Effect of White Noise on Working Memory Using Event-Related Potentials

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***Abstract* — We investigated the effect of white noise on working memory performance using electroencephalography (EEG). Six healthy subjects participated in this study, and each subject performed a 2-back task under white noise and no sound conditions. After a series of EEG preprocessing, the amplitude of event-related potential (ERP) was calculated. The results indicated an increase in average accuracy and mean P300 amplitude during the white noise condition compared to without it, suggesting that white noise might enhance working memory performance. However, due to the limited number of participants, statistical power was not attained. In our future studies, we will perform additional experiments with more subjects.**

I. Introduction

Working memory refers to the brain system used to temporarily store and manipulate information needed for complex cognitive tasks. Working memory capacity is closely related to learning and reading comprehension abilities, highlighting its importance. Recent studies have explored enhancing working memory capacity using external stimuli, such as transcranial electrical stimulation (tES) and sound-based auditory stimulation. However, while tES can cause discomfort and requires a separate electrical stimulator, auditory stimulation has the advantage of being accessible and easily integrated with wearable devices, as it can be provided anywhere with earphones or speakers.

White noise is a functional auditory stimuli known to enhance brain processing abilities, improving attention and cognitive performance [1]. Previous studies have primarily focused on inattentive children or those with attention deficit hyperactivity disorder (ADHD), showing cognitive improvement with strong white noise stimuli around 80 dB [2, 3]. Recently, it has been found that appropriate levels of white noise can positively affect working memory performance in healthy adults [4]. However, most studies have only reported behavioral performances, such as task accuracy or reaction time, without sufficient neurophysiological evidence.

Working memory is based on the continuous neural activity of a complex cerebral cortical network. These cortical dynamics can be observed by measuring neural oscillations using electroencephalography (EEG). Working memory is associated with EEG activity in the frontal and parietal regions, which can be simultaneously observed in the central area [5]. Therefore, this study aimed to neurophysiologically confirm the modulation of working memory capacity by white noise using central EEG. To this end, EEG was measured during working memory tasks with and without white noise, and changes in EEG patterns were analyzed under each condition.

II. Method

A. Data acquisition

Six healthy adults (2 males, 4 females, aged 21.67 ± 3.01 years) participated in this study. EEG was measured during cognitive tasks with and without white noise using Smartfones (mBrainTrain, Belgrade, Serbia), a wearable EEG measurement device in the form of a headset capable of simultaneous EEG measurement and white noise presentation (Fig. 1). EEG data were recorded at a sampling rate of 500 Hz, maintaining all electrode impedances below 15 kΩ during measurement. The study protocol was approved by the Institutional Review Board (IRB) of Korea University [KUIRB-2023-0139-01].

B. Auditory stimuli

We used white noise at 65 dB (mono track, 32-bit floating point with a sampling frequency of 44,100 Hz), which has shown to enhance visual working memory performance in healthy adults [4]. The white noise was generated using Audacity software (version 3.0.2 for Windows, generating white noise with a bandwidth of 86 Hz to 22.007 kHz). The generated white noise was delivered to participants through the Smartfones device.

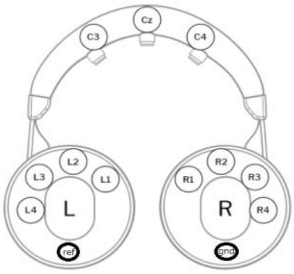

Fig. 1 EEG montage of the Smartfones EEG device by mBrainTrain (Belgrade, Serbia).

C. Experimental paradigm

A 2-back task, widely used in neuroscience and electrophysiology studies, was used as the cognitive task in this study [6]. The experiment was conducted in a shielded room to minimize external noise, and participants seated approximately 50 cm from the screen. Participants performed the 2-back task under both White Noise and No Sound conditions [4]. The visual stimuli consisted of random numbers (0-9) presented sequentially with an inter-stimulus interval of 1500 ms and a presentation time of 500 ms. Participants were instructed to press the right key on the keyboard if the current stimulus matched the one from two earlier (target stimulus) and the left key if it did not (non-target stimulus). They had to respond within 2 seconds, and missed or multiple responses were considered incorrect. The task consisted of 120 stimuli, with a target to non-target stimulus ratio of 3:7 [7]. Participants performed the task once under each condition, with a 5-minute break between two conditions. To exclude the learning and stimulation effects, half of the participants started with the White Noise condition, and the other half with the No Sound condition. Before the experiment, a brief practice session with 10 stimuli was conducted until 100% accuracy was achieved to ensure that participants were familiar with the 2-back task [8]. The performance of the 2-back task was evaluated based on accuracy and mean reaction time.

D. EEG data analysis

To remove artifacts from raw EEG data, we performed a band-pass filtering between 0.5 and 30 Hz. Subsequently, an automatic noise removal algorithm, artifact subspace reconstruction (ASR), was applied to remove ocular and muscle artifacts, followed by independent component analysis (ICA) to manually remove any remaining artifacts. The artifact-free EEG data were segmented from -200 to 800 ms based on the stimulus onset and divided into target and non-target stimuli for event-related potential (ERP) analysis. Segments with amplitudes exceeding ±150 μV were excluded from the analysis. The P300 amplitude was calculated by averaging the power in the 300 – 500 ms window. Data from the ear electrodes were excluded from the analysis as they were not within the region of interest.

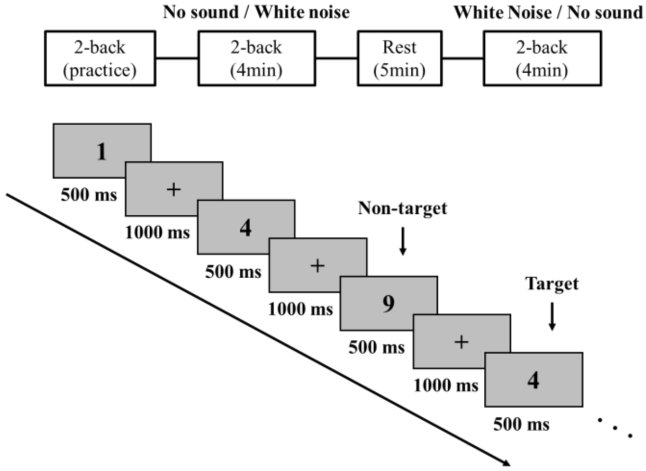

Fig. 2 Scheme of the experimental protocol used in this study.

III. RESULTS

Table 1 shows the accuracy and reaction time for each of the six participants, as well as the average results. There was a trend towards higher average accuracy in the white noise condition, with all participants, except one subject (S1). While reaction times generally increased under the white noise condition, the differences were minimal

Table 1 Individual accuracy and reaction time

	Accuracy (%)		**Reaction time (ms)**	
	White noise	**No sound**	**White noise**	**No sound**
S1	91.53	93.22	272.81	252.35
S2	94.07	88.98	342.97	316.47
S3	90.68	87.29	293.26	250.93
S4	99.15	98.31	497.74	358.78
S5	96.61	91.53	166.51	221.41
S6	90.68	83.05	364.82	478.57
Mean (Std)	93.79 (3.50)	90.40 (5.24)	323.02 (110.07)	313.08 (95.33)

Fig. 3 shows the average ERP of six participants for target and non-target stimuli in both conditions, with the P300 component appearing between 300 – 500 ms. Both conditions showed larger P300 amplitudes for target stimuli than for non-target stimuli, indicating successful task performance.

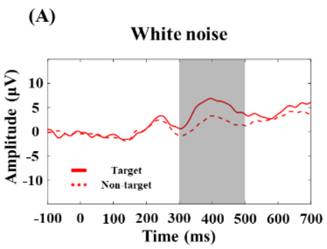

Fig. 3 (A) Average ERP of white noise condition, (B) Average ERP of no sound condition

Figure 4 presents the average target ERP under no sound and white noise conditions, with Table 2 quantifying the P300 values in the 300 – 500 ms window. The average ERP for target stimuli showed similar P300 patterns in both the no sound and white noise conditions. Although the average P300 amplitude tended to be higher under the white noise condition, individual P300 values did not consistently increase for all participants.

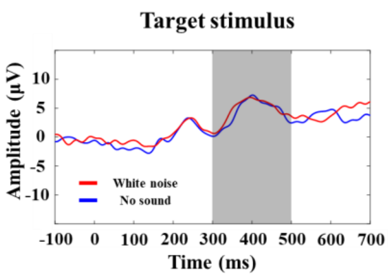

Fig. 4 Target stimulus average ERP of both condition

Table 2 Individual P300 amplitude

	Target ERP (μV)	
	White noise	**No sound**
S1	4.40	3.96
S2	5.52	2.75
S3	10.96	11.15
S4	0.36	-0.38
S5	4.06	3.97
S6	3.13	4.37
Mean (Std)	4.74 (3.51)	4.30 (3.78)

IV. Conclusions

This study aimed to neurophysiologically confirm the effect of white noise on working memory capacity using EEG in healthy adults. The amplitude of the P300 is correlated with individual performance on cognitive tasks [10]. The average accuracy of the working memory task and the P300 amplitude tended to increase under the white noise condition, suggesting a potential positive effect of white noise on working memory. However, the effect was not consistent across all participants, and the limited number of participants precluded statistical significance. Future studies will recruit additional participants to obtain more conclusive results.

Acknowledgment

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