ORIGINAL ARTICLE

Effect of Audio White Noise Stimulation on EEG Voltage Patterns during Visual Learning Assessment

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ABSTRACT

Introduction: The advancement of brain modalities has attracted many researchers to discover the effect of auditory stimuli on brain activities and responses. Until recently, fewer studies were reported investigating the relationship of audio white noise on visual learning phases using electroencephalography (EEG) modality. Objectively, current research targets to solve this issue by including indicator based brain activities. In addition, this research also discovered the differences among brain patterns during encoding and recognition that are not deeply investigated. **Materials and Methods:** Experimental work was conducted with twenty participants from higher learning institutions. They were instructed to learn the visual items and retrieve them at a specific time and under particular circumstances. The brain responses during the assessment were recorded using an EEG machine and processed via a Butterworth bandpass filter to eliminate the artefacts and extract meaningful features. **Results:** It was observed that the most influential EEG channels were F7 and Fp2, with ranges between 20 to 60 μV and 9 to 50 μV. Similar patterns of rise and decrease trend were also found for tested conditions. High EEG mean voltage was found for difficult levels compared to easy levels. In addition, the behavioural result showed a better score for audio white noise compared to the control condition. **Conclusion:** The results were associated with activating brain activities related to judgment and verbal expression. Audio white noise is recommended to improve visual learning based on the indicators.
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Keywords: Brain responses, Electroencephalography channels, Mean voltage, Visual learning, Trend pattern

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INTRODUCTION

Students in institutional learning rely on visual information to remember and learn graphic aids (1,2). Therefore, the students must obtain good visual learning skills because they are constantly engaged with visual information from diagrams, maps, charts, and graphs. A similar concept is applied in processing visual information as others in the brain. The stages of visual information processing are encoding, storage, and recognition (3). The initial stage is encoding through visual or eyes to record and capture the visual stimuli. After that, the visual data is kept in the visual memory system for later access. The final stage of this process is when the person recalls the information, known as the recognition stage. The processes are linked together, and the ability of the brain to process the information depends on those stages. The high efficiency of the visual information process in the brain will provide optimal individual ability and performance. Therefore, the suspected factors that will affect visual memory must be investigated.

Previous researchers reported that the circumstances or environment with audio could enhance human memory and cognitive function. The variables that need to be considered based on environmental factors are cognitive and memory assessment characteristics, audio attributions, and others. Thus, the proposed research aims to discover the impact of audio white noise on visual memory function according to EEG voltage patterns. The motive for executing this study is due to past research primarily being interested in audio stimulation's effect using behavioural datasets alone. In addition, the relationship between memory performance and brain activities and comparing brain patterns during encoding and recognition stages was not fully discovered. Hence, this work will suggest the best conditions, either silent or audio white noise, for visual learning and the discovery of brain activities in different environments and learning stages.

Audio white noise refers to a blanket of sound composed of all frequencies equally, developing a shushing or hissing sound. It has been found that the audio white noise impacts cortical function and is used for numerous therapeutic and interventional applications. An early investigation in 1667 reported that white noise could treat Pope Clement IX's insomnia (4). To date, this audio was tested on perception and learning (5–7), sleep quality (8,9), postural control (10,11), and treat tinnitus (12,13). Soderlund et al., reported that listening to white noise improved children's memory and reading ability compared to no audio circumstance (14). Besides, they also state that inattentive and attention deficit hyperactivity disorder (ADHD) children managed to score better in cognitive assessment. Awada et al. found that audio white noise provides better cognitive performance for normal adults from several tests of Test Battery, Continuous Performance Test, Stroop Test, Two-back Test, Remote Associate Test, and Typing Performance Test (15). They conclude that it managed to sustained attention, speed, and accuracy of performance as well as minimized stress levels and improved creativity.

Egeland et al., (16) indicated that audio white noise had significant effect on lower or high ADHD children for Conners' Continuous Performance Test-3. It shown improved performance in later parts of the test and decreased response variability under the most prolonged event rate. Meanwhile, Herweg and Bunzeck suggest that audio white noise has no general effect on the cognitive functions of subjects aged 18 to 35 (17). Helps et al., (14) also obtained negative results where the normal-attentive children's performance was unaffected by audio white noise exposure. There is no profound evidence of their benefits based on existing research regarding the effect of audio white noise on human performance. It also presents mixed results that are unclear to understand.

Noise effect is usually correlated with stochastic resonance. This concept is noise-improved signaling in any threshold-based system, with noise requiring a threshold to be permitted before the signal is registered (18,19). Stochastic resonance generally exists in non-linear dynamic systems that do not function optimally. Recently, this resonance has been found in the human nervous system, which is believed to benefit sensory signal detection. In this case, if the person is exposed to a weak stimulus lower than the hearing threshold, it aids the stimulus in being detected when the noise is introduced to the signal. It happens because the noise will interact with the weak stimulus, making it detectable. Until now, audio white noise has been investigated to discover its effect on human performance. However, a deep understanding of its effect is still inconclusive that require further discovery. There are certain unresolved questions regarding their effect.

Among the issues in existing studies is the low discovery of audio white noise effects on human visual memory compared to music-based research. In addition, most studies preferred children as subjects in experiments, whereas only limited work could be found focused on adults. Another issue is that the indicators used to assess the effect mainly depend on behavioural data. The limitation of only including this data is the body response cannot be determined. The behavioural result may show good scores, but the participant could also experience bad stress from the provided stimulation. Therefore, including physiological signals such as brain responses may help the researcher understand the body condition of the participant during stimulation to determine the best state for memory improvement without causing health deterioration. Less investigation using physiological measurements is because complex and complicated processes will also increase experimental duration. A combination of behavioural results with brain signals can better explain the stochastic resonance effect from white noise on adult visual memory. Also, most research based audio stimulation preferred recording or analyzing EEG signals during memorization or recognition. EEG is preferred for experimental research. The advantages of using EEG compared to others are that it has a shorter acquisition duration, excellent temporal resolution, is user-friendly, safe, and non-painful to subjects, and has an affordable cost (20,21). The EEG devices reflect the cortical electrical activity of acquired brain signals. Determining and correlating the EEG patterns between those periods is better for observing the similarities and differences.

This work's novelty is investigating audio white noise effect on adult visual memory based on behavioural data and physiological signals. Another contribution from this work is implementing a non-complicated method and the minimum time of program execution for processing EEG signals to indicate the pattern under the provided stimulation and information process period. In addition, this work also introduces simple ways of interpreting the EEG responses based on time-domain voltage. The pattern of EEG voltage can be used as initial screening in selecting the affected brain location instead of using all channels to extract other features. Obtaining an optimal EEG channel will decrease processing time with promising outcomes. The procedure and findings from this study can be used as a reference for other researchers who work in this area, and novice individuals can also implement it because it presents things in understandable ways.

METHODOLOGY

Data collection

The experimental study was performed in the control laboratory for data collection purposes. The target was to acquire brain signals using an EEG device during visual memory's encoding and recognition stages. The raw EEG signals were saved in ASCII format and processed in MATLAB. Another aim was to collect the behavioral data from memory assessment and record it in SPSS software for processing.

Criteria of participants

Participation of subjects in the experimental work was paid as an appreciation for their willingness to join the study. All of them were Electrical Engineering students from Universiti Teknologi Malaysia, Johor Bahru. The total number of subjects was 20, 14 of whom were women and 6 were men, with ages ranging from 19-26. Initially, their health status was determined, and they should be in healthy condition, not have hearing and vision problems, and not experience chronic diseases. In addition, they were also asked to fill out the consent and demographic forms to obtain their basic self-information and permission to join the research.

Visual learning assessment and test environment

This study's memory assessment-based visual learning was altered from Zhang et al., 2009 (22). Their work consists of 15 object-number pairs that need to be memorized by participants in 1 minute. In this work, the images were reduced into 10 object-number paired and need to be remembered within 2 minutes. The memory task consists of objects paired with numbers that come with black, white, and grey colours to hinder the effect of colour on the subject's performance. The assessment was categorized into two parts: easy and difficult. The easy category contains objects paired with two-digit numbers, and the difficult category contains four-digit numbers. The participants were given 2 minutes to memorize the assessment, and a similar duration was also applied to recall the task. The timeline of the experiment is depicted in Figure 1.

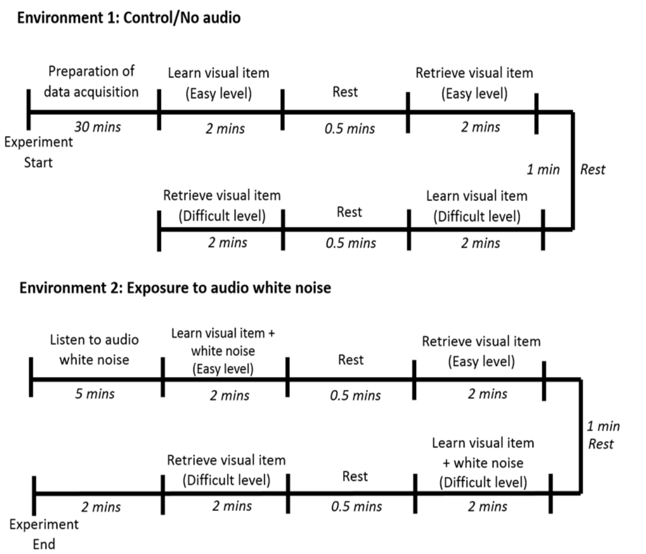

Fig. 1: The timeline of visual learning executes for control and audio white conditions.

The test environments were divided into control without audio presence; the other condition was exposure to white noise during the assessment. The study employed pure white noise that was freely downloaded from the mc2method.org website, which has the potential to benefit visual memory. Generally, white noise is audio produced by combining all audible sound frequencies played at an equal amplitude or intensity. The volume of white noise was adjusted to a moderate level of 40-50 decibels to minimize the effects on hearing. Video making and editing were used to create the assessment and to fix the period between participants. The desktop with the assessment stimulation program was placed 90 centimetres away from participants.

Protocol of EEG data acquisition and experimental procedures

An experiment was conducted in a medical electronic-specific laboratory in the morning around 9 a.m. The participants were asked to arrive 30 minutes earlier before the experiment to fill out the provided form and prepare for data acquisition purposes. Neurofax EEG machine has a cap that applies a 10-20 electrode placement system for brain signal monitoring and acquisition. Before starting, the instructors briefed the experimental flow, and the participants were also asked to minimize their movement to reduce the occurrence of artefacts in brain signals. Figure 2 illustrates the experiment flow for this study. Then, the stimulation program was opened, and participants were asked to execute all the tasks. The EEG monitored the brain signal during the assessment. The EEG monitor was set with 10 mV of sensitivity, 0.3 time constant, 70 Hz internal high-pass filter, and average pattern. The EEG system consists several electrodes of Fp1, Fp2, F7, F3, Fz, F4, F8, T3, T4, T5, T6, C3, C4, P3, O1, O2, and two reference electrodes (mastoid: A1 and A2).

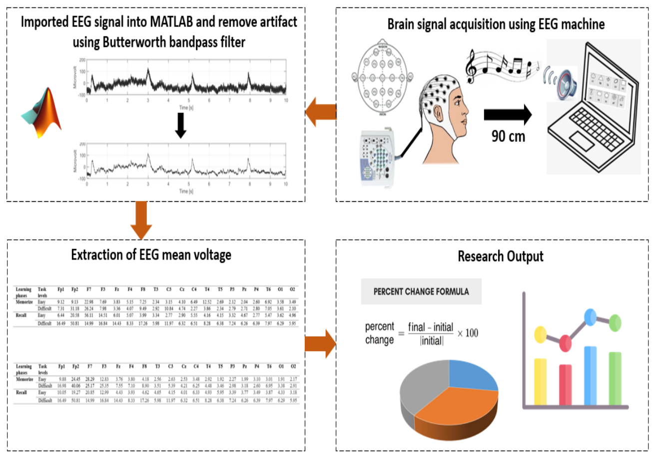

Fig. 2: Architecture of proposed work

EEG Data processing and analysis

The acquired raw EEG signal was sampled at 500 Hz and appropriately saved according to specific types of assessment and circumstances. Then, the EEG dataset was imported and processed using MATLAB software for segmentation, artefact elimination, and feature extraction. The EEG dataset was initially segmented based on the learning phases of remembering and retrieving duration. After that, the artefacts were removed via a Butterworth bandpass filter at 4-45

Hz for all EEG datasets. The used MATLAB code for artefacts removal is "butter(1, [4 45]/(fs/2), 'bandpass')". Throughout this filter, the low-frequency artefacts with a frequency lower than 4 Hz, such as eye movements, and high-frequency artefacts with a frequency higher than 45 Hz, for instance, muscle movement and power line interference, were removed. The last stage was extracting relevant EEG features. In this work, the mean voltage was obtained and analyzed for comparison based on percentage changes. The MATLAB code used for mean voltage extraction is "mean(EEG_Channel??)". The mean voltage was acquired from all 19 EEG channels from each participant and recorded in Microsoft Excel to obtain the average mean voltage value. The differences in mean voltage patterns between the remembering and retrieving processes were discussed based on resulted outcomes.

Behavioral data evaluation

This indicator is used to assess participant's memory of visual information based on the number of items they successfully retrieved. During experimentation, the participants must remember all the visual items within the stipulated period and retrieve the missing number of each object. They must match the pair during the encoding phase to get the mark. If the object-number paired is not matched correctly, it is considered incorrect. If participants retrieved all the numbers correctly with the paired objects, they would earn full marks of ten. Figure 3 shows the example of the answer and how the marks are given. The significant difference in scores was evaluated based on paired samples t-test analysis. The high score achieved by participants indicates better memory performance, whereas poor performance can be seen from low scores. The relation between memory performance and brain responses can be associated with behavioral data to determine the best condition for visual information learning.

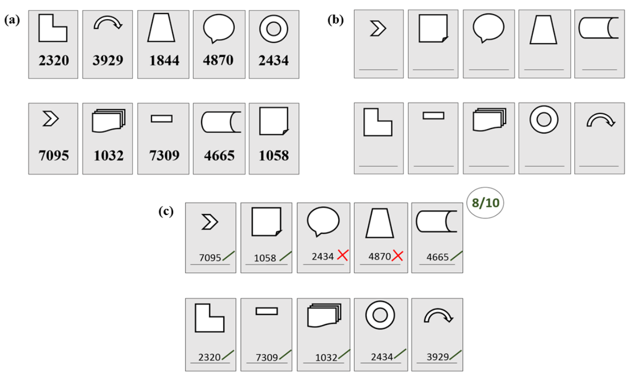

Fig. 3: Example of visual assessment for this study: a) assessment used for encode phase, b) answer sheet used for retrieval phase, and c) score given based on participant responses

ETHICAL CLEARANCE

This research had been registered and approved by the Malaysia National Medical Research Register (NMRR) under Reference No. 21-02365-GVD.

RESULTS

The section described the effect of audio white noise and visual learning on EEG voltage patterns. In addition, the scoring result from the visual assessment was also included to associate with the EEG voltage pattern and revealed the suitable conditions for learning visual information. This work acquired EEG mean voltage as the investigated feature for selecting optimal channels. In certain cases, the researcher may only be interested in the most influenced brain locations instead of focusing on all brain parts to reduce processing and analyzing complexity. Thus, our research aims to mitigate this problem by introducing a simple method to choose optimal channels from EEG voltage. Patterns of EEG voltage were discussed based on tested environments and visual assessment difficulty.

EEG voltage pattern for control test environment

The finding in Table I showed that the frontal (F) channel obtained the highest mean voltage compared to other channel locations for encoding and recognition periods. The highest mean voltage was observed from the F7 channel (easy level: 22.98 mV) and Fp2 channel (difficult level: 31.18 mV) for the recognition period of the control condition. The most exciting part was that the pattern of both phases was similar. For the recognition phase, the high mean voltage was found at F7 (56.11 mV) and Fp2 (40.06 mV) channels for easy and difficult levels, respectively.

Generally, the F7 location refers to verbal expression, whereas the Fp2 location represents judgment. In this regard, it indicated that the participants imagined the assessment in the verbal illustration to aid them in encoding and recognizing the visual information. Increasing task difficulty had raised the judgment on assessment. This happened because the participants needed to discern how to match the images with their respective digit numbers. Focusing on the visual learning phase, the results showed that the recognition period's mean voltage was higher than the encoded phase for all EEG channels. Therefore, it revealed that the brain worked actively in the recognition phase rather than encoded phases for both task difficulties. The possible reason is the increased visual information that needs to be encoded and recognized. According to the analysis, the percentage change among the phases of the easy assessment category was 37%, and for the difficult assessment, it was 31%.

The F3 and F4 are related to motor planning and are responsible for organizing the body's actions to determine the steps taken and the required action needed to complete a particular task. The mean voltage of F3 channels was a bit higher for the recognition phase because the participant needed more action for retrieving visual information than in the encoded phase. However, different variations can be found for F4 channels. Based on the analysis, it can be remarked that the frontal brain location was the most affected for visual information learning under control/no audio condition as stated in Libedinsky and Livingstone., 2011 (23) work. It reflects high brain activities involved in this brain location. It may be associated with frontal brain location executive functions related to memory storage, judgment, and managing thinking, which is included in this work.

The other brain locations mostly yielded a mean voltage below 10 mV. It indicates that the brain activities at the temporal, parietal, occipital, and central levels were fair to each other in the tested conditions. Referring to temporal location, it is seen that the T6 channel achieves a high mean voltage compared to others that are associated with motivation and emotional understanding. This indicates the participant may feel motivated and interested in the provided assessment. Compared between the encoded and recognition phases, the mean voltage was high for encoded, reflecting their mood and emotion, which increased during remembering rather than retrieving the visual information. Then, the central part of the brain location is usually related to mobility and noises during EEG acquisition. The values were less evident than others, revealing that the filtering method efficiently removed noises in EEG signals.

Focusing on the occipital location, which is significant for visual processing, it was observed that the EEG mean voltage was higher during the recognition phase compared to the encoding phase (24). The possible reason was that during recognition, the occipital location is more active in processing the information because they need to retrieve it. The brain must work hard in certain situations to recall the encoded information. Although the occipital location is responsible for visual processing, the frontal location acquired high mean voltage, which could be because it plays a vital role in this work. The cause of the high mean voltage may be the participant's need to interpret the given assessment because it was present in objects and numbers, which involved further understanding of the learning items. Therefore, it increased brain activities at the frontal location. The final location was the parietal, which exhibits the lowest mean voltage, below 5 mV. The parietal location is usually highly activated when a high cognitive assessment is provided. Since this work only involved memory assessment, brain activity was relatively low because it did not involve complex information processing and analysis. Based on the EEG mean voltage pattern, it can be stated that learning visual information in a controlled environment causes different brain activities at other locations.

EEG voltage pattern for exposure of audio white noise

The effect of audio white noise on the visual learning of this study is depicted in Table II. Among the channels, the frontal (F) location was the most influential for this test environment. As described earlier, a similar influence was also found for the control environment. Thus, it revealed that the high responses of brain activities were detected in the frontal part of the brain for both environments. High EEG mean voltage was found at F3, F7, Fp1, and Fp2. Encode and recognition of easy category assessment caused high mean voltage at the F7 location with values of 28.29 mV and 20.85 mV, respectively. However, the difficult assessment category caused a high value at the Fp2 location for both encode 40.06 mV and recognition phases 50.81 mV. A similar trend pattern was found for audio white noise in control conditions, in which the Fp2 and F7 locations were the most influential regarding judgment and verbal expression.

Focusing on other brain locations showed that the mean value was mostly below 10 mV. It indicates the brain activities at temporal, parietal, occipital, and central locations were almost similar during visual assessment under exposure to audio white noise. Among them, the difficulty level of the recognition phase yields a high mean voltage compared to others, which could be due to the brain's need to work hard to retrieve the information. The participant may have felt challenged and burdened to retrieve the encoded items for difficult

Table I: EEG mean voltage (millivolts) for control condition at different learning phases and task levels

Learning phases	Task levels	Fp1	Fp2	F7	F3	Fz	F4	F8	T3	T4	T5	T6	C3	Cz	C4	P3	Pz	P4	O1	O2
Encode	Easy	9.12	9.13	22.98	7.69	3.83	5.15	7.25	2.34	12.52	2.69	6.92	3.15	4.10	6.49	2.12	2.04	2.60	3.58	3.49
	Difficult	7.31	31.18	26.24	7.98	3.36	4.07	9.49	2.92	3.86	2.34	7.05	10.84	4.74	2.27	2.79	2.71	2.80	3.61	2.10
Recognition	Easy	6.44	20.58	56.11	14.51	6.01	5.07	3.99	3.34	4.16	4.15	5.47	2.77	2.90	5.55	3.32	4.67	2.77	3.62	4.96
	Difficult	16.98	40.06	25.17	25.35	7.55	7.10	8.90	3.51	4.48	3.46	6.95	5.39	4.21	6.25	2.98	3.18	2.60	3.38	2.91

Table II: EEG mean voltage (millivolts) for audio white noise condition at different learning phases and task levels

Learning phases	Task levels	Fp1	Fp2	F7	F3	Fz	F4	F8	T3	T4	T5	T6	C3	Cz	C4	P3	Pz	P4	O1	O2
Encode	Easy	9.88	24.45	28.29	12.83	3.77	3.80	4.18	2.56	2.92	1.92	3.01	2.63	2.53	3.48	2.27	1.99	3.10	1.91	2.17
	Difficult	16.98	40.06	25.17	25.35	7.55	7.10	8.90	3.51	4.48	3.46	6.95	5.39	4.21	6.25	2.98	3.18	2.60	3.38	2.91
Recognition	Easy	10.05	19.27	20.85	12.99	4.43	3.93	4.62	4.65	4.93	5.95	3.87	4.15	4.01	6.33	3.39	3.77	3.49	4.33	3.18
	Difficult	16.49	50.81	14.99	16.84	14.43	8.33	17.26	5.98	8.28	6.38	7.97	11.97	6.32	6.51	7.24	6.26	6.39	6.29	5.95

level assessment, which caused an increase in brain activities. The lowest mean value was observed at the O2 location. Although the occipital region was responsible for visual processing, both occipital (O1 and O2) locations exhibit lower mean values than frontal. The frontal location also plays a significant role in this case, where the possible cause is that the visual information interpretation has dominantly occurred during assessment. The participants may interpret the visual information into something they can easily remember. Besides, the mean value at temporal, occipital, parietal, and central was higher during recognition than encode phases. It revealed that brain activities were more active at these locations while visual information was retrieved.

From the assessment difficulty point of view, the rise and lessen of the mean voltage pattern was dissimilar to the control environment, where the difficult assessment category obtained high mean voltage for all brain locations. Besides, the F7 location for both learning phases yielded EEG mean voltage lowered for the difficult assessment category than the easy level. Therefore, it showed that exposure to audio white noise reduced verbal expression. Nevertheless, the other brain locations exhibited high mean voltage for the difficult assessment category. It showed that the brain needs to work actively due to the many images needing memorization. The change in percentage between encoding and recognition of audio white noise for the easy and difficult assessment categories was 9% and 25%, respectively.

The control and audio white noise conditions were compared based on the total value EEG voltage in Figure 4. The encoding phase of audio white noise was higher than the control condition, with a percentage difference of 0.4 % and 24 % for easy and difficult assessment levels, respectively. The difference was higher for difficult level assessments. Meanwhile, difference variation and pattern were found for recognition phases, where easy level control conditions exhibited a higher mean value of about 20 % than audio white noise. However, the difficult assessment level yields a higher mean value in the audio white noise condition of about 20 % percentage difference. The factors that cause the variation come from different learning phases and the difficulty of assessment. Hence, it can be remarked that the learning environment, types of learning information, and task difficulty can influence brain activities.

Behavioural Results and Its Relationship with Brain Activity based EEG Mean Voltage

The scoring results of the visual memory assessment are depicted in Table III. It showed that the easy level assessment obtained better mean correctness than the difficult level assessment. It may occur because of the different number of images required to remember between easy and difficult levels. Increasing the number of items to be remembered will decrease participants' memory performance. From the test environment perspective, the encoding and recognition abilities were improvised when exposed to audio white noise rather than without audio for both assessment categories.

Table III: Behavioral data of easy and difficult level assessment under control and audio white noise conditions

Learning environment	Average score	Standard deviation	*t*-value	*p*-value
Easy level assessment				
Control	7.3	2.4	-2.463	0.101
Audio white noise	8.8	2.18		Non-significant
Difficult level assessment				
Control	3.35	2.03	-1.726	0.024
Audio white noise	4.45	1.56		Significant

Paired sample t-test analysis yielded a t-value of -2.463 and a p-value of 0.101 for the easy level assessment. No effect was observed in the scoring results of either environment. In contrast, the outcome of the difficult level assessment showed a significant impact for both environments, with a t-value of -1.726 and a p-value of 0.024. Hence, it confirms that the audio white noise had the potential to improve visual memory positively, mainly for difficult level assessment. The conjecture for this improvement was because of the stochastic resonance effect when exposed to audio white noise. The stochastic resonance effect from audio white noise benefit memory performance had been proved by Soderlund et al., 2020 (25), Angwin et al., 2017 (26), and Jain and Wagani, 2019 (27). Obstructing distractions will improve participants' alertness and attention levels (28,29). This is demonstrated by hypersynchrony in the frontal brain lobe, which is linked to attention state and working memory.

Referring to behavioral data and EEG voltage pattern of total mean value, the brain activities during encoding

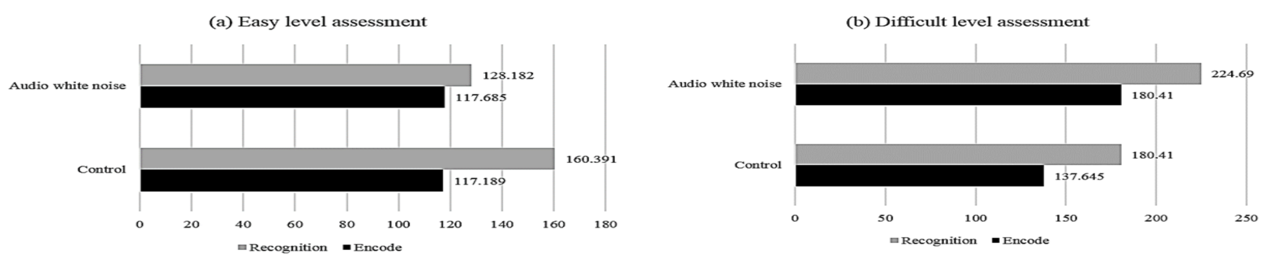

Fig. 4: Total mean voltage of EEG from 19 channels for easy and difficult level assessment under control and audio white noise conditions

visual memory increased when audio white noise was exposed. This occurs because the brain needs to work extra to filter the coming white noise during the remembering or encoding phase. In contrast, the mean voltage of the control condition was lower because no additional disturbance was added during the encoded phase. From here, it can be stated that the increased brain activities from the additional disturbance of audio white noise had improved the visual information encoded and registered in the brain. The behavioral data shows that the score was better under audio white noise than the control condition, indicating more successful information was encoded.

Meanwhile, different mean voltage patterns were observed for the recognition phase with behavioral data. The participants were retrieving the visual information in no audio, which was believed to be an unexpected pattern. The mean voltage of control conditions was high for easy level assessment, whereas, for difficult level assessment, the audio white noise yielded a high mean voltage. Concerning behavioral data, the brain does not need to work hard to retrieve visual information successfully at an easy level. However, increasing task difficulty requires the brain to retrieve the information correctly. This work shows that the learning environment plays a significant role in successfully processing visual information in the brain and retrieving it accordingly.

DISCUSSION

Audio white noise is among the potential stimuli for improving learning abilities. Nevertheless, numerous published works focus on the effect based only on behavioural results. The limitation of depending on this indicator is that its association with body responses cannot be investigated. The body reacts differently to each stimulus, and this unique response can be discovered to see the difference. This recent work found the pattern of EEG voltage that can reflect brain activities during the assessment. Unlike the previous study, the EEG signal was recorded from two learning phases: encoding and recognition. Brain responses were compared, and their relation to behavioral data was discussed.

Throughout the analysis, the EEG channels at locations F7 and Fp2 showed the highest mean voltage for both learning phases with values between 20 and 50 µV. These brain locations are associated with verbal expression and judgement. The possible reason for this channel activation is that the participants need to give judgment for each object and number in the assessment, and they also try to express the items verbally to ease remembering and recognition. The difficult level of assessment yields a higher EEG voltage than the easy level because the brain is required to operate actively to process the input information. Therefore, it increases brain activities.

The most influential brain region was the frontal lobe tested condition, which manages voluntary movement, expressive language, and high-level executive function. The trend pattern of audio white noise stimulation was almost similar to the control condition. The total EEG voltage showed that the value was lowered for audio white noise during the remembering phase. It revealed that the brain is not required to operate hard enough to process visual information under audio white noise exposure successfully.

CONCLUSION

The proposed work successfully investigated the effect of audio white noise on visual memory based on the EEG voltage feature. The behavioural results were used as a second indicator to determine the participant's performance under different test environments and associated with EEG voltage patterns. The analysis found that the Fp2 and F7 locations were the most affected, with ranges between 9 to 50 µV and 20 to 60 µV, respectively. These channel locations were associated with judgment and verbal expression. The rise and drop of the EEG mean voltage pattern was similar in control and audio white noise conditions. Besides, the difficult level assessment yielded a higher EEG mean voltage than the easy assessment. Therefore, it indicated that the brain activities were raised when remembering and recalling the visual information of the difficult level assessment. The brain must operate actively in the recognition rather than the encoded phase. Referring to behavioural data, it was found that the participants can encode and recognize superior under exposure to audio white noise. The mean correctness of the easy assessment category was 8.8, and the difficult assessment category was 4.45 compared to no audio, with the mean correctness of the easy level being 7.3 and the difficult level being 3.35. Hence, this study suggested that people listen to audio white noise while executing visual assessment to improve their memory performance. In addition, future work can also focus on extracting more features from frontal brain location to deeply understand brain activities as it is the most affected for visual learning information to save processing time.

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