incorrect answers increased as the EEG power levels increased. Similarly, α and γ waves in the right frontal lobe were positively correlated, and the number of incorrect answers increased as the EEG power levels increased.

Table 3. Correlation between the sleep diary and Uchida-Kraepelin test results.

Correlation coefficient (ρ)	Amount of task	Number of incorrect answers
Question 1	−0.04	0.01
Question 2	−0.01	−0.03
Question 4	0.01	0.15
Question 5	0.06	0.09
Question 9	0.08	0.18

Table 4. Correlation between the Uchida-Kraepelin test and EEG power levels.

Correlation coefficient (ρ)		Amount of task	Number of incorrect answers
L-frontal	δ	0.02	0.29
	θ	0.07	0.29
	α	0.09	0.43
	β	0	0.523*
	γ	0.06	0.503*
R-frontal	δ	0.03	0.38
	θ	0.11	0.39
	α	0.04	0.498*
	β	0.04	0.49
	γ	0.12	0.522*
L-temporal	δ	0.02	0.21
	θ	0.01	0.19
	α	−0.04	0.24
	β	−0.02	0.33
	γ	0.11	0.47
R-temporal	δ	0.06	0.45
	θ	0.12	0.44
	α	0.39	0.28
	β	0.35	0.23
	γ	0.36	0.21
Central	δ	0.04	0.28
	θ	0.07	0.23
	α	0.06	0.4
	β	0.05	0.48
	γ	0.08	0.49

Continued

L-parietal	**δ**	**−0.08**	**0.22**
	θ	**−0.14**	**0.18**
	α	**0.02**	**0.23**
	β	**−0.16**	**0.26**
	γ	**−0.01**	**0.37**
R-parietal	**δ**	**−0.12**	**0.19**
	θ	**−0.2**	**0.12**
	α	**−0.3**	**0.16**
	β	**−0.24**	**0.22**
	γ	**−0.2**	**0.22**
L-occipital	**δ**	**−0.03**	**0.3**
	θ	**−0.13**	**0.24**
	α	**0.09**	**0.21**
	β	**0.03**	**0.34**
	γ	**−0.15**	**0.4**
R-occipital	**δ**	**−0.1**	**0.3**
	θ	**0.03**	**0.18**
	α	**0.13**	**0.08**
	β	**0**	**0.25**
	γ	**−0.1**	**0.33**

*$p < 0.05$, Spearman's rank correlation coefficient.

4. Discussion

In this study, we examined the effects of sleep on brain activity during concentration tasks using EEG. Although no significant correlation was observed between sleep duration and concentration performance, the correlation between concentration performance and EEG power levels showed a significant correlation between α, β, and γ waves in the frontal lobe. These changes in brain activity may have affected the performance in the concentration task. These results suggest that concentration performance is influenced by brain activity, but sleep duration does not have a direct impact on concentration performance. A previous study reported no significant relationship between subjective sleep quality measured using the Pittsburgh Sleep Quality Index or sleep diaries and performance in working memory, executive function, or procedural learning among healthy young adults (Zavecz et al., 2020). The findings of this study align with the findings of a previous study. The frontal lobe, responsible for working memory, executive function, and decision-making, is also widely thought to be involved in concentration tasks.

Based on the correlation between Uchida-Kraepelin and EEG findings, changes in the frontal lobe appear to play a key role in concentration performance. First, an increase in right frontal α-wave activity indicates reduced cortical activation, reflecting inhibitory control and stress-related regulation (Akil et al., 2024). Similarly, elevated left frontal β-wave activity is associated with performance monitoring and error correction, as β power typically rises following mistakes or task updates (Ricci et al., 2019). This suggests increased cognitive effort or motor correction during task errors. Lastly, increased frontal γ-wave power has been linked to elevated stress levels (Minguillon et al., 2016). Thus, greater stress during the task may heighten γ activity, correlating with more frequent errors. Collectively, these findings suggest that alterations in frontal lobe (α, β, and γ) activity are closely related to cognitive control, stress regulation, and error occurrence during concentration tasks.

Previous studies have shown that chronic stress alters the neural mechanisms underlying working memory and executive function (Liu et al., 2020). Therefore, the increased number of errors observed in the concentration task may be attributed to elevated stress levels and corresponding changes in frontal lobe EEG activity.

This study has several limitations. First, it included only healthy young adults; thus, the findings may not generalize to older individuals or patients with neurological disorders. Second, the concentration task was limited to the Uchida-Kraepelin test, leaving uncertainty regarding whether similar cerebral activity patterns would occur during other concentration tasks. Third, EEG data were not collected during sleep, making it unclear whether sleep-related brain activity influenced task performance the next day. Future studies should include larger and more diverse samples, employ multiple task types, and investigate cerebral activity under varying physiological and psychological conditions.

5. Conclusion

In conclusion, no significant correlation was found between sleep quality and concentration performance. However, a significant correlation was found between frontal α, β, and γ wave activities, suggesting that increased power in these frequency bands is associated with a higher number of errors in the concentration task. These findings indicate that concentration performance tasks are primarily influenced by frontal lobe activity, independent of sleep quality.

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Ethical Approval

This study was approved by the Ethics Committee of Nishikyushu University (approval no. 24ULJ22). Informed consent was obtained from all subjects involved in the study.

Data Availability Statement

The datasets generated and analyzed in the current study are available from the corresponding author upon reasonable request.

Conflicts of Interest

The authors declare no conflict of interest.

References

Akil, A. M., Cserjési, R., Nagy, T., Demetrovics, Z., Németh, D., & Logemann, H. N. A. (2024). The Relationship between Frontal Alpha Asymmetry and Behavioral and Brain Activity Indices of Reactive Inhibitory Control. *Journal of Neurophysiology, 132,* 362-374. https://doi.org/10.1152/jn.00046.2024

Alhola, P., & Polo-Kantola, P. (2007). Sleep Deprivation: Impact on Cognitive Performance. *Neuropsychiatric Disease and Treatment, 3,* 553-567.

Gao, C., Uchitomi, H., & Miyake, Y. (2023). Cross-Sensory EEG Emotion Recognition with Filter Bank Riemannian Feature and Adversarial Domain Adaptation. *Brain Sciences, 13,* Article 1326. https://doi.org/10.3390/brainsci13091326

Jalali, R., Khazaei, H., Paveh, B. K., Hayrani, Z., & Menati, L. (2020). The Effect of Sleep Quality on Students' Academic Achievement. *Advances in Medical Education and Practice, 11,* 497-502.

Landry, M., da Silva Castanheira, J., Raz, A., Baillet, S., & Sackur, J. (2024). A Lateralized Alpha-Band Marker of the Interference of Exogenous Attention over Endogenous Attention. *Cerebral Cortex, 34,* ebhad457. https://doi.org/10.1093/cercor/bhad457

Lee, M., Song, C., Shin, G., & Lee, S. (2019). Possible Effect of Binaural Beat Combined with Autonomous Sensory Meridian Response for Inducing Sleep. *Frontiers in Human Neuroscience, 13,* Article 425. https://doi.org/10.3389/fnhum.2019.00425

Leng, Y., Knutson, K., Carnethon, M. R., & Yaffe, K. (2024). Association between Sleep Quantity and Quality in Early Adulthood with Cognitive Function in Midlife. *Neurology, 102,* e208056. https://doi.org/10.1212/wnl.0000000000208056

Liu, Q., Liu, Y., Leng, X., Han, J., Xia, F., & Chen, H. (2020). Impact of Chronic Stress on Attention Control: Evidence from Behavioral and Event-Related Potential Analyses. *Neuroscience Bulletin, 36,* 1395-1410. https://doi.org/10.1007/s12264-020-00549-9

Minguillon, J., Lopez-Gordo, M. A., & Pelayo, F. (2016). Stress Assessment by Prefrontal Relative Gamma. *Frontiers in Computational Neuroscience, 10,* Article 101. https://doi.org/10.3389/fncom.2016.00101

Morin, C. M., Jarrin, D. C., Ivers, H., Mérette, C., LeBlanc, M., & Savard, J. (2020). Incidence, Persistence, and Remission Rates of Insomnia over 5 Years. *JAMA Network Open, 3,* e2018782. https://doi.org/10.1001/jamanetworkopen.2020.18782

Okajima, I., Suzuki, M., Tanizawa, N., Kajiyama, I., Ichikawa, R., & Akitomi, J. (2025). Does Digital Cognitive Behavioral Therapy Improve the Insomnia and Depression of Workers to Healthy Levels? An Open Trial. *BioPsychoSocial Medicine, 19,* Article No. 13. https://doi.org/10.1186/s13030-025-00334-y

Ricci, S., Tatti, E., Mehraram, R., Panday, P., & Ghilardi, M. F. (2019). Beta Band Frequency Differences between Motor and Frontal Cortices in Reaching Movements. In *2019 IEEE 16th International Conference on Rehabilitation Robotics (ICORR)* (pp. 1254-1259). IEEE. https://doi.org/10.1109/icorr.2019.8779373

Seoane, H. A., Moschetto, L., Orliacq, F., Orliacq, J., Serrano, E., Cazenave, M. I. et al. (2020). Sleep Disruption in Medicine Students and Its Relationship with Impaired Academic Performance: A Systematic Review and Meta-Analysis. *Sleep Medicine Reviews, 53,* Article 101333. https://doi.org/10.1016/j.smrv.2020.101333

Zavecz, Z., Nagy, T., Galkó, A., Nemeth, D., & Janacsek, K. (2020). The Relationship between Subjective Sleep Quality and Cognitive Performance in Healthy Young Adults: Evidence from Three Empirical Studies. *Scientific Reports, 10,* Article No. 4855. https://doi.org/10.1038/s41598-020-61627-6

Zhai, D., Chen, Q., Yao, Y., Ru, T., & Zhou, G. (2024). Association between EEG Microarousal during Nocturnal Sleep and Next-Day Selective Attention in Mild Sleep-Restricted Healthy Undergraduates. *Nature and Science of Sleep, 16,* 335-344. https://doi.org/10.2147/nss.s442007