RESEARCH ARTICLE

ACTA Vol. 19, No. 4, 2021, 427-443
NEUROPSYCHOLOGICA

Received: 21.05.2021
Accepted: 30.07.2021

A – Study Design
B – Data Collection
C – Statistical Analysis
D – Data Interpretation
E – Manuscript Preparation
F – Literature Search
G – Funds Collection

EVENT-RELATED POTENTIALS REVEAL IMPAIRED EMOTION-COGNITION INTERACTION IN INDIVIDUALS WITH PUBLIC SPEAKING ANXIETY

Farah Shahnaz Feroz[1] [A,B,C,D,E,F,G], Muhammad Hairulnizam Mat Ali[2] [B,C,D,E,F], Afiq Idzudden Ismail[2][B,D,E], Ahmad Rifhan Salman[2][B,D,E], Faaizah Shahbodin[3][B,D,E]

[1] Pervasive Computing & Educational Technology (PET), Fakulti Kejuruteraan Elektronik dan Kejuruteraan Komputer (FKEKK), Universiti Teknikal Malaysia Melaka (UTeM), 76100 Durian Tunggal, Melaka, Malaysia
[2] Fakulti Kejuruteraan Elektronik dan Kejuruteraan Komputer (FKEKK), Universiti Teknikal Malaysia Melaka (UTeM), 76100 Durian Tunggal, Melaka, Malaysia
[3] Pervasive Computing & Educational Technology (PET), Fakulti Teknologi Maklumat dan Komunikasi (FTMK), Universiti Teknikal Malaysia Melaka (UTeM), 76100 Durian Tunggal, Melaka, Malaysia

SUMMARY

Background: This study used reaction time (RT) and event-related potential (ERP) analysis in an emotion-cognition Eriksen-Flanker (ECEF) task to investigate behavioral and neural abnormalities in individuals with public speaking anxiety (PSA). Although 25 per cent of people worldwide suffer from PSA, there is currently a lack of standardized assessment or biomarkers to detect emotion-cognition abnormalities in individuals with PSA.

Material/ Methods: RT and ERP were compared between 12 subjects with high (H) PSA and 12 subjects with low (L) PSA in the ECEF experiment. EEG was recorded with the 14-channel Emotiv EPOC+.

Results: RT data showed a significant Flanker Effect across groups in the neutral and emotional (PSA-related) conditions, with increased Flanker effect in the HPSA group. On average, LPSA subjects were faster than the HPSA subjects in the ECEF task. HPSA subjects showed aberrant ERP responses in two ways. Firstly in the reversed N200 conflict effect with increased frontocentral amplitude in the incongruent compared to the congruent condition. Secondly, in the absence of the P200 frontocentral emotional modulation found in LPSA subjects. In the HPSA group, decreased P200 amplitude is significantly related to impaired behavioral performance in the neutral congruent condition.

Conclusions: RT and ERP are useful in modern medicine because they successfully unveiled the biomarkers of abnormalities during the interaction of emotion and cognition. Impaired conflict processing in PSA-related conditions was found at the N200 and P200 windows in HPSA individuals.

Key words: public speaking anxiety, Flanker, emotion, cognition, P200, N200, emotiv, EEG

INTRODUCTION

Public speaking anxiety (PSA) often results in impaired critical thinking skills and cognitive performance that might lead to mediocre academic performance, reduced career prospects, and low quality of life [1–4]. Although the fear of public speaking is pervasive in our modern society, with approximately 25% of individuals report experiencing it [2,5], the underlying brain-behavior mechanisms of this fear have yet to be understood. Despite their validity and reliability, standard self-assessment tools such as [2,6,7] only evaluates the behavioral aspects of PSA.This paper aims to integrate measures of behavioral performance and the modulation of cortical evoked activity, that allows for a more direct assessment of the dysfunction in comparison to behavioural measures alone.

Various modifications of the ECEF task have been used to study emotion-cognition dysfunctions in vulnerable individuals, such as those suffering from depression [8], anxiety [8], social anxiety [9,10], schizophrenia [11] and autism spectrum disorder [10]. The N200, an ERP conflict-related negativity at the frontocentral electrodes at 200ms after stimulus onset, is a prominent marker in the Flanker task and has been linked to conflict processing at the anterior cingulate cortex (ACC) [8,12]. In experimental studies, the N200 window is related to emotional-cognitive interactions [13,14] and has also been associated with anxiety-related disorders [15–17]. Overall, there seems to be some evidence to indicate the role of the N200 window with emotion-cognition interations in individuals with anxiety-related disorders.

The P200, recognized by an upward deflection that occurs about 200 ms after stimulus, is related to emotional perception [18] and emotional modulation during cognition in the Flanker task [19]. The P200 ERP component is sensitive to the emotional meaning of words and has been linked to emotion-cognition disturbances in patients with generalized anxiety disorder (GAD) [20]. It has also been discovered to be a biomarker [21,22] for attention-bias related impairment in patients suffering from depression. Increased P200 amplitude has also been found to be associated with emotional stimuli in experimental studies in healthy subjects [23,24]. Collectively, these studies outline a critical role of the P200 window in emotion-cognition tasks. The findings from the current study is important in establishing P200 to emotion-cognition disturbances in HPSA subjects.

Despite the high prevalence rates of PSA, up to now, no behavioral or ERP ECEF task has been conducted to investigate emotion-cognition deficiencies relating to this fear in individuals suffering from HPSA. Current research trend on the ECEF task is summarized in Table 1.

There is a current shift in neuroscience research, driving towards lower cost, portable neurotechnology devices that are easy to assemble and require faster

Table 1. A summary of ECEF experiments conducted in PSA and non-PSA research

RT-based PSA study	ERP PSA study	ERP, non-PSA study	Low-cost EEG, non-PSA study
nil	nil	[8,11,12,19,25–28]	nil

set-up time than traditional complex, bulky, and costly clinical equipment. Low-cost EEG headsets, such as the EMOTIV Epoc +, have been used for ERP research in recent years. The accuracy of the technology of this device has been validated by independent studies many times over [29–31].

To the knowledge of the researchers, this is the first time that low-cost EEG equipment has been used to study the effects of PSA on emotion-cognition abnormalities in individuals with HPSA. The results of this research might be critical to the plausible neural mechanisms for the struggle that HPSA individuals face in selecting their responses during anxiety. This study hypothesizes abnormalities in the modulation of emotions during cognition at the N200 and P200 windows in the HPSA group.

MATERIALS AND METHODS

Materials and methods used in the study are summarized in the flow chart in Fig. 1 below.

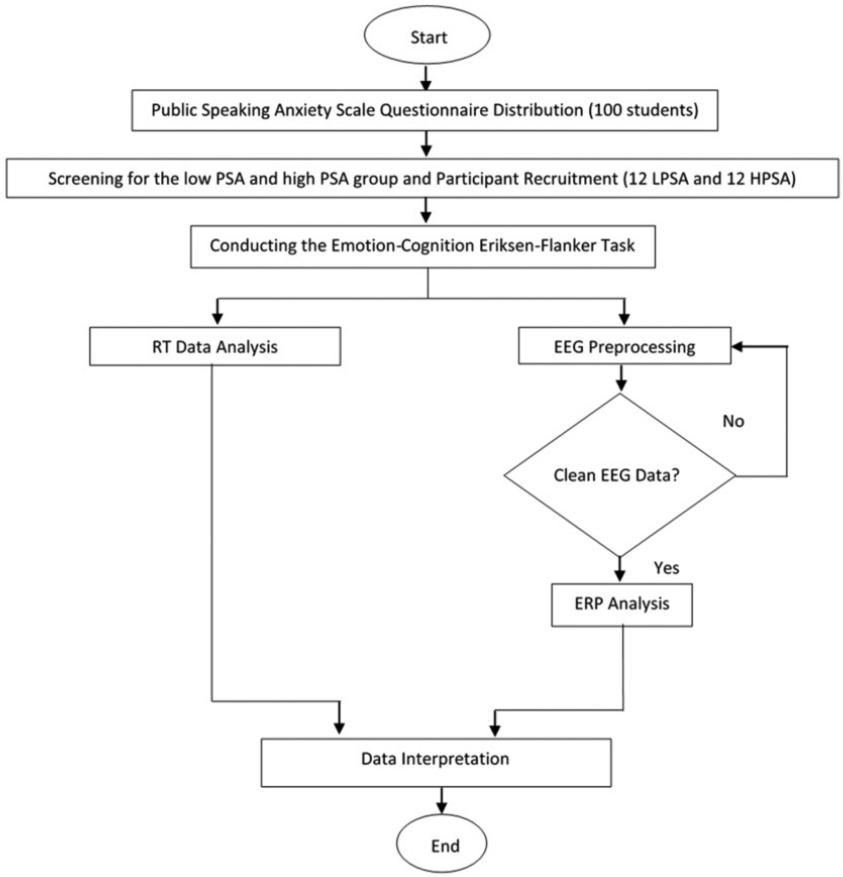

Fig. 1. Flow chart summarizing the materials and methods used in the study

Table 2. Participant demographic characteristic

	LPSA		***HPSA***			
	n or mean	***SD***	***n or mean***	***SD***	***Z / t***	***p-value***
Gender (m/f)	5/7		6/6		-0.40	0.68
Age	21.33	0.49	21.58	1.31	-0.62	0.54

Participants

A total of a hundred undergraduates of the Faculty of Electronic and Computer Engineering (FKEKK), Universiti Teknikal Malaysia (UTeM), participated in the Public Speaking Anxiety Scale (PSAS) questionnaire [2] to assess the level of severity of their PSA. Following a screening, twelve students suffering from high PSA and twelve students with low PSA (matched for gender and age) were included in the EEG experiment. The demographic characteristics of the groups are presented in Table 2.

Written informed consent was attained from all participants following the explanation of the objective and nature of 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 relevant national and institutional committees' ethical standards on human experimentation and with the Helsinki Declaration of 1975, as revised in 2013.

Exclusion criteria for all participants include any previous psychiatric disorder or treatment, current substance abuse or dependence, the presence of major somatic or neurological conditions, color blindness, and history of reading and learning disorder. Handedness was assessed with the revised short-form of the Edinburgh Handedness Manual [32]. All participants had normal to the corrected-to-normal vision and were native speakers of the Malay language.

The severity of PSA symptomatology was assessed with the Public Speaking Anxiety Scale (PSAS) (Bartholomay and Houlihan 2016). PSAS was developed to measure cognitive, behavioral, and physiological dimensions of fear-related responses to public speaking. The questionnaire is a highly reliable and valid measure to assess PSA. The PSAS is a 17-item self-report measure where responses were measured in a Likert-format with a score ranging from a minimum value of 1 “not at all” to a maximum value of 5 “extremely.” Total scores on this scale range from a value of 17 to 85. There are five items on this scale that are reverse coded.

Paradigm and Task

The paradigm of this study was adapted from [12]. Stimuli consisted of three emotional, PSA-related words [33] or neutral words appearing at the center of the screen. Participants were instructed to identify the ink color of a centrally presented target word while ignoring the color of the irrelevant flanker words above and below the target word by pressing a keypad button. Flanker and target colors could

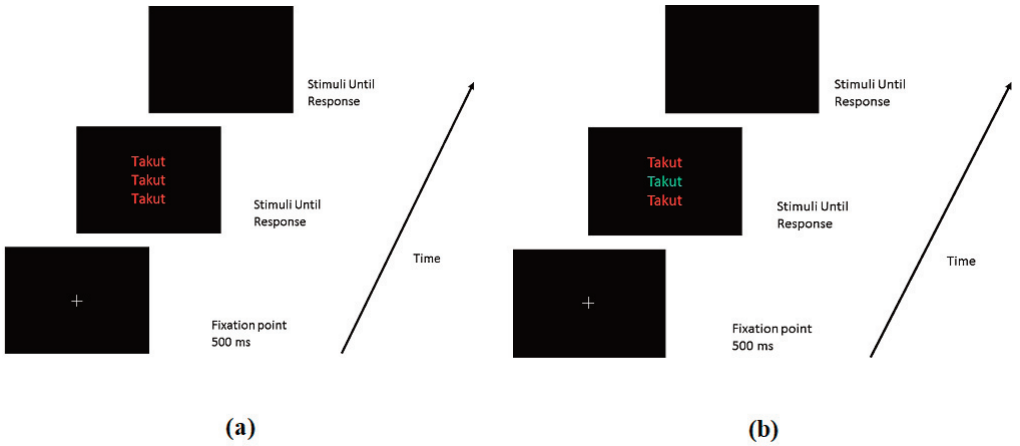

Fig. 2. A schematic illustration of the emotion-cognition Flanker paradigm in the emotional (a) congruent and (b) incongruent conditions, adapted from [12]

be identical or different, creating congruent and incongruent trials. A schematic illustration of the emotional-cognition Flanker paradigm is featured in Fig. 2.

The stimuli words were presented in the native language of the participants (Malay language) because studies have shown higher interference in native speakers compared to non-native speakers of word stimuli [34,35]. Further, language proficiency has been found to influence results in the Stroop task [36,37].

A total of 256 stimuli delivered in 4 blocks were presented in a pseudo-random order with the condition that no color appeared twice in succession. Participants were instructed to respond to the ink color of the middle word as quickly and as precise [38] as possible by pressing one of the four horizontally aligned keys, standing for the four ink colors. The displayed stimulus in each trial was terminated after each response. The next stimulus appeared 1500 ms after the previous response. Upon completion of each block, a minimum of three minutes rest period was allocated.

EEG Recording

The EEG recording was acquired using the EMOTIV EPOC+ 14 channel EEG system and Emotiv Pro software. EEG recording was implemented in a noise attenuated and dark room. Continuous EEG was recorded from 14 monopolar felt-based gold-plated electrodes placed approximately in locations AF3, AF4, F3, F4, F7, F8, FC5, FC6, T7, T8, P7, P8, O1, O2 according to the Modified Combinatorial Nomenclature for the 10–20 positioning system [39]. During recording, all electrodes were referenced to common mode sense (CMS) while driven right leg (DRL) served as the ground. Data collection was performed at a sampling rate of 128 Hz, with the impedances being kept below 5kΩ for all recordings.

Stimuli were presented with Presentation (Neurobehavioral Systems). Before the actual task, a color-to-key acquisition session and a practice session were conducted for all participants. The color-to-key practice was designed to help participants rehearse and memorize the color mapping of the buttons on the response keypad. After the color-to-key acquisition session, participants were given a practice session with ten trials not presented during the actual task.

EEG Pre-processing

EEG data were bandpass filtered (0.3 – 30 Hz). The method discussed in [31] was applied to solve timing drift and jitter issues experienced during EEG recording. With automatic detection of an amplitude criterion of ± 80 μV and visual verification, intervals containing muscle movements and artefacts in any EEG channel were not included for analysis. ICA was performed for eye movements and blinks correction. Epochs of 1700 ms (200 ms pre to 1500 post-stimulus) were constructed for each condition after re-referencing to common average reference. These were then evaluated for ERP analysis [40,41]. Lastly, a baseline correction with a period of 150 ms pre-stimulus was performed. EEG preprocessing was performed using EEGLAB [42–45] and ERPLAB [46].

Statistical Analysis

In compliance with 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 in this study. Multiple comparisons were conducted with Bonferroni *t* as it is robust to violations of sphericity [47] and its applicability regardless of the significance of the *F* test [48–51]. The statistical analyses of this study utilized the STATISTICA 8.0, SPSS version 20, and MATLAB R2019b. Moreover, all bar graphs in this paper reported the 95% confidence interval [52].

Behavioral Data

Mean RT and error rates were calculated for every subject. Repeated measures, mixed-design ANOVA were performed on the RT and accuracy data, with stimulus type as the within-subjects factor (with factors emotion (neutral, PSA-related) and congruence (congruent, incongruent)) and group (HPSA, LPSA) as the between-subjects factor.

Event-Related Potentials

After the removal of artefacts, ERPs for correct response trials were averaged for each subject and condition. The number of trials ranged from 40 to 64 for each condition. The main effects or interactions did not differ significantly across the various conditions [group effect; $F_{1,22} = 0.06$, partial $\eta^2 = <0.01$, $p = 0.82$].

The ERP effects investigated in this study were the N200 fronto-central negative deflection in the incongruent, compared to the congruent trials across all levels of emotion and the P200 fronto-central emotional modulation. The mean

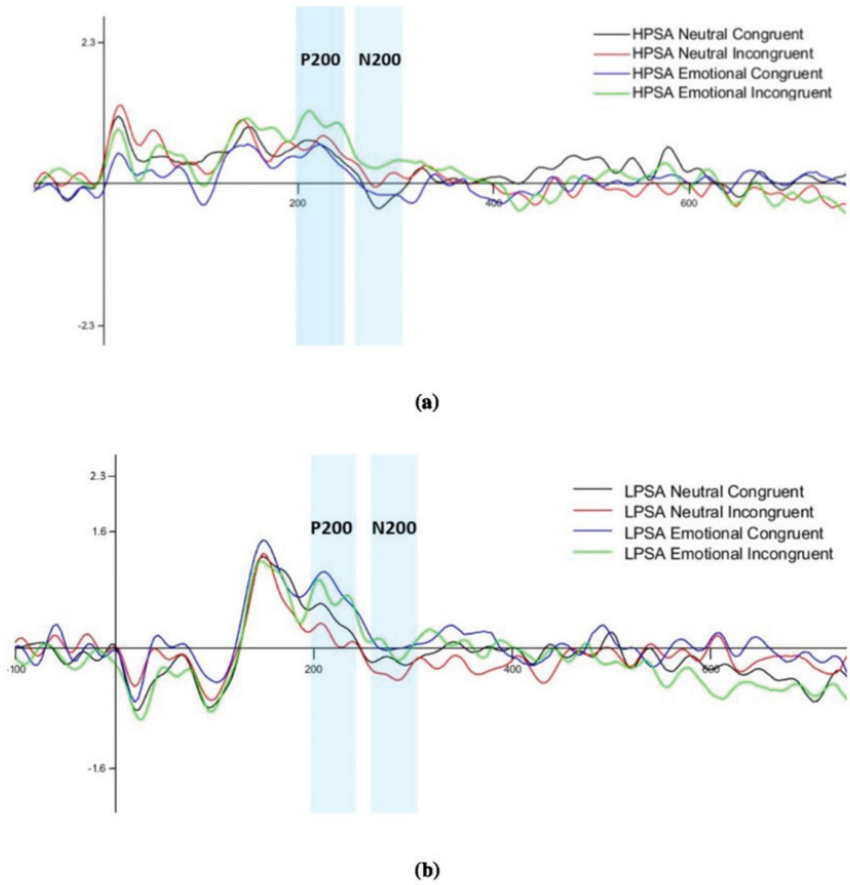

Fig. 3. The ERP grand average wave (unit in μV) at pooled frontocentral electrodes in the incongruent and congruent, neutral, and emotional conditions for (a) HPSA and (b) LPSA subjects. Time frames highlighted in blue are the P200 (197.7-247.7 ms) and N200 (256.3 - 306.3 ms) windows

pooled amplitude of the frontocentral electrodes (FC5, FC6, cf. [14,53,54]) was used as the dependent variable.

Based on previous literature findings, the N200 (256.3 - 306.3 ms; peak at 281.3 ms) and the P200 (197.7-247.7 ms; peak at 222.7 ms) time windows, illustrated in Fig. 3 were investigated.

The N200 and P200 windows were defined as ± 25 ms from the two highest peaks amplitude of the grand-average difference wave of the LPSA and HPSA groups. The mean amplitudes at each window (P200 and N200) at the pooled fronto-central electrodes for each stimulus type (congruence,emotion) were calculated and analyzed with repeated measures, mixed-design analysis of variance (ANOVA).

RESULTS AND DISCUSSION

Abnormal emotion-cognition interactions may be pivotal, in the dysfunctions associated with PSA [55]. Current research has shown behavioral impairments in individuals suffering from HPSA affecting their education, work and social lives. Nevertheless, the time windows and brain regions relating to the dysfunctions have yet been attained. In addressing the gaps of previous studies, this study compared the RT and ERP at the P200 and N200 windows during the ECEF task in HPSA and LPSA subjects.

Behavioral Data

Error Rates

Mixed ANOVA revealed significant emotion × congruence interaction effect [F (1,22) = 7.17, GG Epsilon = 1.00, partial η^2 = 0.24, p = 0.01]. Bonferroni t showed significant higher error rate in the incongruent neutral condition compared to the congruent neutral condition in the LPSA group [t (32.71) = 2.04, p = 0.02] illustrated in Fig. 4 (a).

On average, LPSA subjects had higher error rates (1.99 ± 0.42)% compared to HPSA subjects (1.43 ± 0.42)%, although the mixed ANOVA revealed non-significant group effect [F (1,22) = 0.86, partial η^2 = 0.04, p = 0.36]. All analyses performed henceforth exclude error responses.

Reaction Time

We found a significant behavioral Flanker effect (Equation 1) across the groups [F (1,22) = 103.5412, GG Epsilon = 1.00, partial η^2 = 0.8248, p <.01]. On average, congruent trials were responded faster (884.423 ms, SE 68.326) than incongruent trials (1153.115 ms, SE 81.76) across all emotional conditions.The effect is illustrated in Fig. 4 (b). This significant behavioral Flanker effect demonstrated conflict elicited by the task. The Flanker effect was higher in HPSA (131.848 ms) compared to LPSA (106.758 ms).Based on Table 3, the HPSA subjects (1067.51 ± 65.78) ms were on average slower than the LPSA subjects (947.49 ± 65.78) ms, although the mixed ANOVA showed non-significant group effect [F (1,22) = 1.66, partial η^2 = 0.07, p = 0.21]. HPSA group has the highest Flanker Effect in the emotional PSA-related condition.

Equation 1
Flanker Effect = RT Incongruent – RT Congruent

The significantly higher error rate in the incongruent compared to the congruent neutral condition in LPSA subjects suggests an increased focus on the emotional condition in LPSA subjects. Furthermore, the lower error rates in the HPSA group, especially in the incongruent emotional condition suggest increased attention in these conditions. This study highlights increased attention in HPSA in-

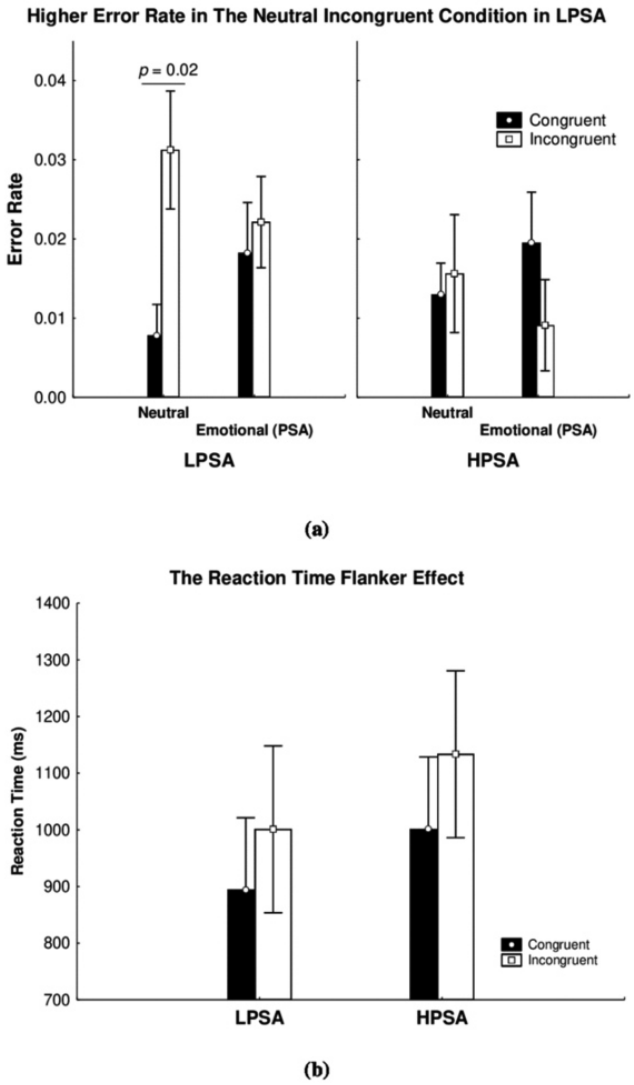

Fig. 4. Behavioral Flanker Effect

Table 3. Averaged RT in for each emotional and congruence condition for the HPSA and LPSA subjects

Group	Condition	RT (ms)	SE (ms)	Flanker Effect (ms)
LPSA	Neutral Congruent	903.796	59.588	110.189
LPSA	Neutral Incongruent	1013.986	72.313	
LPSA	PSA Congruent	884.423	68.326	103.326
LPSA	PSA Incongruent	987.749	81.761	
HPSA	Neutral Congruent	990.502	59.588	123.247
HPSA	Neutral Incongruent	1113.749	72.313	
HPSA	PSA Congruent	1012.665	68.326	140.450
HPSA	PSA Incongruent	1153.115	81.761	

dividuals in the task and to the emotional content of the stimuli, resulting in higher response accuracy. It seems possible that these results are due to the power of the PSA-related words to capture visual attention in HPSA individuals.

The significant Flanker effect found in this study demonstrates conflict elicited by the stimuli. The Flanker effect was significant across the groups; however, the effect, on average, is higher in HPSA subjects. Further, we found that the emotional inducing PSA-related words impaired conflict processing in HPSA individuals, but accelerated conflict processing in LPSA subjects. The expedited conflict processing in healthy subjects in the emotional condition was also found in [12]. Moreover, previous studies have reported similar emotional-related impairment during cognitive control in subjects suffering from depression, anxiety, and schizophrenia [8,54].

The observed deficiency may be explained with the idea that HPSA individuals may require higher RT in comparison to LPSA individuals in the incongruent condition due to their struggle to inhibit irrelevant responses, especially in PSA-inducing conditions. This impairment may be due to the power of the emotional stimuli to attract and retain their attention, thus preventing cognitive control. The error rates and RT findings showed increased attention in HPSA individuals to the PSA-related stimuli causing them to be cautious in getting the correct answer; however, this resulted in increased RT in the incongruent condition, even when the stimuli are not PSA-related.

ERP Data

Reversed N200 Conflict Effect in HPSA Group

There was a trend towards significant increased frontocentral amplitude in the incongruent items in contrast to congruent items, at the N200 window [F (1,22) = 3.09, GG Epsilon = 1.00, partial η^2 = 0.12, p = 0.09]. Fig. 5 (a) illustrates reversed frontocentral negativity in HPSA but not in LPSA subjects. Detailed averaged amplitude for each condition is described in Table 4.

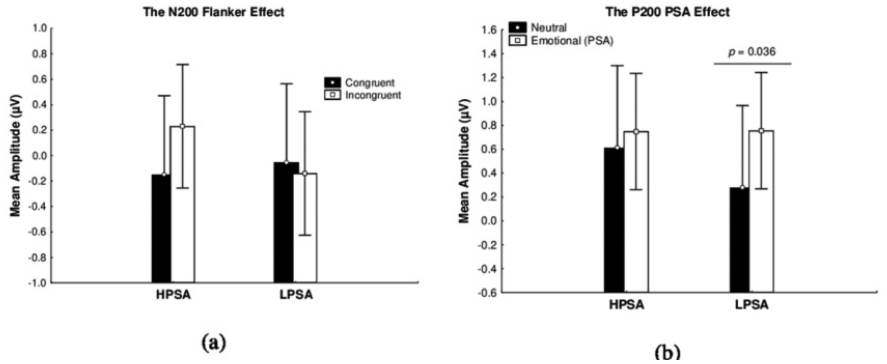

Fig. 5. ERP Responses Describing the ERP Flanker-related components at the N200 and P200 in HPSA and LPSA subjects. (a) Increased amplitude in the incongruent (white) as compared to the congruent (black) items in HPSA at the N200 window and (b) Increased amplitude in the emotional (white) as compared to the neutral (black) items which were significant in LPSA at the P200 window

Table 4. The ERP N200 amplitudes for each emotional and congruence condition for the HPSA and LPSA subjects

Group	Condition	Mean Amplitude (μV)	SE (μV)	N200 FlankerEffect (μV)
LPSA	Neutral Congruent	-0.151	0.342	-0.154
LPSA	Neutral Incongruent	-0.305	0.371	
LPSA	PSA Congruent	0.0403	0.308	-0.016
LPSA	PSA Incongruent	0.0247	0.272	
HPSA	Neutral Congruent	-0.177	0.342	0.304
HPSA	Neutral Incongruent	0.127	0.371	
HPSA	PSA Congruent	-0.122	0.308	0.456
HPSA	PSA Incongruent	0.333	0.272	

The results of the study showed significant N200 conflict modulation across groups in both emotional conditions. Detailed investigation revealed that the averaged N200 conflict effect was reduced in the emotional compared to the neutral items in LPSA subjects. The N200 conflict was decreased in the HPSA group, similar to the findings of [8] in anxious subjects. Interestingly, reversed N200 conflict modulation was observed in the HPSA group in this study. Amplitudes were more positive in the incongruent compared to the congruent condition, with increased reversed N200 conflict modulation in the emotional condition. Consequently, we speculate decreased ERP N200 conflict negativity to be related to reduced attentional resources used to solve conflict processing in HPSA subjects. This combination of findings supports the conceptual premise that in the case of HPSA subjects, there is an emotional interference by the PSA-related stimuli content that could be related to attention bias during conflict processing, causing impaired cognitive control at the N200 window.

Significant Higher Amplitude in the Emotional Condition in LPSA at P200

There was a significant emotional modulation effect at the P200 window [F (1,22) = 7.59, GG Epsilon = 1.00, partial $\eta^2 = 0.26$, $p = 0.01$]. On average, the amplitude is higher in the emotional (0.75 ± 0.17) μV compared to the neutral (0.45 ± 0.23) μV conditions as illustrated in Fig. 5 (b). Further multiple comparison Bonferroni t revealed the modulation was significant in the LPSA group [t (25.52) = 2.06, p = 0.036] but not in the HPSA group.

Thus, emotions modulated the P200 window in LPSA but not HPSA subjects. Increased amplitude in the emotional condition in contrast to the neutral condition was significant in this group. In line with the findings of this study, [18,19] showed increased P200 amplitude in negative compared to neutral trials in healthy subjects. Furthermore, the findings of this study corroborates the ideas of [56] that the interference of negative stimuli increased P200 amplitude compared to positive stimuli in healthy subjects. We speculate that increased attention to the PSA-related words caused increased P200 amplitude in the LPSA group compared to neutral words. HPSA subjects, however, seem to process neutral stimuli similar to emotional stimuli at this window. It can thus be suggested that, similar to

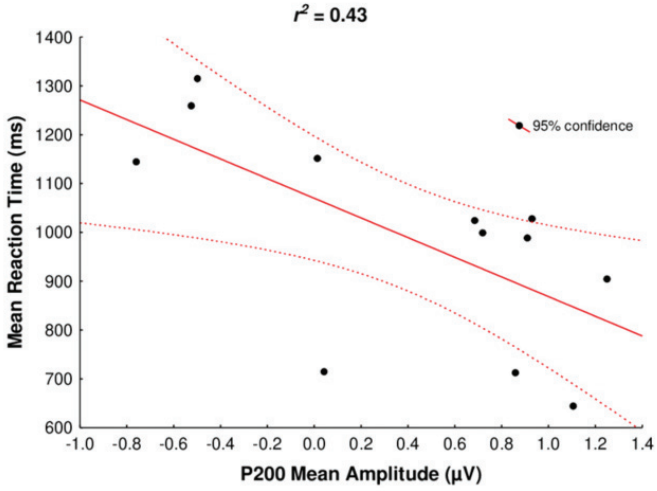

Fig. 6. Scatterplot shows decreased P200 amplitude correlated to higher RT in HPSA subjects

[57], anxious arousal in individuals with anxiety is associated with P200 and is not specific to anxiety-inducing stimuli.

Brain-Behavior Interrelations

In the HPSA group, the P200 ERP data was negatively correlated with mean RT in the neutral congruent condition (r = -0.66, p = 0.02), see also Fig. 6. HPSA subjects with less P200 fronto-central amplitudes required a longer time to resolve the modified Flanker task in the neutral, congruent condition.

Increased P200 amplitude is associated with reduced performance in HPSA subjects. Increased attention to neutral words reduced performance. Indubitably, the P200 emotional dysmodulation in HPSA subjects, linked to impaired performance, has been added to the current literature.

Limitation and Future Direction

While acknowledging the outcome of the study, it should be noted that larger sample sizes would afford increased power to detect significant emotion × congruence interaction effect in RT and the N200 and P200 ERP analysis.

The findings of the study provide a benchmark for detecting aberrant time windows and abnormalities in the modulations of emotion during cognition 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 emotion-cognition interaction deficiencies in these debilitating conditions.

CONCLUSION

This study revealed the biomarkers of emotion-cognition abnormalities in HPSA individuals, detected with the Emotiv EPOC+. Impaired conflict processing in PSA-related conditions were identified at the N200 and P200 windows. Emotional dysmodulation during conflict was detected at the P200 window in HPSA individuals. Decreased ERP activity occurring at the P200 window within the fronto-central region in the HPSA subjects is associated with increased RT in the neutral congruent condition. At the N200 window, HPSA subjects produced reversed N200 ERP Flanker conflict effect, speculated to be related to impaired cognitive control due to emotional interference by the PSA-related stimuli content.

The results of this study provide new insights into the time window and brain regions involved in the emotion-cognition impairment in HPSA subjects, which may be relevant for understanding the neural mechanisms underlying the disturbances of HPSA individuals in selecting their responses in highly-charged emotional-cognitive situations.

Ethics approval and consent to participate

Written informed consent was attained from all participants following the explanation of the objective and nature of 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 relevant national and institutional committees' ethical standards on human experimentation and with the Helsinki Declaration of 1975, as revised in 2013.

Acknowledgment

We deeply appreciate the time and effort spent by the volunteers who participated in this study. This research was supported by UTeM and Pusat Pengurusan Penyelidikan dan Inovasi (CRIM), UTeM.

List of Abbreviations

ACC – anterior cingulate cortex
ANOVA – Analysis of Variance
CMS – common mode sense
DRL – driven right leg
EEG – electroencephalography
ECEF – Emotion-Cognition Flanker Experiment
ERP – event-related potentials
f – female
FKEKK – Faculty of Electronic and Computer Engineering
H – high
HPSA – high public speaking anxiety
L – low

LPSA – low public speaking anxiety
m – male
ms – millisecond
PSA – public speaking anxiety
PSAS – Public Speaking Anxiety Scale
RT – reaction time
SE – standard error
UTeM – UniversitiTeknikal Malaysia Melaka

REFERENCES

[1] Blume BD, Dreher GF, Baldwin TT. Examining the effects of communication apprehension within assessment centres. J Occup Organ Psychol 2010:663–71. https://doi.org/10.1348/ 096317909X463652.
[2] Bartholomay EM, Houlihan DD. Public Speaking Anxiety Scale: Preliminary psychometric data and scale validation. Pers Individ Dif 2016;94:211–5. https://doi.org/10.1016/j.paid.2016.01.026.
[3] Devi SI, Feroz FS. Oral communication apprehension and communicative competence among electrical engineering undergraduate in UTeM. J Hum Cap Dev 2008;1:1–10.
[4] Carlee Arnett, Ferran Suñer. Leveraging Cognitive Linguistic Approaches to Grammar Teaching with Multimedia Animations. J Cogn Sci (Seoul) 2019;20:365–99. https://doi.org/10.17791/jcs.2019.20.3.365.
[5] Theo Tsaousides. Why Are We Scared of Public Speaking? Psychol Today 2017.
[6] McCroskey JC. Measures of communication – bound anxiety. Speech Monogr 1970;37:269–77. https://doi.org/10.1080/03637757009375677.
[7] Cho Y, Smits JAJ, Telch MJ. The Speech Anxiety Thoughts Inventory: scale development and preliminary psychometric data. Behav Res Ther 2004;42:13–25. https://doi.org/10.1016/S0005-7967(03)00067-6.
[8] Kanske P, Kotz SA. Effortful control, depression, and anxiety correlate with the influence of emotion on executive attentional control. Biol Psychol 2012;91:88–95. https://doi.org/10.1016/j.biopsycho.2012.04.007.
[9] Chen S, Yao N, Qian M, Lin M. Attentional biases in high social anxiety using a flanker task. J Behav Ther Exp Psychiatry 2016;51:27–34. https://doi.org/10.1016/j.jbtep.2015.12.002.
[10] Dickter CL, Burk JA, Fleckenstein K, Kozikowski CT. Autistic traits and social anxiety predict differential performance on social cognitive tasks in typically developing young adults. PLoS One 2018;13:e0195239. https://doi.org/10.1371/journal.pone.0195239.
[11] Liu Y, Zhang D, Zhao Y, Tan S, Luo Y. Deficits in attentional processing of fearful facial expressions in schizophrenic patients. Sci Rep 2016;6:32594. https://doi.org/10.1038/srep32594.
[12] Kanske P, Kotz S a. Modulation of early conflict processing: N200 responses to emotional words in a flanker task. Neuropsychologia 2010;48:3661–4. https://doi.org/10.1016/j.neuropsychologia.2010.07.021.
[13] Balconi M, Vanutelli ME. Hemodynamic (fNIRS) and EEG (N200) correlates of emotional inter-species interactions modulated by visual and auditory stimulation. Sci Rep 2016;6:23083. https://doi.org/10.1038/srep23083.
[14] Feroz FS, Leicht G, Steinmann S, Andreou C, Mulert C. The Time Course of Activity within the Dorsal and Rostral-Ventral Anterior Cingulate Cortex in the Emotional Stroop Task. Brain Topogr 2017;30:30–45. https://doi.org/10.1007/s10548-016-0521-3.
[15] König N, Steber S, Borowski A, Bliem H, Rossi S. Neural Processing of Cognitive Control in an Emotionally Neutral Context in Anxiety Patients. Brain Sci 2021;11:543. https://doi.org/10.3390/brainsci11050543.
[16] Seo S, Kim B. Event-Related Potentials Related to Anxiety in Emotion-Attention Interaction. Model Simul Eng 2014;2014:1–5. https://doi.org/10.1155/2014/408252.

[17] Righi S, Mecacci L, Viggiano MP. Anxiety, cognitive self-evaluation and performance: ERP correlates. J Anxiety Disord 2009;23:1132–8. https://doi.org/10.1016/j.janxdis.2009.07.018.
[18] Schutter DJLG, de Haan EHF, van Honk J. Functionally dissociated aspects in anterior and posterior electrocortical processing of facial threat. Int J Psychophysiol 2004;53:29–36. https://doi.org/10.1016/j.ijpsycho.2004.01.003.
[19] Dong G, Yang L, Shen Y. The course of visual searching to a target in a fixed location: Electrophysiological evidence from an emotional flanker task. Neurosci Lett 2009;460:1–5. https://doi.org/10.1016/j.neulet.2009.05.025.
[20] Han HY, Gan T, Li P, Li ZJ, Guo M, Yao SM. Attentional bias modulation by reappraisal in patients with generalized anxiety disorder: an event-related potential study. Brazilian J Med Biol Res 2014;47:576–83. https://doi.org/10.1590/1414-431X20143622.
[21] Hu B, Rao J, Li X, Cao T, Li J, Majoe D, et al. Emotion Regulating Attentional Control Abnormalities In Major Depressive Disorder: An Event-Related Potential Study. Sci Rep 2017;7:13530. https://doi.org/10.1038/s41598-017-13626-3.
[22] Kropotov JD. Functional neuromarkers for neuropsychology. Acta Neuropsychol 2018;16:1–7. https://doi.org/10.5604/01.3001.0011.6504.
[23] Thomas SJ, Johnstone SJ, Gonsalvez CJ. Event-related potentials during an emotional Stroop task. Int J Psychophysiol 2007;63:221–31. https://doi.org/10.1016/j.ijpsycho.2006.10.002.
[24] Kanske P, Plitschka J, Kotz S a. Attentional orienting towards emotion: P2 and N400 ERP effects. Neuropsychologia 2011;49:3121–9. https://doi.org/10.1016/j.neuropsychologia.2011.07. 022.
[25] Zhang J, Teo T, Wu C. Emotion Words Modulate Early Conflict Processing in a Flanker Task: Differentiating Emotion-Label Words and Emotion-Laden Words in Second Language. Lang Speech 2019;62:641–51. https://doi.org/10.1177/0023830918807509.
[26] Li W, Jiang Z, Liu Y, Wu Q, Zhou Z, Jorgensen N, et al. Positive and negative emotions modulate attention allocation in color-flanker task processing: Evidence from event related potentials. Motiv Emot 2014;38:451–61. https://doi.org/10.1007/s11031-013-9387-9.
[27] Trujillo N, Gómez D, Trujillo S, López JD, Ibáñez A, Parra MA. Attentional bias during emotional processing: Behavioral and electrophysiological evidence from an Emotional Flanker Task. PLoS One 2021;16:e0249407. https://doi.org/10.1371/journal.pone.0249407.
[28] Miller RK, Martin FH. Dynamic versus static indicators of threat: N2 and LPC modulation index attack intent and biological relevance during an affective Flanker task. Int J Psychophysiol 2020;158:158–71. https://doi.org/10.1016/j.ijpsycho.2020.08.007.
[29] Duvinage M, Castermans T, Dutoit T, Petieau M. A P300-based Quantitative Comparison between the Emotiv Epoc Headset and a Medical EEG Device. Biomed Eng Online 2012. https://doi.org/10.2316/P.2012.764-071.
[30] Badcock NA, Mousikou P, Mahajan Y, Lissa P De, Thie J, Mcarthur G. Validation of the Emotiv EPOC ® EEG gaming system for measuring research quality auditory ERPs 2013:1–17. https://doi.org/10.7717/peerj.38.
[31] Kotowski K, Stapor K, Leski J, Kotas M. Validation of Emotiv EPOC + for extracting ERP correlates of emotional face processing. Biocybern Biomed Eng 2018;8.
[32] Veale JF. Edinburgh Handedness Inventory – Short Form: A revised version based on confirmatory factor analysis. Laterality Asymmetries Body, Brain Cogn 2014;19:164–77. https://doi.org/10.1080/1357650X.2013.783045.
[33] Mandeville MY. Using a Unique Cognitive Approach--A Variation of the Stroop Test--in the Identification and the Measurement of Public Speaking Anxiety. Annu Meet Speech Commun Assoc 1994.
[34] Eilola TM, Havelka J. Behavioural and physiological responses to the emotional and taboo Stroop tasks in native and non-native speakers of English. Int J Biling 2011;15:353–69. https://doi.org/10.1177/1367006910379263.
[35] Baumeister JC, Foroni F, Conrad M, Rumiati RI, Winkielman P. Embodiment and Emotional Memory in First vs. Second Language. Front Psychol 2017;8. https://doi.org/10.3389/fpsyg.2017.00394.

[36] Braet W, Noppe N, Wagemans J, Op de Beeck H. Increased Stroop interference with better second-language reading skill. Q J Exp Psychol (Hove) 2011;64:596–607. https://doi.org/10.1080/17470218.2010.513735.
[37] Marian V, Blumenfeld HK, Mizrahi E, Kania U, Cordes A-K. Multilingual Stroop performance: Effects of trilingualism and proficiency on inhibitory control. Int J Multiling 2013;10:82–104. https://doi.org/10.1080/14790718.2012.708037.
[38] Mike Dacey. Association and the Mechanisms of Priming. J Cogn Sci (Seoul) 2019;20:281–321. https://doi.org/10.17791/jcs.2019.20.3.281.
[39] American Electroencephalographic Society Guidelines for Standard Electrode Position Nomenclature. J Clin Neurophysiol 1991;8:200–2. https://doi.org/10.1097/00004691-199104000-00007.
[40] Müller A, Vetsch S, Pershin I, Candrian G, Baschera G-M, Kropotov JD, et al. EEG/ERP-based biomarker/neuroalgorithms in adults with ADHD: Development, reliability, and application in clinical practice. World J Biol Psychiatry 2020;21:172–82. https://doi.org/10.1080/15622975.2019.1605198.
[41] Markiewicz K, Kaczmarek BLJ, Kropotov JD, MacQueen WD, MacQueen BD, Pachalska M. Cognitive Dysfunctions In A Minimally Verbal (MV) Patient With Autism Spectrum Disorder (ASD). Acta Neuropsychol 2019;17:301–10. https://doi.org/10.5604/01.3001.0013.5950.
[42] Delorme A, Makeig S. EEGLAB: an open source toolbox for analysis of single-trial EEG dynamics including independent component analysis. J Neurosci Methods 2004;134:9–21. https://doi.org/10.1016/j.jneumeth.2003.10.009.
[43] Delorme A, Palmer J, Onton J, Oostenveld R, Makeig S. Independent EEG Sources Are Dipolar. PLoS One 2012;7:e30135. https://doi.org/10.1371/journal.pone.0030135.
[44] Makeig S, Onton J. ERP features and EEG dynamics: An ICA perspective. In: Luck SJ, Kappenman ES, editors. Oxford Handb. Event-Related Potential Components, 2011.
[45] Onton J, Makeig S. Information-based modeling of event-related brain dynamics. Prog. Brain Res., vol. 159, 2006, p. 99–120. https://doi.org/10.1016/S0079-6123(06)59007-7.
[46] Lopez-Calderon J, Luck SJ. ERPLAB: an open-source toolbox for the analysis of event-related potentials. Front Hum Neurosci 2014;8. https://doi.org/10.3389/fnhum.2014.00213.
[47] Maxwell S. Pairwise multiple comparisons in repeated measures designs. J Educ Behav Stat 1980;5:269–87.
[48] Wilcox R. New designs in analysis of variance. Annu Rev Psychol 1987;38:29–60. https://doi.org/10.1146/annurev.psych.38.1.29.
[49] Games PA. Multiple Comparisons of Means. Am Educ Res J 1971;8:531–65. https://doi.org/10.3102/00028312008003531.
[50] Hancock GR, Klockars AJ. The quest for α: developments in multiple comparison procedures in the quarter century since. Rev Educ Res 1996;66:269–306. https://doi.org/10.3102/00346543066003269.
[51] Howell DC. Statistical Methods for Psychology. 8th ed. Wadsworth: Cengage Learning; 2013.
[52] Altman DG, Gore SM, Gardner MJ, Pocock SJ. Statistical guidelines for contributors to medical journals. Br Med J (Clin Res Ed) 1983;286:1489–93. https://doi.org/10.1136/bmj.286.6376.1489.
[53] Hanslmayr S, Pastötter B, Bäuml K-H, Gruber S, Wimber M, Klimesch W. The electrophysiological dynamics of interference during the Stroop task. J Cogn Neurosci 2008;20:215–25. https://doi.org/10.1162/jocn.2008.20020.
[54] Feroz FS, Leicht G, Rauh J, Mulert C. The Time Course of Dorsal and Rostral-Ventral Anterior Cingulate Cortex Activity in the Emotional Stroop Experiment Reveals Valence and Arousal Aberrant Modulation in Patients with Schizophrenia. Brain Topogr 2019;32. https://doi.org/10.1007/s10548-018-0677-0.
[55] Feroz FS, Salman AR, Mat Ali MH, Ismail AI, Devi SI, Subramaniam SK. Attentional bias during public speaking anxiety revealed using event-related potentials. Indones J Electr Eng Comput Sci 2021;24:253. https://doi.org/10.11591/ijeecs.v24.i1.pp253-259.
[56] Pan F, Lu Q, Chen Y, Wu X, Li Q. Emotional conflict occurs at a late stage: evidence from the paired-picture paradigm. Transl Neurosci 2016;7:56–61. https://doi.org/10.1515/tnsci-2016-0009.

[57] Fisher JE, Sass SM, Heller W, Silton RL, Edgar JC, Stewart JL, et al. Time course of processing emotional stimuli as a function of perceived emotional intelligence, anxiety, and depression. Emotion 2010;10:486–97. https://doi.org/10.1037/a0018691.

Corresponding author:
Farah Shahnaz Feroz, Pervasive Computing & Educational Technology (PET), Fakulti Kejuruteraan Elektronik dan Kejuruteraan Komputer (FKEKK), Universiti Teknikal Malaysia Melaka (UTeM), 76100 Durian Tunggal, Melaka, Malaysia
e-mail: shahnaz@utem.edu.my