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EX-GAUSSIAN MODEL REVEALS PERFORMANCE BIOMARKERS RELATED TO EMOTION-COGNITION INTERACTION DURING PUBLIC SPEAKING ANXIETY

(Model Ex-Gaussian Menghasilkan Biomarker Prestasi Berkaitan dengan Interaksi Emosi-Kognitif Semasa Kebimbangan Pengucapan Awam)

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ABSTRACT

This research is to compare the reaction time (RT) of low public speaking anxiety (LPSA) and high (HPSA) individuals using Ex-Gaussian modelling technique to investigate behavioural abnormalities in individuals with PSA. Despite the fact that one out of every four individuals worldwide experiences PSA, there remains a notable lack of research on this condition. With that, the RT performance biomarker of PSA is still unclear. This study observed the correlation between Ex-Gaussian parameters and the level of trait anxiety in 12 subjects with LPSA and 12 subjects with HPSA in an emotion-cognition Eriksen-Flanker (ECEF) experiment. Results revealed that sigma (σ) value in congruent trials was significantly smaller than incongruent trials. It was found that increased trait anxiety is related to reduced sigma (σ) value in LPSA subjects. Conversely, in HPSA subjects, trait anxiety is positively correlated with sigma. As for mu (μ) and tau (τ), we observed increased mu (μ) and tau (τ) in the incongruent compared to congruent trials across all emotional conditions. All in all, increased sigma (σ), mu (μ) and tau (τ) in the incongruent condition is related to impaired response preparation, decreased efficiency on automatic information processing and impaired cognitive control in HPSA subjects. With this study, Ex-Gaussian model is useful in biomedical engineering because it could successfully unveil RT performance biomarkers of abnormalities during the interaction of emotion and cognition in HPSA individuals.

Keywords: Ex-Gaussian; public speaking anxiety; Eriksen-Flanker; cognition; emotion

ABSTRAK

Kajian ini bertujuan untuk membandingkan masa tindak balas (RT) individu yang mengalami kebimbangan berucap awam rendah (LPSA) dan tinggi (HPSA) menggunakan teknik pemodelan Ex-Gaussian untuk mengkaji abnormaliti tingkah laku dalam individu yang mengalami kebimbangan berucap awam. Walaupun satu dari setiap empat individu di seluruh dunia mengalami kebimbangan berucap awam, masih terdapat kekurangan kajian dalam bidang ini. Oleh itu, biomarker prestasi RT bagi kebimbangan berucap awam masih belum jelas. Kajian ini mengkaji hubungan antara parameter Ex-Gaussian dan tahap kebimbangan berterusan dalam kalangan 12 subjek LPSA dan 12 subjek HPSA dalam satu eksperimen kognitif-emosi Eriksen-Flanker (ECEF). Hasil kajian menunjukkan bahawa nilai sigma (σ) pada ujian selari adalah lebih kecil secara signifikan daripada ujian tidak selari. Didapati bahawa kebimbangan berterusan yang tinggi berkaitan dengan penurunan nilai sigma (σ) dalam subjek LPSA. Sebaliknya, dalam subjek HPSA, kebimbangan berterusan berkaitan secara positif dengan sigma. Bagi mu (μ) dan tau (τ), peningkatan mu (μ) dan tau (τ) diperhatikan dalam ujian tidak selari berbanding dengan ujian selari di semua keadaan emosi. Keseluruhannya, peningkatan sigma (σ), mu (μ), dan tau (τ) dalam keadaan tidak selari berkaitan dengan persediaan tindak balas yang terjejas, penurunan kecekapan pemprosesan maklumat automatik dan kawalan kognitif yang terjejas dalam subjek HPSA. Kajian ini menunjukkan bahawa model Ex-Gaussian

berguna dalam kejuruteraan bioperubatan kerana ia dapat membongkar biomarker prestasi RT untuk abnormaliti semasa interaksi emosi dan kognitif dalam individu HPSA.

Kata kunci: Ex-Gaussian; kecemasan berkempen awam; Eriksen-Flanker; kognisi; emosi.

1. Introduction

Public Speaking Anxiety (PSA) is a condition in which individuals experience extreme anxiety when speaking in front of a crowd or planning a conversation with others (Gallego *et al.* 2020). This condition is associated with fear and limits opportunities in society, the classroom, and the workplace. PSA is caused by the interaction of individual traits and situational constraints, with trait anxiety being more stable and related to one's personality, while state anxiety is more episodic and dependent on the moment (Kelsen 2019). Previous studies (Nirjhar *et al.* 2021) had shown that PSA is a communication-based phobia that causes an increase in heart rate and sweating while frequently triggering anxious thoughts and feelings. PSA causes physical symptoms such as sweating, trembling, vomiting, and coughing in mentally distressed individuals (Feroz *et al.* 2021a).

PSA is a common issue in our society, with about one in three individuals experiencing symptoms of anxiety. However, despite its prevalence, the performance biomarkers associated with this type of anxiety are still not fully understood. The current research trend on the Ex-Gaussian studies is summarized in Table 1. This study focused on the differences between Emotion-Cognition Interaction in undergraduate students with HPSA and LPSA using the Eriksen Flanker task. The study aimed to compare the Reaction Time (RT) of LPSA and HPSA individuals using the Ex-Gaussian modelling technique. Further, the study aimed to analyze the correlations between the Ex-Gaussian parameters and participants' level of anxiety.

Table 1: A summary of Ex-Gaussian experiments conducted in PSA and non-PSA research

Experiment	Mean RT study	RT using Ex-Gaussian study
Emotion-Cognition Eriksen Flanker (ECEF) (PSA)	(Feroz *et al.* 2021a)	NIL
Emotional Stroop (PSA)	(Feroz *et al.* 2021b)	NIL
Social Performance Task	NIL	NIL
Visual Stimuli	NIL	(Feroz *et al*. 2021b)

Ex-Gaussian modelling is a statistical technique that separates a skewed distribution into three components (σ, μ, and τ) to provide more information than just mean response time (Penner-Wilger *et al.* 2002). This method has been used in studies on Attention Deficit Hyperactivity Disorder (ADHD) (Thomson *et al.* 2021), schizophrenia (Panagiotaropoulou *et al.* 2019), and brain morphometry in multiple sclerosis (Mui *et al.* 2022). Traditional statistical analysis like ANOVA can be inaccurate when sporadic longer reaction times occur, while Ex-Gaussian provides a more accurate analysis by accounting for the exponential part of the distribution. The three parameters obtained from the distribution (μ, σ, and τ) represent the mean of typical responses, variability of typical responses and mean of atypically slow response time, respectively.

The use of traditional statistical methods to measure reaction time (RT) distribution of a subject has been suggested to show inconsistent results. Ex-Gaussian modelling technique has been proposed as a solution as it can separate motor and attentional processes related to state anxiety better (Spangler *et al.* 2021). Studies have shown that higher values in μ and σ indicate impaired motor response preparation/execution, while a higher value in τ indicates significant

lapses in sustained attention (Galloway-Long & Huang-Pollock 2018). However, the psychological interpretation of the Ex-Gaussian components has not been confirmed.

The hypothesis of the study is anxiety-related words cause subject with high PSA to have a higher τ value as compared to low PSA subjects. Due to Flanker effect, we hypothesize that μ value in incongruent condition is higher than the congruent condition for both groups, while for σ, we expect increased σ in incongruent compared to congruent condition indicating an increase in variations.

2. Materials and Methods

2.1. *Participants*

A total of 100 undergraduates of the Faculty of Electronic and Computer Engineering (FKEKK), Universiti Teknikal Malaysia (UTeM) participated in the Public Speaking Anxiety Scale (PSAS) questionnaire (Bartholomay & Houlihan 2016) to assess the level of their public speaking anxiety. After a screening, the experiment included twelve students with high PSA and twelve students with low PSA (matched for gender and age).

All participants were fully informed about the nature and objective of the experiment, and provided written informed consent. The Ethics Committee of Universiti Teknikal Malaysia Melaka (Jawatankuasa Etika (Manusia) Penyelidikan, UTeM) granted approval for the study. The authors affirm that all methods employed in this research comply with the ethical principles for human research outlined by relevant national and institutional committees, as well as the Helsinki Declaration of 1975, with revisions made in 2013.

2.2. *Paradigm and task*

This study adapted the paradigm from (Kanske & Kotz 2010). Three emotional, PSA-related (Mandeville *et al*. 1994) or neutral words appeared in the centre of the screen as stimuli. The participants were instructed to focus on identifying the ink color of the target word located in the centre, while disregarding the color of the flanker words above and below it. The task required the correct keypad button press to match the ink color. The trials included both congruent and incongruent conditions, where the flanker and target colors could either be the same or different.

2.3. *Statistical analysis*

This study adhered to the sphericity requirement of the repeated measures ANOVA by reporting the adjusted Greenhouse-Geisser correction to the univariate repeated measures ANOVA p-values, as well as the unadjusted degrees of freedom and epsilon (ε) values. The statistical analyses were conducted using STATISTICA 8.0, SPSS version 20, and MATLAB R2019b. Additionally, all bar graphs presented in this paper included the 95% confidence interval (Altman *et al.* 1983).

2.4. *Ex-Gaussian analysis*

The values of μ, σ and τ were calculated for every subject and condition using (Zandbelt 2014), a Matlab Toolbox developed by Bram Zandbelt. Repeated measures, mixed-design ANOVA were performed on the data. The within-subjects factor for the analysis was the stimulus type, with two factors of emotion (neutral and PSA-related) and congruence (congruent and incongruent). Meanwhile, the between-subjects factor was the group, which was categorized as HPSA or LPSA.

3. *Results and Discussion*

We found a significant congruence effect for σ across the groups [F(1,22) = 6.709970, GG Epsilon = 1.00, partial η2 = 0.233716, p = 0.016698]. On average, congruent trials have smaller σ (65.77507 ms, SE 6.217310) compared to incongruent trials (83.65071 ms, SE 6.380396) across all conditions. For incongruent trials, we can see that σ is higher in the emotional (84.82634 ms, SE 12.33633) compared to neutral conditions (68.64135 ms, SE 10.31907) in HPSA subjects (see Figure 1). On the other hand, in LPSA subject, we can see that σ is higher in neutral conditions (95.52080 ms, SE 10.31907) compared to emotional conditions (85.61437 ms, SE 12.33633).

We also found that increased trait anxiety is related with reduced σ value in LPSA subjects (r = -0.817339, p = 0.001168). Conversely, in HPSA subjects, trait anxiety is positively correlated with sigma (r = 0.608044, p = 0.035941). The findings observed in this study mirror (Vaurio *et al.* 2009), where σ is significantly higher in children with ADHD, indicating an increased variability, related to impaired motor preparation response.

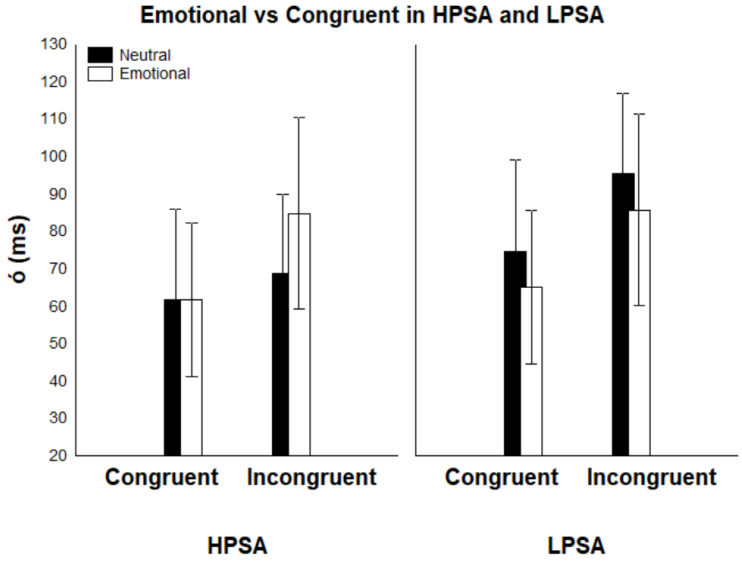

Figure 1: σ values for the emotional and congruent conditions in HPSA and LPSA subjects

HPSA has a higher τ value (52.48787 ms, SE 17.75411) compared to LPSA subjects (29.80493 ms, SE 17.75411) in this study. τ are extremely slow but infrequent responses that follow an exponential distribution and are closely related to short-term lapses of attention (Duschek *et al.* 2022). What is interesting in Figure 2 is the higher Flanker effect (60.80397 ms, SE 31.75157) in the HPSA group in emotional conditions compared to the LPSA group (24.97350 ms, SE 31.75157). A possible mechanism such as impaired cognitive control in HPSA subjects might be related to the higher Flanker effect.

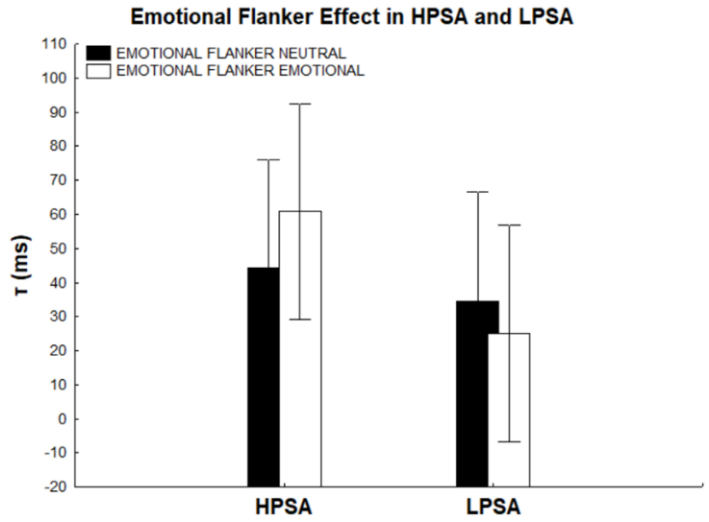

Figure 2: Emotional Flanker effect of τ value in HPSA and LPSA subjects

Typically, HPSA subjects respond slower in comparison to LPSA subjects. From Figure 3, it can be seen that HPSA group has a higher μ as compared to LPSA group. We can also see that the μ value in incongruent condition (688.8952 ms, SE 26.78472 for HPSA; 643.7580 ms, SE 26.78472 for LPSA) is higher than the congruent condition (609.5347 ms, SE 25.71102 for HPSA; 566.8349 ms, SE 25.71102 for LPSA) for both groups (Flanker effect). High values of μ are commonly interpreted as decreased efficiency in automatic information processing (Bresin *et al.* 2011). Higher μ in HPSA is a sign that retrieval procedures in HPSA are less effective compared LPSA (Penner-Wilger *et al.* 2002).

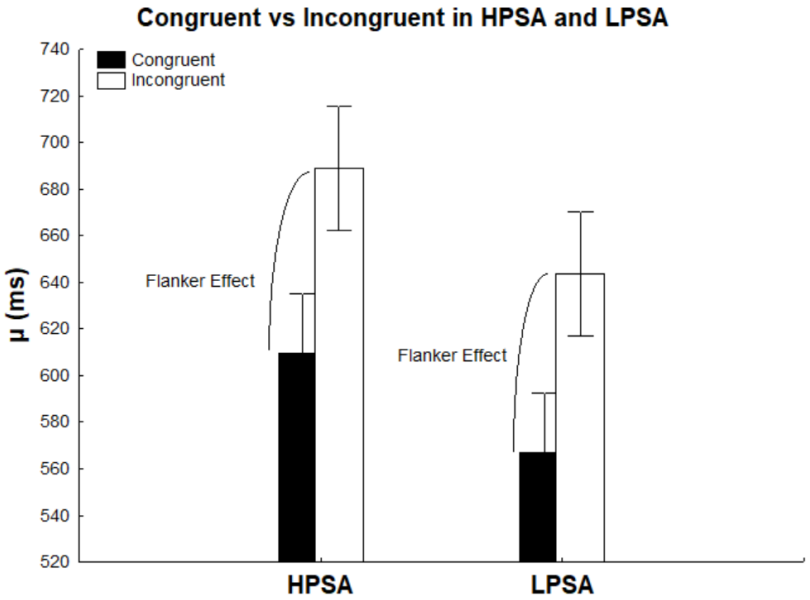

Figure 3: Congruent vs incongruent conditions for μ in HPSA and LPSA

4. Conclusion

The results of this study provide new insights into the performance biomarkers involved in the emotion-cognition impairment in HPSA individuals, based on Ex-Gaussian analysis. Increased σ, μ and τ values in the incongruent condition are related to impaired response preparation, decreased efficiency on automatic information processing and impaired cognitive control in HPSA subjects. With this study, Ex-Gaussian model is useful in biomedical engineering because it could successfully unveil RT performance biomarkers of abnormalities during the interaction of emotion and cognition in individuals with HPSA.

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