

The Effect of Alpha Rhythm Sleep on EEG Activity and Individuals' Attention

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Abstract. [Purpose] This study examined whether the alpha rhythm sleep alters the EEG activity and response time in the attention and concentration tasks. [Subjects and Methods] The participants were 30 healthy university students, who were randomly and equally divided into two groups, the experimental and control groups. They were treated using the Happy-sleep device or a sham device, respectively. All participants had a one-week training period. Before and after training sessions, a behavioral task test was performed and EEG alpha waves were measured to confirm the effectiveness of training on cognitive function. [Results] In terms of the behavioral task test, reaction time (RT) variations in the experimental group were significantly larger than in the control group for the attention item. Changes in the EEG alpha power in the experimental group were also significantly larger than those of the control group. [Conclusions] These findings suggest that sleep induced using the Happy-sleep device modestly enhances the ability to pay attention and focus during academic learning.

Key words: Sleep function, Electroencephalography (EEG), Alpha brain wave

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INTRODUCTION

Sleep function is known to include physical and psychological restoration and recovery, memory consolidation, the discharge of emotions, and the enhancement of cognitive processes¹⁾. Cognitive processes are related to intrinsic academic motivation, learning performance, and task performance, and thus, the cognitive aspects of sleep function have become a popular theme these days^{2–4)}.

It is well known that sleep is closely related to cognitive function, for example, it has been reported that poor sleep quality is associated with decrements in performance in tests of cognition, especially executive function^{1, 5, 6)}. In addition, some studies have reported that task performances, such as, arousal, reaction time, arithmetic operation, short-term or long-term memory, and logic/reasoning decrease when people are deprived of sleep^{5–8)}. These findings suggest that poor sleep quality can have a negative effect on academic performance. In particular, poor sleep can deplete attention and lead to fatigue resulting in severe impediments to academic work^{9, 10)}.

Many previous studies have addressed the relationship between attention and brainwaves. In particular, the alpha waveband has been found to contribute perceptual facilitation as a result of featured-based visual attention^{11–15)}. Alpha waves are relatively lower than other waves, like beta waves, and are closely related to memory, creativity, and academic performance, because they appear during a stable state of the brain, which seems to be in the best state in terms of learning and attention^{16–18)}. Furthermore, many trials have been undertaken to prompt brain states to achieve recovery from memory disorders and cognitive functions¹⁹⁾. In addition, some studies have reported that EEG activity of the alpha and theta wavebands reflect cognitive and memory performance^{16, 20–23)}. It has also been reported that a peak alpha rhythm of less than 10 Hz is associated with poorer academic performance and that an alpha rhythm frequency of more than 10 Hz is associated with better academic performance¹⁹⁾. Furthermore, α waves provide an excellent means of inducing sleep, and it has been shown that alpha rhythm is related to NREM (Non-Rapid Eye Movement) at the beginning of sleep^{24, 25)}.

Despite of these studies, there is a lack of evidence to suggesting a relationship between induced alpha rhythm sleep and attention/cognitive performance. Hence, in this study, we undertook to investigate the effectiveness of alpha rhythm induced sleep on attention.

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SUBJECTS AND METHODS

Subjects

Thirty healthy normal subjects were recruited for this study. Individuals with a neurological or visual impairment or a cognition problem were excluded. All subjects were assigned randomly to either the experimental group, which used the Happy-sleep device, or the control group which used a sham device. The study was approved by the Daegu university ethics committee and participants provided their written informed consent.

Methods

The Happy-sleep sound pillow and Happy-sleep application are produced by Rabiotech (Seoul, Korea). The sound pillow has a bone conduction transducer that can convert electrical signals into vibrations. Thus, allowing sound to be directly conducted to skull and then to the inner ear without being conducted through the eardrum when the occipital region is closely in contact with the device. The Happy-sleep application contains a program to induce deep sleep by emitting only alpha and theta waves. This program is claimed not only to induce deep sleep, but also to improve academic performance by inducing alpha and theta waves. The studies have been performed to confirm the results of this program in Korea, and it has been approved by Korean Mind Training Center (KMTC). The sham device used had an identical shape and produced the same sound. The frequencies generated by the sham device were randomly mixed so as not to settle on any frequent wave, such as, those of an alpha or theta waves, or any other known brain-wave. In addition, no particular wave was provided for more than a second. All other characteristics related to typical use of the Happy-sleep application were imitated.

Before and after the intervention, a brainwave measurement system, QEEG-8 (LXE 3208, LAXTHA Inc., Korea), comprising of 8 channels and Telescan software (LAXTHA Inc., Korea), were used to measure and analyze EEG activity. Rehacom (HASOMED GmbH, Germany), which is a Cognitive Rehabilitation/Brain Performance Training system, was also used to assess Attention and concentration in the behavioral task performance.

This study had a randomized controlled trial design. All subjects in the experimental and control groups performed a behavioral task in the pre- (Day 1) and post test (Day 9) sessions. Between test sessions, there was a one-week training period. In intervention period, all subjects practiced for an hour before sleep each day with the Happy-sleep or sham device, depending on the experimental condition. In the test session, The behavioral task was performed using the Attention & Concentration section of the Rehacom program. The test consists of 3 trials and has 24 levels and it involves finding a picture on the screen that matches a provided picture. After 10 minutes testing, the number of trials, maximum response time, and minimum response time at each level were measured and compared between the pre- and post-testing.

For EEG measurements, brainwaves were measured over a 10-minute period while performing the Rehacom

Table 1. The comparison of reaction times by performing the attention task in the each group

	Device group	Sham-device group	
Max RT	-1892.00±913.85	2892.79±1873.09	*
Min RT	-1689.85±628.03	112.79±255.77	*

Data=Mean ± SE, *p<0.05 between Device group and Sham device group, Max RT: Maximum Reaction Time, Min RT: Minimum Reaction Time

program with 8 electrodes attached to the scalp. Activity in 8 channels was recorded at Fz, Cz, Pz, C3, C4, T7, and T8 in the left/right hemispheres. Electrode placement was in accordance with the international 10–20 system, using an electrode cap. Reference and ground electrodes were attached to the left and right mastoid processes, respectively.

After both groups had performed the pre-testing on the first day, each device was used for a week, and then the post-testing was performed on the ninth day. During the experimental period, all subjects were asked to use the Happy-sleep sound pillow with the application or the sham device respectively for an hour before sleep every day. In addition, they were also instructed not to consume alcohol or caffeine during the study period. Each subject kept a diary, and these were used to confirm that they had complied with the study protocol.

Demographic data such as age (22.87±1.63 years) and gender (male: 13, female: 17) were analyzed by one way ANOVA. To demonstrate intergroup difference in response time changes during the attention task, two dependents variables, namely, maximum reaction time (RT) and minimum RT, were analyzed using the independent t-test. Differences in EEG alpha power during the attention task between the experimental and control groups were analyzed using the independent t-test for each of the eight channels (Fz, Cz, Pz, C3, C4, T7, and T8). All data were analyzed using SPSS ver. 18.0 for Windows, and $\alpha=0.05$ was used as the level of significance.

RESULTS

No significant difference in gender (male: 13, female: 17) or age (22.87±1.63 years), which would have affected performance in the attention task, was found. Table 1 displays the difference between pre- and post-test of the maximum and minimum RTs for each group. For all variables, bivariate analysis showed that RT variation in the experimental group was significantly larger than in the control group ($p<0.05$). Variations of EEG alpha power for the eight channels (Fz, Cz, Pz, C3, C4, T7, and T8) are presented in Table 2. In all channels, changes of EEG alpha power in the experimental group were significantly larger than in the control group ($p<0.05$).

DISCUSSION

In the current study, we found significant reliable improvements in performance at the attention task and in alpha power of EEG activity after sleep when the device was

Table 2. The comparison of EEG alpha powers under the eight channels in the each group

	Device group	Sham-device group	
Ch 1 (Cz)	0.043±0.011	-0.040±0.012	*
Ch 2 (Pz)	0.046±0.013	-0.015±0.008	*
Ch 3 (C4)	0.046±0.010	-0.043±0.010	*
Ch 4 (C3)	0.039±0.013	-0.019±0.011	*
Ch 5 (Fz)	0.046±0.011	-0.019±0.009	*
Ch 6 (Oz)	0.040±0.014	-0.030±0.007	*
Ch 7 (T8)	0.051±0.015	-0.054±0.013	*
Ch 8 (T7)	0.033±0.018	-0.030±0.012	*

Data=Mean ± SE, *p<0.05 between Device group and Sham device group

used. However, no significant changes were observed in the sham-device group. These results imply that sleep produced using the device provides a modest enhancement in attention and focus during academic learning.

Our finding of a decline in response times is in line with previous behavioral experiments using the attention task, and these reflect a gradual reduction in audio-visual entrainment (AVE). Many previous studies have reported that the AVE device can increase attentional skill and decrease impulsive behavior^{26–28}). In addition, according to prior studies conducting cognitive performance and functional outcome with cognitive remediation therapy, motor skill training with the audio-visual stimulation improved performance, indicating that sensorimotor integration processing is a part of motor skill learning^{29, 30}). Thus, we speculate that sleep induced with the device could reduce processing times via cognitive entrainment and increase motor skills.

Recently, many neural activity studies have investigated changes in brain wave activity in different brain areas and their relationships with behavioral changes. According to previous EEG studies, EEG activity of neural areas concerned with deficient attention, hyperactivity, and insufficient sleep, show relatively lower alpha activity^{31–33}). Several studies have revealed that alpha activity, and not theta or beta activity, is the major band associated with arousal, which has been linked to attention, perceptual processing, and semantic memory^{16, 34}). Moreover, alpha activity is of specific interest because its frequency is thought to reflect indirectly the level of cortical activation underlying brain regions^{34, 35}). Greater alpha activity is thought to reflect active preparation of the cortical system for complex information processing, that is, to increase the state of preparedness to perform a task. Accordingly, greater alpha activity is related to positive behavioral outcomes, including rapid and accurate responses, and enhanced cognitive task performance, such as, at attention and target detecting tasks^{36–38}). In the present study, the global increases in alpha activity observed are in line with the findings of previous studies, which found that physiologic arousal and relaxation are achieved during cognitive task. Therefore, it is believed that alpha activity oscillators induce synchronization between immediate execution and selective inhibition by inducing the neuronal excitabilities of multiple processes.

These findings showed that higher alpha activity after sleep with the device could have a direct impact on brain regions, and effectively improve cortical excitability subserving particular cognitive functions, such as, attention. Furthermore, the combined use of this facilitatory device and training could enhance academic learning. We acknowledge that this study has some limitations, for example, task complexity and difficulty were not considered. In addition, we did not analyze cortical excitability volumes of various brain areas.

Further studies on the efficacy of performing and neural mechanisms underlying various behavioral tasks and comparisons of changes in various brain areas as determined by neuro-imaging techniques are required.

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