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Attentional bias during public speaking anxiety revealed using event-related potentials

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ABSTRACT

Analysis of brain signals and their properties provides valuable information regarding the underlying neural deficiencies and enables the diagnosis of attention bias related to public speaking anxiety (PSA). Although 25% people around the world suffer from PSA, currently, there exists a lack of standard assessment in diagnosing the severity of attention bias in individuals with PSA. This study aims to distinguish behavioral and neural abnormalities related to attentional bias during PSA by comparing reaction time (RT) and event-related potential (ERP) correlates of high (H) PSA and low (L) PSA individuals. 12 individuals suffering from HPSA and 12 individuals with LPSA participated in the modified emotional Stroop experiment. Electroencephalography (EEG) was recorded with the low cost, 14-channel Emotiv Epoc+. RT showed slower responses, linked to attentional deficits in HPSA individuals. ERP results revealed the P200 emotional Stroop biomarker, found to be linked to attentional bias in HPSA, but not in LPSA individuals. These results revealed significant RT and P200 ERP abnormalities related to attentional bias in HPSA individuals using the low-cost Emotiv Epoc+.

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1. INTRODUCTION

Individuals suffering from public speaking anxiety (PSA) may experience impaired critical thinking skills and cognitive performance, resulting in mediocre academic performance, limited career opportunities and low quality of life [1]-[3]. Among the most common reasons behind this type of anxiety are fear of committing errors, incompetencies in the spoken language, fear of being negatively evaluated and fear of rejection [4], [5]. Eventhough PSA is highly prevalent in our modern society [6]-[8], there exists a lack of standard evaluation, or biomarkers to detect attention bias related to PSA [6], [9]. Standard self-assessment

tools such as [6] only evaluates behavioral aspects of PSA, neglecting the underlying neural deficiencies that allows for a more direct assessment of the dysfunction, in comparison to behavioural measures alone.

The objective of current study is to detect behavioral and neural abnormalities associated with attentional bias in high public speaking anxiety (HPSA) individuals with the emotional Stroop electroencephalography (EEG) experimental paradigm. The P200 event-related potential (ERP) component, found in emotional Stroop studies, recognized by an upward deflection that occurs about 200 ms after stimulus, is sensitive to the emotional meaning of words and has been linked to attention bias in patients with anxiety [10], [11]. Furthermore, the P200 has been identified as a biomarker [12] for attention-bias related impairment in patients with depression.

Increased P200 amplitude has also been found to be associated with emotional relative to neutral stimuli in experimental studies such as [13]-[15]. Neuroscientists have found more evidence of P200 related to increased intensity during emotions [16] by linking anxious arousal to pronounced P200 in panic disorders. The findings from these experiments are important in establishing the P200 biomarker to attention bias in GAD and panic disorders.

Although much investigation has been done in identifying biomarkers in anxiety and other mental health related disorders [17], [18], up to now, no biomarkers in relation to attentional bias has been established in PSA studies. ERP experiments for the emotional Stroop task has never been conducted to study attentional bias in subjects suffering from HPSA [13], [19], [20]. This is of a primary concern because attentional bias is at the heart of our understanding of PSA.

Thus, no investigation has been conducted to determine the exact timing and brain areas associated with PSA deficits during attention bias. This paper hypothesized that exposure to anxiety-related words would result in increased attention bias, resulting in increased RT and aberrant P200 modulation in HPSA individuals.

2. RESEARCH METHOD

2.1. Related work

Several methods have been used to study the underlying neural deficiencies of attention bias during anxiety. The superior temporal resolution of EEG compared to other technologies such as functional magnetic resonance imaging (fMRI) and positron emission tomography (PET) is a significant advantage [21], [22] in cognitive experimental studies such as this. One method of investigating the neural activation of attention bias during anxiety is by examining the ERPs. ERP allows the EEG recording to reflect the modulations of brain activity moment-by-moment, which is critical in the paradigm of the study. To justify the methodology of this study, a summary table of current studies of mental health disorders and the methodology implemented is featured in Table 1.

Table 1. Summary of current studies of mental health disorders and the implemented methodology

Study	Type of Study / Disorder	Methods/Tools used	Findings
[23]	Investigation of the underlying neural processes of attentional bias modification in Anxiety	Event-related potentials (ERP)	ERP results showed the Late Positive Potential reflects the clinical benefits of attention bias modification intervention
[24]	Classification of autism spectrum disorder (ASD)	Machine learning EEG/facial thermography	Accuracy of 94% in the classification of ASD
[25]	Multimodal attentional bias detection in anxiety	Event-related potentials (ERP)	The N170 component was modulated by both auditory and visual stress signals
[11]	Neural modulations of attentional bias during anxiety	Event-related potentials (ERP)	P200 component was related to attention bias in aubjects with anxiety
[18]	Investigation of neural abnormalities during emotion-cognition interaction in patients with schizophrenia	Event-related potentials (ERP)	Abnornalities in the N450 and late negativity component in patients with Schizophrenia
[26]	Neural correlates of emotional face processing	Event-related potentials (ERP)	The early posterior negativity (EPN) is involved in the processing of emotional content in facial expressions

2.2. Participants

A total of 100 Bachelor of Electronic Engineering students of Universiti Teknikal Malaysia Melaka (UTeM) were assessed for the severity level of their PSA using the public speaking anxiety scale (PSAS) [6] questionnaire. The participants were recruited via Google online forms. After screening, twelve subjects with highest PSAS scores (HPSA) and twelve with lowest PSAS scores (LPSA), matched with respect to age and gender were selected to participate in the EEG experiment. Handedness was evaluated with the shorter version of the Edinburgh Handedness manual [27], [28] and only right-handed participants were selected.

All subjects gave their written consent prior to the experiment. The study was approved by the Ethics Committee of Universiti Teknikal Malaysia Melaka (*Jawatankuasa Etika (Manusia) Penyelidikan*, UTeM). The authors affirm that all procedures performed in this study comply with the ethical standards of the relevant national and institutional committees on human experimentation and with the Helsinki Declaration of 1975, as revised in 2013.

Previous psychiatric disorders or treatment, current substance abuse or dependence, the presence of major somatic or neurological disorders, colour blindness, and a history of reading and learning disorder were the exclusion criteria for all participants. Only Malay language native speakers were chosen as participants in this study, due to the nature of the stimuli.

2.3. Task and procedure

Prior to the actual experiment, a practice session and a color-to-key learning session were performed. The color-to-key session was designed to assist participants in rehearsing and memorizing the color mapping of the response keys. Participants performed the assignment manually, using the right index and middle finger for the blue and yellow colors respectively, and their left middle and index finger for the red and green colors. Next, participants were given a practice session with 41 Stroop trials that were not presented during the actual task.

Two blocks of stimuli, consisting of 60 neutral words and 60 emotional, PSA-related words were presented in a pseudo-random order. The stimuli words, adapted from [29] were presented in the Malay language. Stimuli words were horizontally aligned at the center of the screen. Words such as book and cloud were examples of the neutral stimuli and words such as critic and stutter were examples of the emotional stimuli. Participants were instructed to press the the response keys that matches the ink color of the emotional or neutral word as quickly and as accurately as possible [18], [30].

Each trial started with a fixation cross shown at the center of the screen for a duration of 500 ms. Then, a stimulus was presented and remained on the screen until the participant initiated a response. Following the response, the next fixation point remained on screen for 1500 ms, as illustrated in Figure 1. Participants were instructed to keep their eyes fixated on the monitor and fingers resting on the response keys during the entire experiment. A minimum of 3 minutes rest period was allocated after each block in this study to reduce lingering emotional effects.

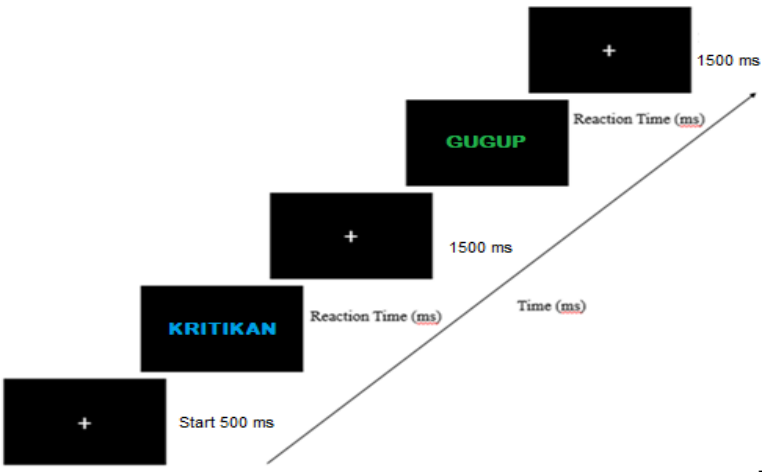


Figure 1. A schematic illustration of the emotional Stroop paradigm in the emotional condition

During the study, participants sat in a dark, quiet room. The computer screen was set at a viewing distance of 70 cm. Participants were instructed to leave all electronic devices away, sit still, restrict excessive eye movements and remain focused on the task. NBS Presentation software documented all RT for analysis.

2.4. EEG recordings

Continuous EEG activity was recorded using the Emotiv excess post-exercise oxygen consumption (EPOC) headset. The Emotiv EPOC produces 256 samples per second with 14 monopolar felt-based gold-plated electrodes positioned approximately at the 10-20 positioning system locations AF3, AF4, F3, F4, F7, F8, FC5, FC6, T7, T8, P7, P8, O1, O2 [26]. The EEG recording was acquired using the Emotiv pro software. In Emotiv EPOC+, electrodes F3 and F4 reflect the frontal lobe and are of significant interest in this research.

A modification to the Emotiv Epoc+, discussed in [26] was applied to solve timing drift. The stimuli marking circuit unit, shown in Figure 2, consisted of a twisted-pair cable connecting the BPW34 photodiode to the O1 and O2 electrodes separated from the scalp by rubber pads. A small white square was created at the right bottom corner of each stimulus image and the diode was attached to the square. The white color differs significantly in luminance, compared to the blank (black) screen and is used for stimulus detection. The photodiode filled the square and was not visible to the participants.

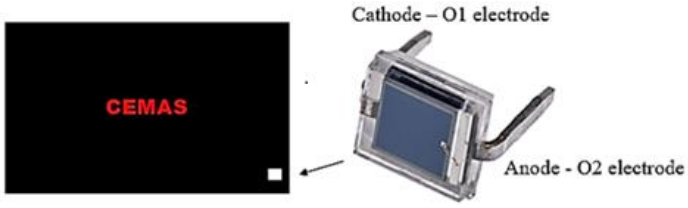


Figure 2. The stimuli marking circuit used in the EEG experiment

2.5. EEG preprocessing

EEG preprocessing was done with EEGLAB [31]-[34]. Raw EEG signals were bandpass filtered from 0.3 to 30 Hz. The sampling rate was 128 Hz. Artifact rejection was then performed to remove noise from muscle movements. Eye movements and blinks were then corrected using ICA. Next, for each condition, epochs of 1700ms were generated 200ms pre to 1500ms post-stimulus and were evaluated for ERP analysis using ERPLAB [35]. Finally, a baseline correction with a period of 150 ms pre-stimulus was performed. The ERPs were then averaged for each subject and condition to produce the averaged ERP waveforms for further analysis.

2.6. Statistical analysis

In order to analyze data, repeated measures, mixed-design ANOVA were conducted on RT and ERP data using STATISTICA 8.0, SPSS version 20, and MATLAB R2019b. Stimulus type (neutral and emotional) was defined as the within-subjects factor and group (HPSA, LPSA) as the between-subjects factor. In compliance to the sphericity requirement of the repeated measures ANOVA, the adjusted greenhouse-Geisser correction to the univariate repeated measures ANOVA *p*-values, the unadjusted degrees of freedom and epsilon values were reported throughout this paper. All multiple comparison tests conducted in this study used the Bonferroni t method as it is robust to violations of sphericity [36].

2.7. Event-related potentials

The ERP effect investigated in this study was the P200 emotional Stroop effect. The mean pooled amplitude of the F3 and F4 frontal electrodes was used as the dependent variable. Based on previous literature, the P200 (150 - 250 ms; peak at 200 ms) time window, illustrated in Figure 3 was analyzed. The P200 window was defined as ± 50 ms from the two highest peaks amplitude of the grand-average difference wave of the LPSA and HPSA groups.

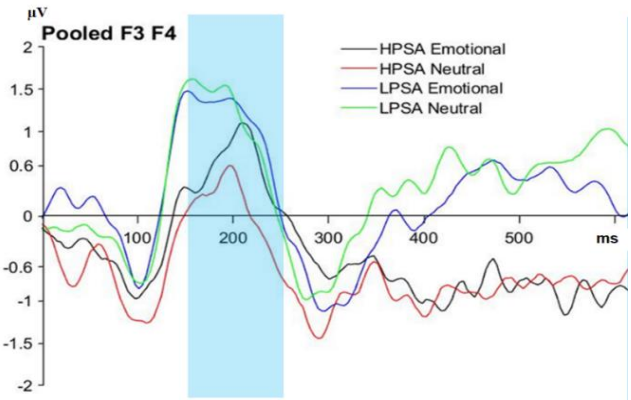


Figure 3. The average ERP waveforms of the P200 window at the pooled F3 and F4 electrodes for HPSA and LPSA subjects, for each condition (neutral and emotional)

3. RESULTS AND DISCUSSION

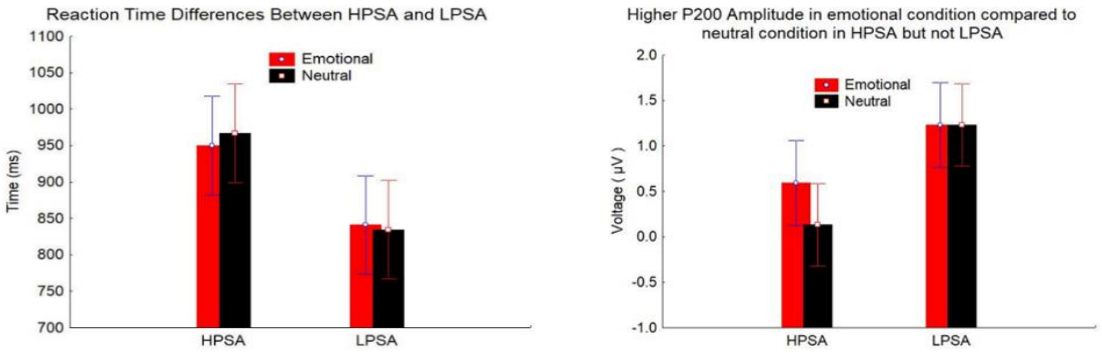
3.1. Error Rates

The mixed-design ANOVA for the error rates revealed that there were no significant differences for any main effects or interactions across conditions [F (1, 22) =1.01, partial η^2 = 0.04, p = 0.33]. However, on average, HPSA subjects made more mistakes in the emotional Stroop task with a mean error rate of 0.1083, in comparison to LPSA subjects (mean error rate = 0.0847). Error responses were excluded in all analysis performed henceforth [18], [29].

3.2. Reaction time (RT) analysis

It was apparent in Figure 4(a) that on average, HPSA subjects were slower in completing the emotional Stroop task compared to LPSA subjects, indicating attentional deficits in the HPSA group. The mean reaction time for HPSA subjects in the emotional and neutral conditions were 949.77 ms and 967.00 ms, respectfully. On the other hand, the mean reaction time for LPSA subjects was 841.10 ms in the emotional condition and 834.59 ms in the neutral condition.

Based on the literature [22], [37], the behavioral emotional Stroop effect, defined as longer mean RT in the emotional compared to the neutral condition measures attentional bias towards emotional words. In this study, the emotional Stroop effect was evident in LPSA subjects but the effect was reversed in HPSA subjects. Thus in this experiment, PSA-related emotional stimuli facilitated Stroop processing in HPSA subjects. Our results were in line with studies such as [38], [39] implicating attention bias toward threat words facilitated the task for the high anxiety group of subjects.The mixed-design ANOVA for RT revealed no significant differences for any main effects or interactions across conditions [F (1, 22) =0.43, partial η^2 = 0.02, p = 0.52].



(a) (b)

Figure 4. These figures are; (a) mean RT differences between HPSA and LPSA subjects in the emotional and neutral conditions and (b) mean ERP at the pooled frontal electrodes at the P200 window indicating higher P200 in the emotional compared to neutral conditions for HPSA but not LPSA subjects

3.3. The P200 emotional stroop effect

Figure 4(b) showed larger P200 amplitude in the emotional compared to the neutral conditions for HPSA subjects but not for LPSA subjects, indicating the P200 emotional Stroop ERP effect in HPSA subjects. The mean voltage amplitude in HPSA subjects for the emotional condition was 0.59 µV and 0.13 µV for the neutral condition. The mean voltage amplitude for LPSA subjects for the emotional and neutral conditions were 1.23 µV. Although the emotional differences in amplitude between groups were apparent in Figure 4(b), mixed-design ANOVA (emotion × group) revealed that the differences were not statistically significant [F (1, 22) =1.15, partial η^2 = 0.05, p = 0.29].

The higher P200 amplitude in the emotional relative to the neutral condition in HPSA subjects indicated enhanced processing towards threat stimuli. Emotional-laden PSA-related cues were more salient in HPSA subjects, indicating potential biomarker in the detection of PSA. The findings here are in line with studies such as [13]-[15], particularly in individuals with high-trait anxiety [10], [40]. These findings have important implications of revealing the functional significance of the P200 waveform modulations to attention bias in HPSA subjects.

The findings of the study provide a benchmark for detecting aberrant time windows and abnormalities related to attention bias for future anxiety studies. Notably, the experiment could be extended to participants with other sub-types of anxiety, such as mathematics anxiety and examination anxiety, to unveil the neurobiology and neuropsychiatry aspects of attentional bias deficiencies in these debilitating

conditions. To generate more sophisticated premises, assumptions, speculations and predictions about attentional bias during HPSA, source localization analysis could be performed in order to understand the time course of the activation within brain regions involved in attention bias.

4. CONCLUSION

To date, this is the first study that showed the P200 emotional Stroop-related attentional bias in HPSA subjects at the frontal brain region, indicating a possible biomarker in the detection of attentional bias in HPSA individuals. At the P200 window, exposure to the anxiety-inducing words evoked higher amplitude in the PSA-related emotional condition compared to the neutral condition in HPSA subjects, but not in LPSA subjects. Furthermore, HPSA subjects were generally slower than LPSA subjects throughout the task.

This research was able to distinguish behavioral and neural abnormalities related to attentional bias during PSA. The results here help the understanding of the behavioral and brain mechanisms underlying attentional bias in individuals with PSA. It is anticipated that the results of this study may lead to future interdisciplinary research designed to assist at the diagnosis level of attention bias in individuals with PSA. This creates crucial implications for future practice in increasing quality of life among people of the society, with early intervention.

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