ORIGINAL ARTICLE

Evaluation of Emotional State and Memory Performance Under Exposure of Different Music Genres Based Eeg on Power Spectral Density and Mean Frequency Band

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ABSTRACT

Introduction: Human mental and emotional states can be stimulated through various factors. Music engagement is among the stimulus that can affect and is easily practiced. However, confirming an efficient music genre is still unclear and needs further investigation. This study explores the effect of various music genres on mental and emotional states, specifically examining their impact on working memory through electroencephalography (EEG) measurements. **Materials and Methods:** With over 5000 EEG samples collected from 30 participants, the research focuses on power spectral density (PSD) in the alpha and beta frequency bands at brain regions P3, Pz, and P4. Each participant engaged in memory assessments under different music conditions: classical, jazz, rock, club electronic, and silence. **Results:** The findings show that classical music significantly enhances calmness, reduces stress, and improves memory recall, with the highest alpha PSD associated with relaxation recorded in classical music sessions. In contrast, rock and club electronic music yielded the lowest memory performance, likely due to their stimulating nature, which increased stress and hindered focus. The data also indicate that beta PSD, linked to alertness and focus, spikes under challenging conditions, especially with rock music, suggesting increased cognitive load. Conversely, jazz and classical music facilitated a relaxed state conducive to better memory recall, reflected in both behavioral and EEG data. **Conclusion:** In summary, classical music emerges as the optimal genre for improving mental relaxation and memory retention, while high-stimulus genres like rock appear to impair working memory in learning contexts.
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INTRODUCTION

Mental stress loaded the person with mental tension and worry caused by a struggle situation. The person who experiences stress is unable to relax and concentrate as well as will feel a range of emotions, such as irritability and anxiety. The common symptoms of stress are headaches, upset stomach, other body pains, and trouble sleeping. Mental stress is a natural human response that encourages us to deal with threats and challenges (1). The person's reactions toward stress will significantly affect overall well-being. Stress affects both the body and mind, and a little stress is necessary to aid us in performing daily activities effectively. However, too much stress causes mental and physical health problems. Discovery of a suitable method to release and minimize stress can help people feel less overwhelmed and improve their physical and psychological well-being. Several techniques can be practiced to release stress during leisure activities and professional work, such as applying aromatherapy, exercising regularly, practicing mindfulness meditation, eating healthy and well-balanced meals, etc.

There is strong evidence that mental stress has a crucial effect on learning. For instance, it has been found that the memory recall can be affected by stress. Shields et al. (2017) state that most students struggle to recall information during evaluation in stressful circumstances (2). Until recently, the impact of mental stress on the process of encoding information is controversial. Some researchers claimed that stress enhances memory functions (3), whereas others stated stress improves memory encoding (4). Nevertheless, it is troublesome to determine the factors that are liable for the reported discrepancies. It was found that stress can be a positive stimulator when the person can control it, but it becomes a negative factor when the situation cannot be handled. Hence, it can be remarked that moderate stress is required to enhance memory and learning. Chronic and excessive stress have negative impacts on learning. Stress at high levels can impair attention, cognitive function, and memory retrieval, contributing to difficulties in attentional level, information processing, and gaining knowledge (5,6). These impacts led to a degradation of cognitive and physical performance.

Mental healing through music exposure is a common strategy to manage stress during learning, leisure activities, or other professional work (7). The problem with existing studies is that the association between mental stress and working memory performance under music is still unclear and inconclusive. The researchers report contrasting findings. Particular work found that music had beneficial effect on emotional and memory performance (8–11), whereas some reported that it had negative or null effect (12–14). Researchers discovered that mental stress or any stimulation of the human body triggers brain activity (15). Assessment of brain responses toward stimulation is challenging because each individual suffers stress differently. Other than that, the reliability of assessing their effect relies on the method of assessment and analysis. Traditionally, the impact of mental stress and other stimulation on humans has been evaluated using subjective methods through self-report questionnaires. The limitation of using this method is inaccurate responses from participant because not always aware to response. In addition, this method is also less informative than physiological measures.

Very few studies had used both physiological and subjective methods for mental loaded with music and memory assessment. The combination of this measuring method will increase the experiment's reliability and accuracy and can be synergetic to each other. It can reveal the interrelation between body responses and mental and emotional states during music engagement. This recent work used both methods to acquire responses from participants and the brain signals. Hence, the relation between indicators and detailed explanation of their effect can be investigated. Monitoring brain responses using EEG is among of the well-known physiological technique that had been practiced, since this technique easy to be implement, non-painful and harmless to participants. Numerous features can be extracted from EEG signals such as mean, median, standard deviation, skewness, kurtosis, peak amplitude, Hjorth parameters, and energy (16). This work preferred to extract power spectral density and mean frequency band. The main reason of acquired these features are because of it non-complex to be understand and implement in Matlab. Besides, it also proficient for discover the brain responses changes because of stimulation. Hence, this recent work select the power spectral density and mean frequency band as indicator to be associated with memory scores to discover effect of music on memory performance.

MATERIALS AND METHODS

Experimental set-up

The method and procedure applied in this experiment were approved by the Malaysian National Medical Research Register (NMRR) with Registration No. 21-02365-GVD. The experiment was carried out in a controlled laboratory under the observation of the laboratory assistant.

The selection of subjects was based on interview responses. The subjects should be in good health, free from psychoactive drugs and neurological symptoms, and have normal hearing and vision. Thirty subjects were chosen to participate, 15 of whom were females, and the others were males (17,18). Their ages were between 19 to 25 years old. First, each subject must complete a consent form and provide demographic information. After that, the subjects were requested to sit on a non-conducting comfortable chair in front of a computer monitor consisting of the desired assessment. The subjects were worn with an EEG scalp comprising nineteen electrodes for brain signal acquisition, and the baseline of EEG data was acquired for 5 minutes. The EEG-9100A/G/J/K (Nihon Kohden, Tokyo, Japan) model with a sampling frequency of 500 hertz was employed to monitor and record the EEG data. This EEG device model's acquisition system must be set before recording the brain signal. The acquired EEG data was stored on another computer for offline analysis.

The flow of experiment and EEG data monitoring

Before the signal acquisition, the subjects were instructed to relax, control the blinking and movement of their eyes, and reduce their body movement to avoid excessive artifacts contaminating the EEG signal. The brain signals were acquired based on the international standard of a 10-20 electrode placement system. The additional electrodes of A1 and A2 were mounted at the right and left ears of the subjects as references to active electrodes. The acquired EEG signals were converted into ASCII format to be processed using Fast Fourier Transform. At first, the subjects were given explanations about the process involved in the experiment. The subjects need to execute memory assessments for two levels of difficulties. The main aim of implementing different degrees of difficulties for memory assessment was to load and burden the brain to process the input information. This will also cause light stress because the subjects need to remember a list of words in a stipulated duration while listening to certain music. Throughout this assessment, the most suitable music genre can be determined for releasing stress and improving memory performance. The music was exposed to the subject through headphones, and the list of words was played from a video, as shown in Figure 1.

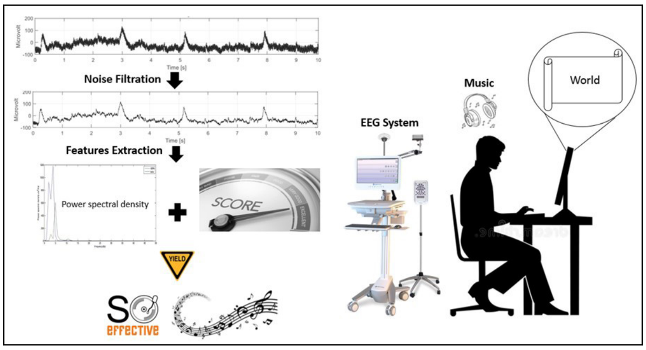

Figure 1: Architecture of proposed research regarding the effect of music genre on emotional and mental performance based on brain responses and behavioral data measurements

After the subject is ready, a video is played from a computer monitor in front of the subject, and Task 1 of the level memory assessment is started immediately. The subjects must remember all the words provided within a minute of the video. The time interval of each word was 6 seconds. After that, the subjects were instructed to sit in silence and recall the memorized words for a minute. Later, the subjects were allowed to write down as many words as possible on blank paper as had been recalled within a minute. The subjects can randomly write the words and are not required to list the words in a sequence as presented in the video. Before continuing to the next part of the experiment, the subjects were given one minute to rest and relax. Then, the experiment was carried out by changing from silence into listening to background music condition during the memorization and recollection periods for one minute (Sumarti et al., 2023). The music genre was varied into Jazz (Love Me or Leave Me), Classical (Bach's Cello Suites), Rock (Afterlife), and Club Electronics (Crackin). These types of music was selected because it met the criteria for this experiment that aim to use various genres. Beside, these music genre also well-known among user to be listened during doing their daily activities. Thus, it suitable to be tested the effectiveness for memory. Lyrics (singer voice) composed with the music was filtered, where only the music was used in experiment. This avoid the effect of lyrics and language on memory performance. After finishing all five sessions of the experiment for Task 1, the subjects were given half an hour to rest and regain their energy before continuing to Task 2 of the difficult task. Task 1 consists of 10 words, Task 2 consists of 15 words, and the time interval of each word is 4 seconds. The time frame of the experiment is shown in Figure 2. In summary, this figure shows the transition from Task 1 and Task 2 with the time allocation for the five (5) conditions set and the interval time given to each subject.

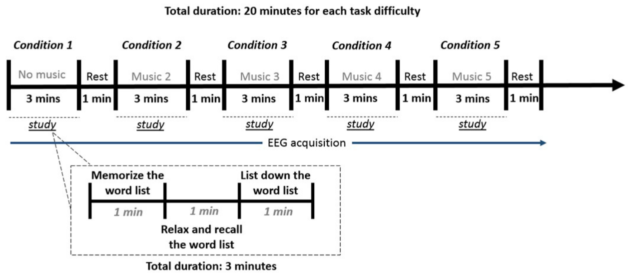

Figure 2: Timeframe of the experiment

Behavioral data processing

The total number of recalled words was calculated for each subject and part of the experiment sessions. It began by grouping the answer sheet from the subjects into the same types of music: silent, Jazz, classical, rock, and club electronics. Then, the total number of the correct recall words was calculated to observe which type of music gives the highest number of recall words. The results were kept in Microsoft Excel for further analysis with EEG signals to find their correlation.

EEG signal processing

Three steps in analyzing EEG data were employed to achieve the research objectives: brain signal acquisition during the experimental session, noise filtration from raw EEG signal, and feature extraction. The raw brain signal acquired from the EEG device was converted into ASCII format for further processing with MATLAB software. Then, the pre-processing stage was done by selecting the related EEG channel electrode using a simple MATLAB command. In this project, the electrodes were focused only on P3, P4, and Pz as these channel locations represent human beings' resting state and calming mind. In addition, the desired EEG data segment that needs to be analyzed is also determined. It had been found that the segment of 10 seconds was analyzed.

These selected channels was then filtered with Wavelet 1-Dimensional denoising through soft-thresholding technique to remove the unnecessary component from signals. The wavelet filter toolbox-based Discrete Wavelet Transform (DWT) was set into Daubechies mother wavelet order 4 (db 4) with eight decomposition levels for filtration. The Db4 was chosen due to its ability to process the EEG signal and decompose until level 8. Matlab command of "wmaxlev" was used to determine the maximum wavelet decomposition level to avoid unreasonable maximum level values. Meanwhile, the command "wden" was applied to help automatically denoise the EEG signals using a wavelet. After that, the denoise EEG signals were imported into different folders for further extraction of features. Two features extracted from EEG signals are the power spectral density of alpha and beta frequency bands and the mean alpha band. The Fast Fourier Transform processed the denoise EEG signals to yield power spectral distribution. The compute frequency domain of EEG signals contains several brain frequency bands of beta, alpha, theta, gamma, and delta (Gannouni et al., 2021). However, only alpha (8 – 12 Hz) and beta (13 – 30 Hz) bands were chosen because this work involves the participant memorizing, recalling, thinking, and relaxing (19). The theta and delta bands were unsuitable because related to dreaming and fall-asleep states that were impossible and rarely occurred. The gamma band is also neglected because music listening does not involve a planning mechanism that is related to this band. The PSD of alpha and beta bands was obtained from P3, P4, and Pz. The mean alpha value was acquired from the EEG signal processed through DWT at level D7. The other D1, D2, D3, and D4 coefficients represent the noises, whereas D5 and D6 reflect the gamma and beta bands. D8 represents the theta band, and A8 is composed of a low frequency of the delta band. The signal from level D7 was processed to obtain the mean value. The aim was to identify the working memory performance of the subjects in memorizing the word lists while listening to music.

RESULTS

Behavioral data

The score from the assessment was grouped into two categories: easy level (Assessment 1) and difficult level (Assessment 2). Throughout this indicator, the types of music that help the subjects learn the visual assessment better and feel more relaxed can be discovered. Figure 3 showed that the average score of subjects was the highest for Classical music. The subjects earned high scores for both task difficulties, 23%. However, the difficult level assessment score depicted the Jazz genre obtained at 23%. It showed both of these genres succeeded in improving visual working memory performance. However, Jazz music showed a slightly lower score of 21% for the easy level than Classical music. Thus, classical music was the most efficient way to learn visual memory assessment. The next highest average score was followed by silent (no audio), club electronics, and rock genres. The sequence of effectiveness was ranging in descending manner from classical, to Jazz, to silent , to club electronics, and finally the rock music. The lowest score was found in rock music for both task difficulties, yielding a 16% percentage of correctness.

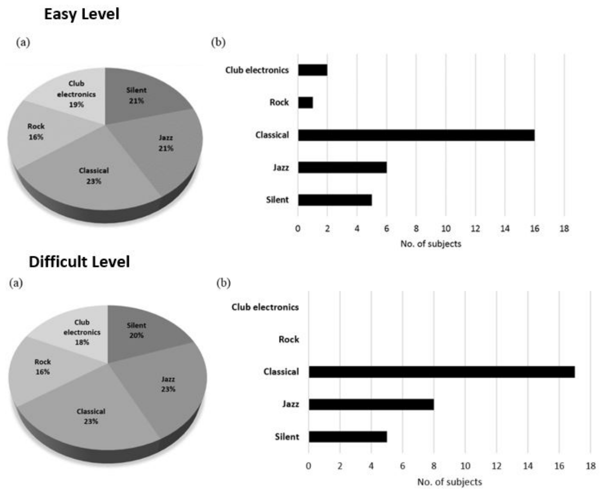

Figure 3: Assessment score for different music genres: (a) Percentage correctness and (b) total number of subjects that scored highest of recall words

This work also determines the total number of subjects who scored high during the recalling session to confirm the optimal learning condition based on music. There was a slight difference in the average score between the music genres. Both task difficulties showed that most subjects perform better in learning visual memory when listening to Classical music. More than half of subjects obtained the highest score, full marks for both difficulties in Classical music. Jazz music scored second highest, followed by silent, club electronics, and rock. There was a big difference between Classical and Jazz music. The difference was 63% for easy and 53% for difficult levels. Based on the graph in Figure 3, listening to Classical and Jazz music led to increased subjects acquiring high marks when difficult assessment was provided. It revealed that both types of music improve visual working memory. However, for no audio condition, the number of subjects who obtained high scores was reduced from 6 people to 5 people only. Similar findings were also shown for club electronics and rock music, where none of the subjects had high scores under difficult assessments. The decrement indicates that the no audio condition, Club Electronics, and rock were not efficiently listened to during visual memory learning. This proved that soft, calm, and relaxed music permits subjects to focus better than hard and without any music.

Pattern of power spectrum density of alpha and beta frequency bands

The PSD values of alpha and beta bands at P3, Pz, and P4 channels from 30 subjects were taken and averaged to observe their pattern. Based on Figure 4, the PSD of alpha was found to be higher for classical music, followed by Jazz music and silent conditions for the selected electrode channels. The highest PSD of alpha was seen from the Pz channel for both difficulties. This channel is related to cognitive processing, which is the most essential part of this work. It reveals alpha oscillation mainly occurred at the Pz location when listening to classical music. A similar pattern was also observed for Jazz music and silent conditions. However, rock music showed the highest alpha PSD at the P3 channel, associated with cognitive processing for verbal reasoning. The club electronic had high alpha PSD at the P4 location for the easy level and the P3 location for the difficult level. The PSD of alpha for all types of music was decreased for most channels for difficult tasks compared to easy levels. This could be because the subjects' performance decreased as the task became more difficult. Due to the increased loaded information in the brain, the subjects could not relax, which led to improve their performance much harder during the difficult level assessment. The total PSD of alpha for all music genres in easy and difficult assessment was depicted in Table 1.

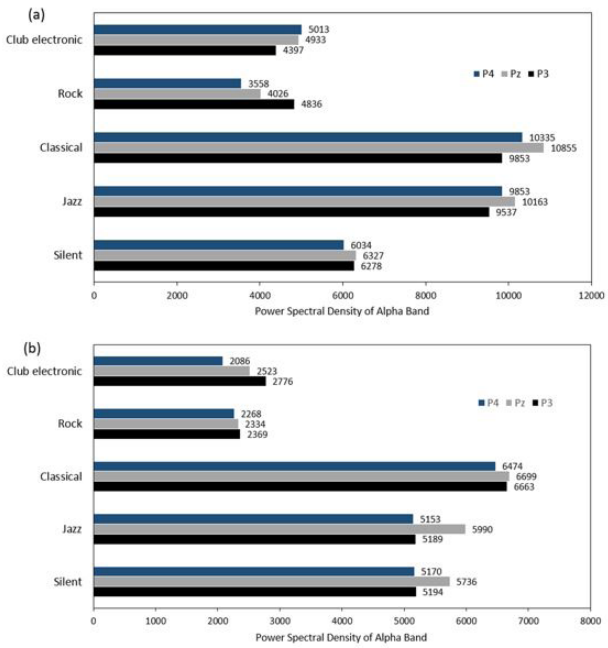

Figure 4: Power spectral density of alpha band at P3, Pz, and P4 electrodes for different task difficulties: (a) easy level and (b) difficult level

Table I : Total PSD from selected channels at different task difficulties and music genres

	Silent	Jazz	Classical	Rock	Club electronic
Total PSD of Alpha Band					
Easy level	18639	29553	31043	12420	14343
Difficult level	16100	16332	19836	6971	7385
Total PSD of Beta Band					
Easy level	10701	10438	14967	8689	7906
Difficult level	8476	7768	6735	16562	9721

Generally, the alpha band represents relaxed awareness without attention and concentration. A high value of PSD of alpha represents the subjects in a calm state while assessing the provided condition. The total PSD of alpha showed that classical music yields the highest value, followed by Jazz, silent/no audio condition, club electronic, and rock. These results reflected that music genre affected the pattern of alpha's PSD. Music's attributes play a prominent role in influencing the state of subjects. The subjects were more relaxed and enjoyed when listening to Classical music compared to other conditions. The second choice of music genre that can be listened to during learning was Jazz, as its PSD value was not much different from Classical music. The lowest total PSD of alpha was observed from rock and club electronic. Their difference was significant with the classical music. This could be due to subjects feeling disturbed by these genres that are loud, overwhelming, and unpleasant to listen. Another interesting finding is that the silent/no audio condition also exhibits low PSD of alpha. It revealed that the subjects may feel disturbed under this condition. The presence of specific audio stimulation can help to be more relaxed. Therefore, it can be remarked that classical and jazz music was suitable for listening to to increase subjects' relaxation during assessment.

Beta oscillation represents active thinking, high wakefulness, alertness, and focus. High PSD of the beta band indicates high alertness, focus, and thinking of subjects toward the assessment. The rise and drop pattern of the PSD of the beta band was a little bit different from the PSD of the alpha band. The highest PSD was found at the P3 channel for classical music in easy level assessment and the Pz channel for rock music in difficult level. The P3, Pz, and P4 channels showed the highest for rock music of difficult level assessment. It showed that the subjects need to give high focus, alertness, and thinking due to increased task difficulties and the presence of rock music. The subjects need to filter out the disturbance caused by rock music to execute the actual assessment. This condition is either good or bad, depending on a person's capability to divide the task correctly. Meanwhile, Classical music led to a decrement in PSD for difficult level assessment. However, the trend was not in line with classical. This occurred due to different levels of alertness, focus, and thinking the subjects gave during this assessment. Listening to rock music yields the lowest PSD value at channel Pz for the easy level and the highest value for the difficult level. Pz location is associated with cognitive processing and plays a main role in successfully processing visual items in the brain. Concerning score assessment, it was found that the rock music caused poor performance. This could be associated with the pattern of Pz location.

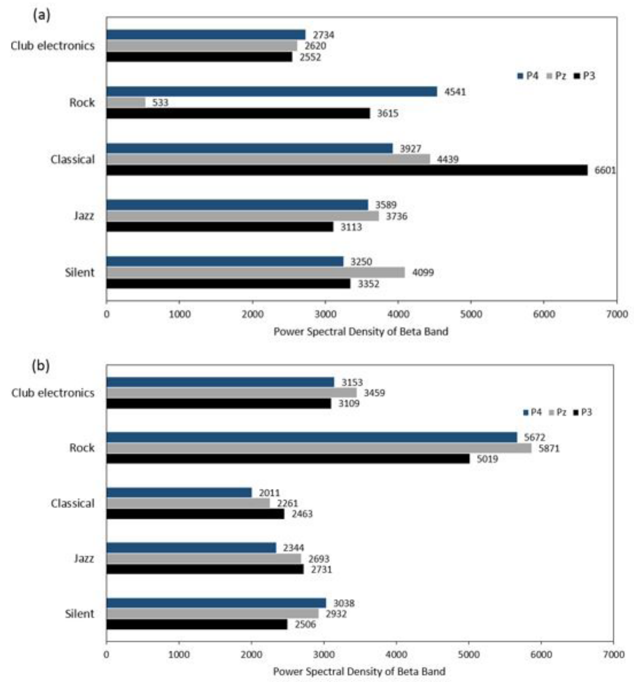

Figure 5: Power spectral density of beta band at P3, Pz, and P4 electrodes for different task difficulties: (a) easy level and (b) difficult level

Referring to Table 1, the total value from three selected channels demonstrated that classical music was the highest for the easy level. In contrast, Rock music showed the highest for the difficult level. The potential reason for this pattern was that beta oscillation was found during this music. It indicated the subjects needed extra focus, alertness, and thinking during this condition. Their brain must work hard to learn and process visual information while also needing to filter the disturbance from added music. The provided music improves or lowers performance, depending on how the brain processes the stimuli. Therefore, the alpha mean value was extracted to determine the exact effect and correlation of music genre with visual performance.

Evaluation of the alpha mean value

Figure 6 depicts the alpha mean value for different music genres of easy and difficult level assessment. According to Tumari et al., (20), a higher mean value indicated lower working memory during the study. The trend pattern of both assessment difficulties was similar, where the high alpha mean value was observed from rock music. Meanwhile, the lowest value comes from classical music. The sequence of alpha mean value from lowest to highest was Classical, Jazz, Silent, Club Electronics, and Rock is the highest. The alpha mean value for each music genre can be referred in Figure 6. This sequence was similar to the behavioral data discussed before. Therefore, there was a correlation between the alpha mean value and the assessment score. Decreasing the alpha mean value represents better retrieval of visual information. This indicates that the subjects have an excellent working memory while learning visual information. Meanwhile, the subjects have a poor working memory while learning rock and club electronic music. It was already expected that upbeat songs lead to a low working memory of the learning process. The loudness and disturbing hard clanking sound from the drum and guitar may affect the learning performance as the music increases the stress and headache in the subjects.

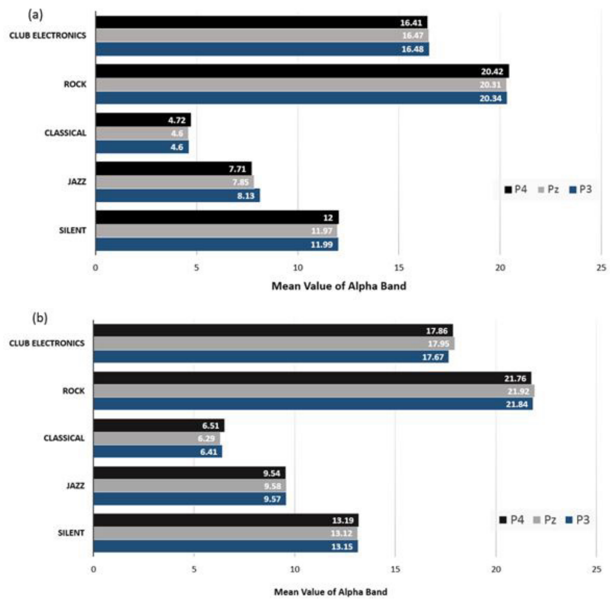

Figure 6: Alpha mean value at P3, Pz, and P4 electrodes for different task difficulties: (a) easy level and (b) difficult level

DISCUSSION

The research methodology was carefully structured to investigate how different music genres influence working memory through EEG signal analysis. By including diverse music genres, the study aimed to capture a range of emotional and cognitive responses that might impact working memory. EEG data were collected from electrodes placed on P3, Pz, and P4 brain regions, associated with memory and relaxation. The power spectral density (PSD) values for alpha and beta frequency bands were calculated to determine participants' relaxation and focus levels. Alpha PSD, which correlates with calmness, was consistently higher in classical music sessions, suggesting a reduction in stress and improved memory retention. Conversely, rock and club electronic music produced lower alpha PSD values, correlating with a more stressful cognitive state. Beta PSD, reflecting alertness and cognitive load, was particularly high in rock music sessions during more difficult tasks. This finding suggests that stimulating genres like rock music may increase mental strain and interfere with memory performance. The increase/decrease in mental strain and inteference to the memory performany of any music genre was always compared to the control condition (silence). The overall methodology proved robust in capturing cognitive responses across music genres, integrating both subjective (recall performance) and objective (EEG data) measures. The results consistently indicated that classical music facilitated an optimal environment for memory recall, likely due to its calming effects, whereas rock music, with its more intense rhythm and structure, often disrupted cognitive performance by inducing a heightened alert state. The study's combined use of EEG and behavioral data is a notable strength, providing insights into the physiological and psychological impacts of music on memory. These findings contribute to a deeper understanding of music's role in cognitive function and suggest practical applications in educational and therapeutic settings where cognitive performance and relaxation are critical.

CONCLUSION

This work focused on the effects of different music genres on visual learning. Brain activities were acquired using an EEG device and processed via a wavelet-based method. The features of PSD for alpha and beta frequency bands were obtained to observe the level of relaxation or stress of the subjects when listening to certain music. It can be remarked from this project. Alpha and beta waves have existed during the measurement of EEG signals. Throughout the analysis, it was proven that classical music aids the most visual learning. Meanwhile, upbeat music, such as rock and electronic club, caused poor visual information processing. Classical music is one of the best; it helps reduce stress and increase relaxation. This can be proven from alpha PSD, where the highest value was found for both task difficulties. The behavioral result aligned with the alpha mean value, where the subjects scored excellent in the classical music condition. The lowest score was observed for rock and club electronic music. The alpha mean for classical music was the lowest, indicating an excellent working memory. Meanwhile, rock music is the worst for relaxing and focusing during learning assessment. Based on the data received, the value of the beta PSD was highest, and the alpha PSD was lowest for both task difficulties while listening to rock music. Besides, the average number of recalled words was the weakest for both task difficulties when listening to rock music. Hitherto, it can be concluded that the best music genre for visual learning was Classical music.

ACKNOWLEDGEMENTS

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