

Biomarkers of attention bias during public speaking anxiety

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ABSTRACT

The analysis of brain signals and their properties yields significant insights into the fundamental neural impairments associated with attention bias in individuals suffering from public speaking anxiety (PSA). This study aims to identify electroencephalogram (EEG) and performance biomarkers of attention bias in individuals with public speaking anxiety using the ex-Gaussian modeling technique, frontal alpha asymmetry (FAA) and delta-beta correlation (DBC). 12 subjects with high (H) PSA and 12 subjects with low (L) PSA performed the modified emotional stroop task. EEG data were captured using the low-cost 14-channel emotiv Epc+. Results showed that the ex-Gaussian sigma was higher in the emotional condition in the high public speaking anxiety (HPSA) group, indicating attention bias. The study also found higher right FAA in HPSA compared to LPSA group. There was a negative correlation between σ and alpha power in the left region of the brain in the HPSA group, potentially related to attentional bias. Moreover, there was a notable trend towards significantly heightened DBC in the frontal and central regions of the brain among HPSA subjects. In conclusion, in biomedical engineering, the ex-Gaussian model, FAA and DBC are useful because they can identify EEG and performance biomarkers of attention bias in people with PSA.

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1. INTRODUCTION

Despite the fact that a staggering 77% of individuals worldwide experience public speaking anxiety (PSA), current research has yet to explore the potential performance and electroencephalogram (EEG) biomarkers in the frequency domain associated with attention bias in individuals with PSA. In a recent PSA emotional stroop task study [1], individuals with high (H) PSA exhibit increased P200 event-related potential (ERP) component, related to attention bias, compared to the low (L) PSA group. In a PSA Flanker study [2], individuals with high public speaking anxiety (HPSA) showed reversed N200 and decreased P200, related to

abnormalities during the interaction of emotion and cognition. However, these previous studies on HPSA individuals have solely explored mean response times and time-domain event-related potential biomarkers, leaving room for further investigation of EEG biomarkers [3]–[5] in the frequency domain. The goal of this study is to identify EEG and performance biomarkers of attention bias in individuals with PSA using the ex-Gaussian modeling technique, frontal alpha asymmetry (FAA) and delta-beta correlation (DBC).

The ex-Gaussian approach, widely recognized as a reliable model for analyzing reaction time (RT) data [1], has been extensively utilized to identify performance biomarkers in both healthy subjects and patient studies [6]–[8]. However, the application of this model in extracting the three parameters (μ , σ and τ) for analyzing attention bias during PSA remains unexplored. Moreover, FAA and DBC techniques have proven to be valuable methods for extracting EEG biomarkers in the frequency domain within patient studies [9], [10]. Surprisingly, these methods have not been employed to compare subjects with HPSA and LPSA in the emotional Stroop task, thus representing a significant research gap.

In order to bridge the research gap outlined earlier, this study delved into the ex-Gaussian parameters as indicators of attentional bias in individuals with HPSA in the next sections. Furthermore, EEG biomarkers associated with attention bias that were acquired through FAA and DBC analyses will also be discussed. Additionally, correlation analysis was employed to investigate the connection between performance and EEG biomarkers within the realm of attention bias among individuals with HPSA. To the best of our knowledge, this is the first study that implemented the ex-Gaussian analysis on RT, FAA and DBC to investigate attentional bias in PSA individuals.

Individuals with PSA often experience attentional bias, which manifests as a heightened focus on threatening or emotionally unfavorable stimuli. In the context of PSA, this bias is characterized by increased attention towards cues or situations related to public speaking, which are perceived as anxiety-inducing. The emotional stroop task, a widely used paradigm for studying attention bias to emotional words, reveals the emotional stroop effect is observed when individuals take longer to name the colors associated with fear compared to neutral words in anxious subjects [11].

Previous studies have consistently reported higher ex-Gaussian μ values in those with multiple sclerosis (MS) [12], while higher σ values have been associated with individuals experiencing anxiety, potentially linked to attention bias [6]. Moreover, elevated τ values have been found in research focusing on subjects with ADHD [6], fibromyalgia [7] and anxiety [6]. These collective findings align with the hypothesis of our study, further supporting the notion that investigating the ex-Gaussian parameters can shed light on attention bias.

Furthermore, previous anxiety studies have consistently linked anxiousness to elevated right FAA [13], [14]. Heightened DBC activity, which reflects the linear relationship between delta and beta power, has also been associated with anxiety [10]. Based on these findings, the hypothesis for this study posited that individuals with HPSA would exhibit increased right FAA and heightened DBC activity.

2. METHOD

2.1. Participants

One hundred undergraduate students pursuing a bachelor's degree in Electronic Engineering at Universiti Teknikal Malaysia Melaka (UTeM) underwent an assessment to determine the severity of their public speaking anxiety (PSA) using the standardized public speaking anxiety scale (PSAS) questionnaire [15]. From the initial screening, twelve subjects exhibiting the highest PSA scores (referred to as HPSA) and twelve subjects with the lowest PSA scores (referred to as LPSA) were carefully selected. The selection process ensured that the chosen participants were matched in terms of age and gender. Prior to their participation in the EEG experiment, all subjects provided written consent after being thoroughly informed about the study's objectives and procedures. The study received ethical approval from the Ethics Committee of UTeM.

2.2. Task and procedure

During each trial of the experimental task, participants were initially presented with a fixation cross at the center of the screen, which lasted for 500 ms. Subsequently, a stimulus was displayed on the screen until the participant initiated a reaction by clicking the corresponding color keypad button. After the response, the screen remained blank for 1,000 milliseconds before the next trial commenced with the reappearance of the fixation point. Throughout the trials, participants were instructed to maintain their gaze on the monitor and keep their fingers positioned on the appropriate keypad buttons. Detailed information regarding the procedure of this study is illustrated in Figure 1 and could be found in [1].

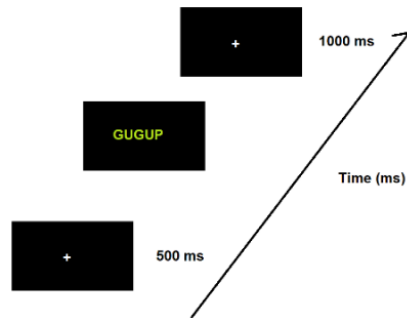


Figure 1. The illustration of emotional stroop paradigm

2.3. EEG recording

Continuous EEG activity was recorded using the Emotiv EPOC headset, a reliable device known for its accuracy and precision. The Emotiv EPOC operates at a sampling rate of 256 samples per second, ensuring high-quality data acquisition. The headset is equipped with 14 monopolar felt-based gold-plated electrodes, strategically positioned according to the internationally recognized 10-20 system. These electrode placements include AF3, AF4, F3, F4, F7, F8, FC5, FC6, T7, T8, P7, P8, O1, and O2. To facilitate the EEG recording process, the Emotiv Pro software was utilized, enabling seamless data capture and management.

2.4. EEG pre-processing

Initially, a band-pass filter ranging from 0.3 Hz to 30 Hz was applied to the data. Subsequently, the data was down sampled to a rate of 250 Hz. To enhance data quality, intervals containing movements and muscle artifacts in any EEG channel were automatically identified using an amplitude criterion of $\pm 80 \mu\text{V}$. These intervals were then visually inspected and excluded from further analysis. Moreover, eye movements and blinks, which can introduce artifacts, were corrected using independent component analysis (ICA), a blind source separation method [16]. After re-referencing to a common average reference, epochs of 1,000 ms were created for each condition for further analysis. Finally, a baseline correction with a period of 150 ms before the stimulus was performed.

2.5. Ex-gaussian model

An alternative approach highly recommended for analyzing RT data involves examining the entire distribution of RT rather than solely relying on mean RT analysis. In this regard, the ex-Gaussian distribution proves to be an exceptionally valuable theoretical framework that effectively captures and summarizes experimental RT data [17]. The ex-Gaussian distribution arises from the convolution of a normal distribution and an exponential distribution. It is characterized by three key parameters: the mean of the normal distribution (μ), the standard deviation of the normal distribution (σ), and the mean and standard deviation of the exponential distribution (τ). To identify the optimal values of μ , σ , and τ that best represent the experimental data, the Exgauss toolbox [18] was employed to fit the ex-Gaussian distribution to the RT data. This approach facilitates a comprehensive understanding of the RT distribution and enables a more nuanced analysis of the underlying cognitive processes.

2.6. Frontal alpha asymmetry

FAA is an established biomarker for anxiety [19]. To obtain the FAA values in this study, we transformed the clean EEG signals obtained from ICA to absolute power (V^2/Hz) using fast fourier transform (FFT). This process is crucial to convert the time domain EEG signal to the frequency domain. The absolute power was then extracted for the F3 and F4 electrodes for each, neutral and emotional condition of the emotional Stroop experiment. Next, the FAA was obtained using the formula $\ln(F4) - \ln(F3)$, as described in [20].

2.7. Delta-beta correlation

To obtain DBC, an established biomarker for anxiety [10], the previous frequency-domain transformed EEG data provided the basis for extracting the power spectrum at the delta (1 to 3 Hz) and beta (13 to 30 Hz) frequencies for each neutral and emotional condition of the emotional stroop experiment. Next, the power spectrum was averaged for distinct brain regions including the frontal (F3, F4, F7 and F8), central (FC5 and FC6), temporal (T7 and T8), and parietal regions (P7 and P8). Pearson's correlation coefficient was

then computed to examine the linear relationship of the power spectrum between the delta and beta frequencies for each brain region.

2.8. Statistical analysis

The values of the ex-Gaussian parameters (μ , σ , and τ) and FAA were subjected to repeated measures, mixed-design analysis of variance (ANOVA), with stimulus type (neutral, emotional) as the within-subjects factor and group (LPSA, HPSA) as the between-subjects factor. The statistical analyses of this study utilised STATISTICA 8.0 and MATLAB R2022b. Moreover, all bar graphs reported the 95% confidence interval.

3. RESULT AND DISCUSSION

3.1. Ex-Gaussian analysis in the emotional stroop experiment

We observed that the σ was higher in the LPSA neutral condition (78.41262, 11.08138ms) compared to the emotional condition (59.98480, 11.71151ms), illustrated in the bar graph in Figure 2. Figure 2(a) shows that this effect is not apparent in the HPSA group (HPSA neutral: 71.30886, 11.08138 ms, HPSA emotion: 73.36592, 11.71151 ms). The repeated measures ANOVA analysis showed non-significant σ differences between both groups (group \times emotion effect) [$F(1, 22)=2.15296$, partial $\eta^2=0.089138$, $p=0.156447$]. The emotional stimuli helped reduce typical RT variation, σ in the LPSA group, but not in the HPSA group, indicating impairment in the regulation of attention in the emotional condition in HPSA individuals [6]. This evidence may suggest a PSA-specific impairment, indicating attention bias in HPSA in emotional conditions.

Pearson product-moment correlation coefficient analysis between σ in the emotional condition and state anxiety showed a trend towards statistical significance ($r=.5001$, $p=.098$, uncorrected) in the HPSA group. The result suggested that increased σ , which has been found to be related to impairment in the variability of typical RT responses [21] in the emotional condition is related to increased state anxiety in HPSA individuals. The effect is illustrated in the scatterplot in Figure 2(b).

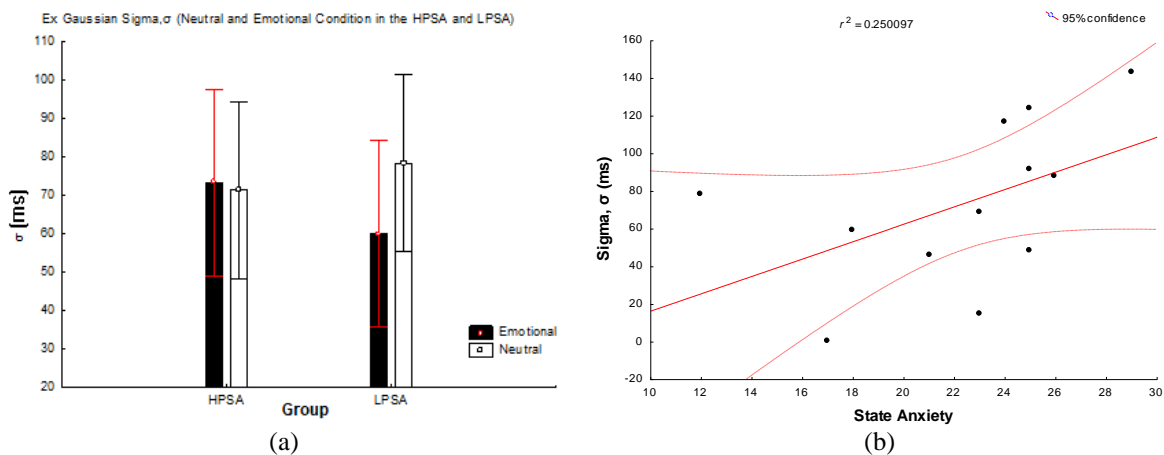


Figure 2. The ex-gaussian σ (a) bar graph of the reduced σ in emotional condition in the LPSA group and (b) scatterplot shows increased σ is related to state anxiety in the HPSA group

We observed a higher μ in the HPSA (560.3746, 20.60063 ms) compared to LPSA (536.4821, 20.60063 ms) group, in line with [7]. However, repeated measures ANOVA showed non-significant μ differences between both the HPSA and LPSA groups [$F(1, 22)=1.43780$, partial $\eta^2=0.03$, $p=0.243251$]. Meanwhile, τ was higher in the HPSA (398.0170, 56.99791 ms) compared to LPSA (301.3621, 56.99791 ms) group, in line with the previous study [22]. The repeated measures ANOVA however, showed non-significant τ between both groups [$F(1, 22)=0.673$, partial $\eta^2=0.061346$, $p=0.42$].

3.2. Frontal alpha asymmetry

Figure 3 shows the mean right FAA Scores for HPSA subjects in the emotional condition were more positive compared to LPSA subjects. This indicates that the HPSA group experienced higher right frontal alpha activation compared to LPSA subjects in the emotional condition. We observed a similar but attenuated

effect in the neutral condition in this group of subjects. Similar findings have been found in [23]–[25] and FAA is an established biomarker for patients with generalized anxiety. In our study, we have extended the application of FAA as a biomarker specifically within the context of PSA. The repeated measures ANOVA (emotion \times group), however, showed non-significant differences between both the HPSA and LPSA groups in the emotional and neutral condition [$F(1, 22)=0.1987$, partial $\eta^2=0.009$, $p=0.6601$].

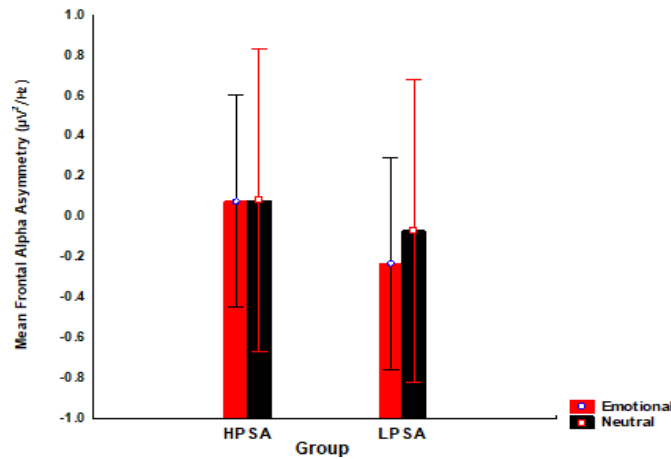


Figure 3. Mean frontal alpha asymmetry in HPSA and LPSA subjects

Additionally, a negative correlation was found between σ and alpha power in the left region of the brain in the HPSA group ($r=-.5411$, $p=0.069$ uncorrected, $p=0.138$ corrected). The association between decreased left alpha power and σ in individuals with HPSA is an interesting finding. Lower alpha power in the left hemisphere may indicate reduced inhibitory control and weaker filtering of distracting information. This could potentially contribute to attentional biases observed in individuals with HPSA, as they may be more susceptible to attentional capture by emotional or salient stimuli.

3.3. Delta-beta correlation

There was a trend towards significant heightened DBC in HPSA subjects within the pooled frontal electrodes (F3, F4, F7, F8) ($r=.6490$, $p=0.022$ uncorrected, $p=0.088$ corrected) and central electrodes (FC5 and FC6) ($r=.6206$, $p=.031$ uncorrected, $p=0.124$ corrected) in the emotional condition, as illustrated in Figure 4. Similar findings have been found in [9], [10], [26], [27] and increased DBC in the frontal and central regions as illustrated in Figures 4(a) and 4(b), are established biomarkers for patients suffering from anxiety. In our study, we have extended the application of DBC at the frontal and central region as a biomarker specifically within the context of public speaking anxiety (PSA).

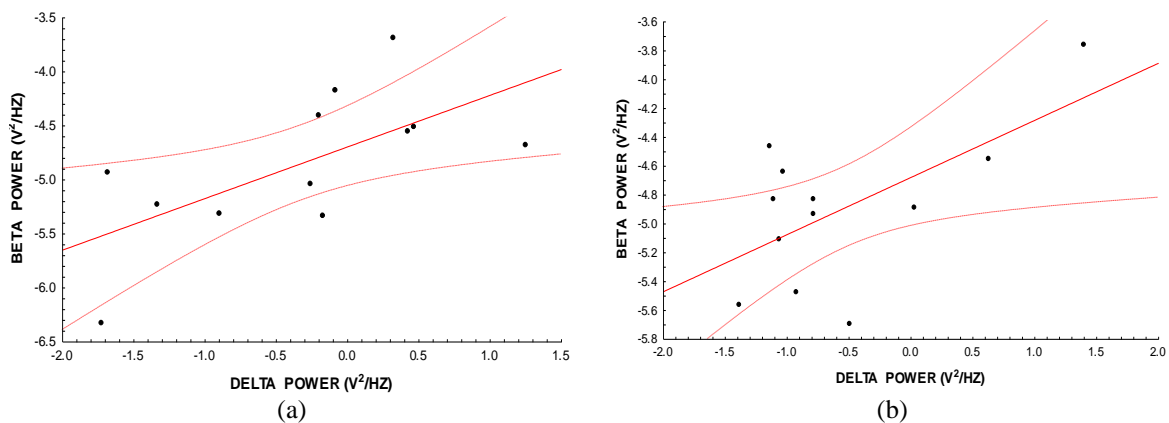


Figure 4. Delta-beta correlation scatterplot for (a) the frontal brain region and (b) the central brain region

4. CONCLUSION

The findings of this study have demonstrated the utility of the ex-Gaussian model in biomedical engineering, particularly in identifying performance biomarkers associated with attention bias in individuals with PSA. In the emotional stroop study, a reduction in σ was observed in the LPSA group in the emotional condition, although this effect was not observed in the HPSA group. The increased σ in the emotional condition can be attributed to the specific impairment in the variability of typical RT caused by PSA, which may be linked to attention bias.

Moreover, our study successfully identified two distinct EEG biomarkers. The first biomarker revealed that individuals with HPSA displayed significantly higher right FAA compared to individuals with LPSA, in line with previous anxiety studies. Interestingly, a negative correlation was found between σ and alpha power in the left region of the brain in the HPSA group, which could potentially contribute to attentional biases observed in individuals with HPSA. For the second EEG biomarker, increased DBC was observed within the frontal and central regions of the brain in HPSA subjects, corroborating with the findings from previous studies.

In the future, these findings could be instrumental in developing targeted interventions for individuals with attention bias related to anxiety disorders. Understanding the specific impairments in variability of RT caused by PSA and their link to attention bias can pave the way for tailored cognitive interventions. Additionally, the identification of EEG biomarkers like FAA and DBC could potentially serve as objective measures for assessing and monitoring attentional biases in clinical settings. This research study opens up avenues for further research and the development of personalized interventions aimed at improving attentional control and cognitive processing in individuals with PSA and related disorders.

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