Investigating Effects of Stimuli on Attentional Focus during Cognitive Test using EEG

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Abstract: Attentional Focus is important for many cognitive processes, as it has great influence on performance of working, studying and many other activities, although, it is difficult to sustain it for a long period. To better comprehend attentional focus, many studies found relationships between EEG signals and attentional focus, however more investigation on methods that facilitate its prolongation are necessary. Previous studies indicate that stimuli, such as color of ambient or background sounds can influence the cognitive state of people. Based on that, we believed that stimuli can affect attentional focus as well. Although, it has not been addressed and proper evaluation is needed. To help people sustain attentional focus longer, as the first step, this research investigates how different stimulus influence attentional focus. For that, a preliminary experiment was conducted in which participants took a cognitive test for a long period while wearing an EEG sensor to induce them to lose attentional focus. During the test, different stimuli were compared. As evaluation, we conducted statistical analysis on the performance and the EEG signals during the exposition of each stimulus. The results of this stage indicated that River Sound obtained higher attentional focus than Red Light.

Keywords: attentional focus, stimuli, EEG, heavy cognitive load, PASAT

1. Introduction

Attentional focus is crucial in cognitive processes [1], influencing performance in work, study, sports, and many other activities. However, sustaining attention over extended periods presents a well-recognized challenge.

Due to the importance of attentional focus in daily life of people, many researchers have studied the mechanisms behind it and found relationships between electroencephalogram (EEG) signals and attentional focus [2] [3]. However, more investigation on methods that facilitates prolonging attentional focus is needed.

Alternatively, studies have shown that external stimuli, such as ambient colors [4] and background sounds [5], can influence cognitive states of people, such as emotion. Based on those findings, we hypothesized that external stimuli might be able to facilitate in sustaining attentional focus. However, to the best of our current knowledge, there are not many studies comparing different stimuli for sustaining attentional focus by assessing their impact on EEG signals.

To test this hypothesis, we selected three ambient colors (red, blue, and green) and three background sounds (white noise, river sounds, and classical music). The stimuli were selected based on their effectiveness in affecting different cognitive states in previous studies [4] [5].

Finally, in this research, we compared how different stimuli affect sustained attentional focus by analyzing their influence on the performance of a cognitive test and EEG signal activity obtained during the exposition to each stimulus.

2. Method

2.1 Sensing method

To acquire EEG signals from the participants, we employed the Muse S 2, a commercially available wearable device produced by InteraXon Inc. [6]. The Muse S 2 features four channels: two on the frontal lobe (AF7 and AF8) and two on the temporal lobe (TP9 and TP10). This device is strategically designed as a comfortable headband, intended to fit comfortably on the heads of most individuals.

2.2 Cognitive Test

To assess the effectiveness of each stimulus on sustaining attentional focus, it is first necessary to place the participants into a situation that easily loses attentional focus. We hypothesized that if participants engage in a cognitive test for an extended period, their attentional focus will naturally decline.

To achieve this, this study employed the Paced Auditory Serial Addition Test, a neuropsychological tool used to assess cognitive functions, particularly attention, calculation, and working memory [7]. During the test, the participants listen to a sequence of numbers presented at fixed interval and are tasked to perform mental addition of the current number to the previous one within the set interval.

2.3 Preliminary experiment

The objective of the preliminary experiment is to evaluate the effectiveness of each stimulus on sustaining attentional focus. To induce loss of attentional focus over an extended period, this study employed the PASAT. We anticipated that participants would begin to lose their attentional focus after approximately 2 minutes of taking the test. That would reflect on the correct answer rate of the test and the EEG signals of the participants.

To compare the effectiveness of each stimulus in sustaining attentional focus, one of the stimuli is introduced after the initial 2 minutes, and the participant continue taking the test for an additional 2 minutes.

To conduct the experiment, it was selected 12 people, aged between 20 to 30 years old, being 2 females and 10 males. Throughout the experiment, the participants wore the EEG sensor to enable analysis of signals. And to avoid external distractions, the experiment was conducted in a silent and isolated room.

To minimize individual differences of the participants in perceived difficulty during the PASAT, we implemented three distinct difficulty levels and a trial test at a medium difficulty. Participants initially completed the trial test, and their performance determined their assignment to the easy, medium, or difficult PASAT group. Difficulty levels were defined by the range of presented numbers: 1-9 (easy), 5-19 (medium), and 11-29 (difficult). Every difficulty maintained a consistent 3-second interval between numbers.

After participants were assigned to their respective difficulty level, the experiment was conducted according to the following steps:

1.Rest (Baseline Measurement) - 2 minutes
2.PASAT non-stimulus (1st half) - 2 minutes
3.PASAT with stimulus (2nd half) - 2 minutes
4.Rest (Baseline Measurement) - 2 minutes

The procedure was repeated seven times, with a different stimulus introduced during step 3 of each repetition. In one case, no stimulus was presented in step 3, serving as a reference for the absence of stimuli.

3. Result

3.1 Correct answer rate

If a stimulus can sustain attentional focus, that would reflect on

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the correct answer rate not decreasing significantly from the 1st half (non-stimulus) to the 2nd half (with stimulus). To assess which stimulus achieved that, we conducted statistical analysis comparing the 1st and 2nd halves of each test.

For that, it we conducted the Shapiro-Wilk normality test to assess data normality, followed by Levene's Test to determine whether the variance across different groups or conditions was statistically equal. In sequence, we performed paired comparisons. Figure 1 shows the comparison of correct answer rate of 1st and 2nd halves for every test.

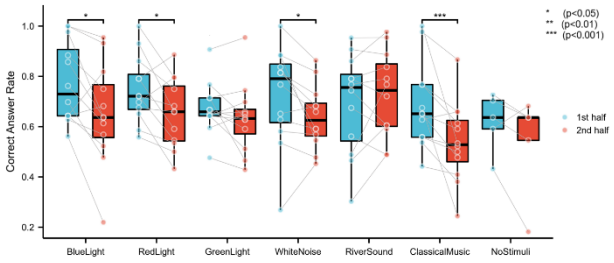

Fig. 1 Comparison of correct answer rate of 1st and 2nd halves

In the case of non-stimulus condition, there was an 8.2% decrease in the correct answer rate. Classical Music had the highest decrease of correct answer rate, with 14.6% reduction, while River Sound was the only stimulus that resulted in an increase, with a 3.4% improvement.

Based on these findings, in comparison to the non-stimulus test, River Sound was the most effective stimulus, while Classical Music performed the worst. We believed that the River Sound provided a relaxing effect that assisted participants to sustain attentional focus, while Classical Music, although amusing, caused distraction in the participants.

3.2 EEG

Previous studies [2] [3] have associated attentional focus with decrease in alpha waves and increase in beta and gamma waves in the right-frontal lobe of the brain. Based on that, as first step, we compared the alpha, gamma, and beta waves of AF8 channel of the EEG sensor, acquired during the 2nd half of the test. For that, we conducted the following data pre-processing and statistical analysis steps for each EEG signal: signal collection and artifact removal using Mind Monitor for Muse S 2 [8] to ensure data quality, outlier filtering via the 3-sigma method to exclude extreme data points, calculation of mean signal values for each individual and test, assessment of data normality using the Shapiro-Wilk test, and testing for equality of variance across different groups or conditions using Levene's Test. Due to the non-normal data distribution, we applied non-parametric tests, including the Kruskal-Wallis test followed by Dunn's test to compare experiments. The results obtained are presented in Figures 2, 3, and 4, illustrating the mean values and significant differences between tests for alpha, beta, and gamma waves, respectively.

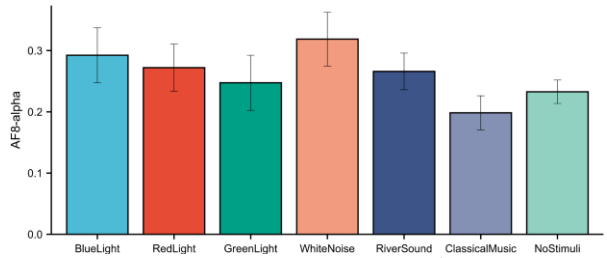

Fig. 2 Mean alpha waves obtained on 2nd half of PASAT

For alpha wave activity, there was no significant difference between the tested stimulus, making it difficult to draw conclusions from those results.

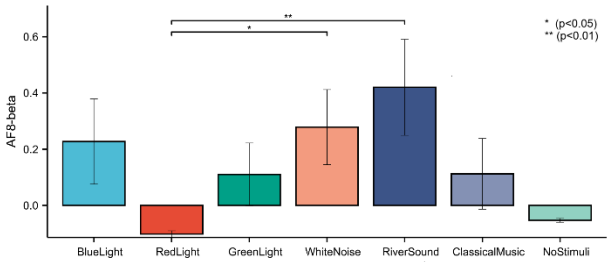

Fig. 3 Mean beta waves obtained on 2nd half of PASAT

As for beta and gamma waves, the highest mean value was obtained during the exposition of River Sound, while the lowest was during Red Light. The increase in both waves is associated with attentional focus and there was a significant difference between the River Sound and Red Light. These findings suggest that River Sound appears to be more effective than Red Light in promoting attentional focus. We believe that the relaxation effect of River Sound might be responsible for facilitating sustain attentional focus during the cognitive test. While Red Light caused tension on participants, resulting in difficulty on sustaining attentional focus.

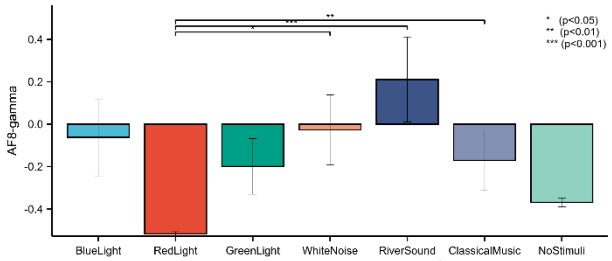

Fig. 4 Mean gamma waves obtained on 2nd half of PASAT

Finally, the results from correct answer rate and EEG signals suggest that among the tested stimuli, River Sound was the most efficient in sustaining attentional focus. However, the number of participants is still short and we still need to conduct further statistical analysis to achieve a concrete conclusion.

4. Conclusion

In this paper, we conducted a comparative assessment of the effectiveness of various stimuli in sustaining attentional focus of participants during a cognitive test. The findings of this stage indicated that River Sound was the most effective in sustaining attentional focus.

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