Original Article

Cognitive process in high neuroticism: incompatible flexibility in frontal brain region

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Abstract:

Objective: This study examines the difference of interference effect in high and low neuroticism.

***Material and Methods*:** Low and high groups of neuroticism performed the congruent and incongruent Stroop Colour Word task in the Event Related Potential session. The ERP P300 was extracted and analysed.

***Results*:** High neuroticism exhibited larger P300 amplitude than low neuroticism in both congruent and incongruent condition.

Conclusion: High neuroticism appraises conflict and non-conflict condition under incompatibility manner driven by prefrontal cortical top–down control.

Keywords: evoked potentials; interference effect; neuroticism; response inhibition

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Introduction

Neuroticism is a trait that is prone to experience negative feelings and emotional instability.[1] Neuroticism has been found to worsen many aspects of achievement in life and had been reported to have negative impact on mental process.[2,4,5]

Past studies have linked neuroticism with emotional reactivity and emotion regulation where sympathetic nervous and limbic systems are involved. The limbic system which consists of the hippocampus, amygdala, septum, and hypothalamus, regulates emotional states such as fear, anxiety, and aggression. In past studies, the amygdala that is a major part of the brain has become an interest in the search for the neurobiological underpinning of neuroticism.[6,7,8]

Individual characteristic such as neuroticism can be a predictor of problematic outcomes in cognitive, emotional and behavioural realms. Cognitive flexibility - the ability of an individual to work efficiently to shift attention by efficiently changing to a new task and give responses at appropriate behaviour level, [9] is part of central aspect of executive functioning which relies on the prefrontal cortex (PFC). In this study, cognitive flexibility was measured at a neuronal level by recording the electroencephalography (EEG) - the summed electrical activity of populations of neurons (pyramidal cells), through the event-related potential (ERP) technique.[10] The P300 – a large positive waveform observed at approximately 300 milliseconds after stimulus presentation, is associated with engagement of attention and involuntarily shifts to changes of the stimuli representations.[7,11,12] It is justified that cognitive system with a high flexibility is able to switch from one task to another in a fast and efficient way resulting from the high speed of mental process.

Materials and Methods

Participant characteristics

This study was participated by 20 volunteers living in Kuala Lumpur, recruited through the convenient sampling. Ten participants (6 men and 4 women) were classified as low neuroticism group (mean=10.6±2.95) and another 10 participants

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(3 men and 7 women) were classified as high neuroticism (mean=22.20±0.71). Mean age for the low neuroticism group was 31.8±5.67 years old, meanwhile for the high neuroticism was 29.1±6.62 years old. All participants were right-handed, had no major medical history or psychiatric illness and had normal-to-corrected vision. Most of them were diploma and bachelor holders.

Procedure

Upon agreement to participate, consent was obtained from participants and the procedure of the study was briefed in detail. In the first part of the study, participants were asked to respond to the Malay Version of FF-NPQ (Neuroticism) scale to determine their level of neuroticism. This scale has four items (in the form of illustration) depicting neuroticism related behaviour that was responded by using 1-7 likert scales from 1 (extremely unlikely) to 7 (extremely likely). Internal construct of the scale was established and reported elsewhere.[13]

In the next part, participants were prepared for the EEG recording in the Event-Related Potential session in which a net cap (consists of 32 electrodes sites corresponding to the 10-20 system) was fitted on their head (scalp). During the ERP session that was held in Clinical Neuroscience Laboratory, participants performed the Stroop task, by which 288 stimuli of two different stimuli types (congruent colour-word stimuli and incongruent colour word stimuli) were presented. This task was derived from an adapted version of the Stroop colour-word task.[14] The STROOP task was widely used to measure the aspect of response inhibition in executive functioning which consists of a baseline task (congruent) and an incongruent task. 'Interference effect' or 'stroop effect' (which refers to the time taken to perform the latter task compared with the basic task) was gathered to indicate the participants' ability to attend selectively to the relevant colour and to suppress processing of the irrelevant word meaning. The psychometric property of the STROOP has long been established in previous reports.[15]

In order to avoid the language bias, Malay words were used. For the two words of incongruent stimuli, the top row consisted of the Malay coloured words such as 'UNGU' (purple), 'BIRU' (blue), 'HIJAU' (green), 'PUTIH' (white) and 'KUNING' (yellow) printed in an incongruent colour to the coloured word (e.g. 'green' printed in red), in order to produce an interference between coloured word and coloured name. The bottom row was again consisted of the Malay coloured words 'UNGU' (purple), 'BIRU' (blue), 'HIJAU' (green), 'PUTIH' (white), 'HITAM' (black) and 'KUNING' (yellow) printed in white. The meaning of the letters or words (e.g. 'HIJAU' - green) at the top row was task irrelevant. The stimuli were presented in 9 blocks. Figure 1 illustrates the schematic experimental paradigm used in Event Related Potential.

During recording, a white "+" was presented for 800 ms in the black screen, followed by one-word trials (top) or two-words trials (bottom) stimuli in random and presented for 250 ms.The duration of presentation of each stimulus was 250 ms and the interstimulus interval was 1200 ms.The task involved pressing a YES or NO button depending on the answer of the stimulus that appeared on the screen. The participants pressed each button with two fingers on their preferred hand, with the wrist resting on a pad.

Ethical clearance: This study was approved by the Ethics Committee ofUniversitiSains Malaysia (reference code USM/JEPeM/19050341 -date:27 April 2020).

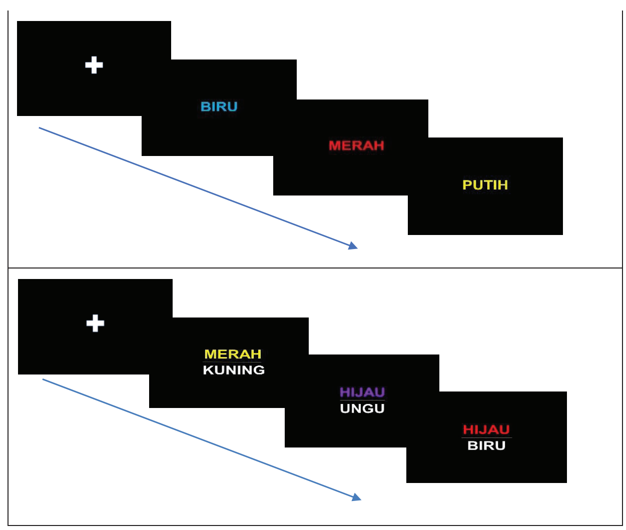

Figure 1: ERP Schematic experimental paradigm.

Analysis

The recorded EEG data from 32 electrode channels were pre-processed using Brain Vision Analyzer version 2.0 software. The ERP peak amplitudes for P300 was examined within the predefined time windows 240 miliseconds – 400 miliseconds.[16]Data was then analysed with Statistical Package of Social ScienceVersion 23. Mann-Whitney U test was used to examine the difference of the P300 amplitude between high and low neuroticism in different condition – congruent and incongruent.

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Results

P300 Amplitudes in congruent condition

High neuroticism participants had higher amplitude of P300 elicited in Fz electrode channel in response to congruent stimuli as compared to the low neuroticism (*U* = 79, *p* = .029) (Figure 2). These differenceswere highlighted in scalp topographical distributions (Figure 3). However, the difference of low neuroticism and high neuroticism was not observed in both Cz electrodes (*U* = 68, *p* = .190) and Pz electrodes (*U* = 47, *p* = .853) (Table 1).

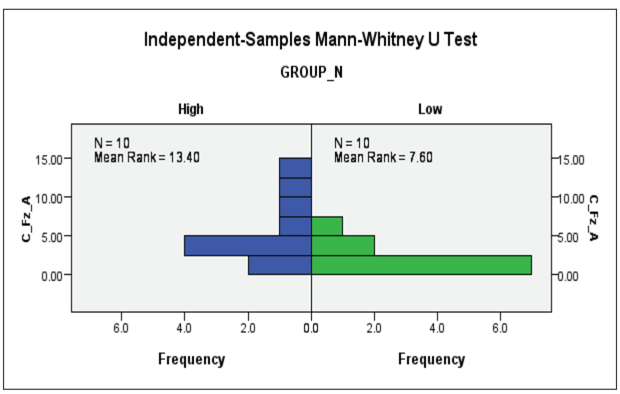

Figure 2: Frequency chart of P300 amplitude in Fz (frontal) electrode channel for congruent stimuli

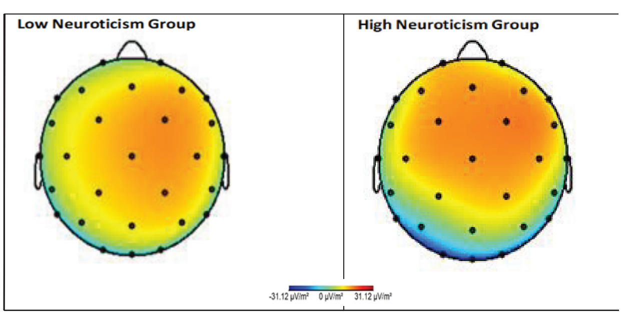

Figure 3: Topological distribution of the ERP components at the maximum peaks of P300 (240 ms – 400 ms) for Low Neuroticism (Left) and High Neuroticism (Right) in congruent stimuli

Table 1. P300 amplitudes elicited in low neuroticism and high neuroticism in responses to congruent condition

Electrode Site	Group	Mean Rank	Sum of Ranks
Fz	Low (N=10)	7.6	76.00
	High (N=10)	13.40	134.00
Cz	Low (N=10)	8.7	87.00
	High (N=10)	12.30	123.00
Pz	Low (N=10)	10.80	108.00
	High (N=10)	10.20	102.00

P300 Amplitudes in incongruent stimuli

High neuroticism participants had significantly higher amplitude of P300 elicited in Fz electrode channel in response to incongruent stimuli as compared to the low neuroticism (U = 80, *p* = .023) (Figure 4). This significant difference can be seen clearly highlighted in the topographical distribution map (Figure 5). However, the differences were not exhibited by other two electrodes - Cz (*U* = 70, *p* = .143) and Pz (*U* = 49, *p* = .971) (Table 2).

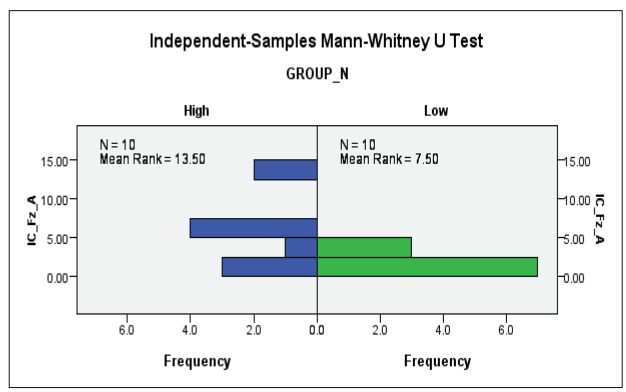

Figure 4: Frequency chart of P300 amplitude in Fz (frontal) electrode channel for incongruent stimuli

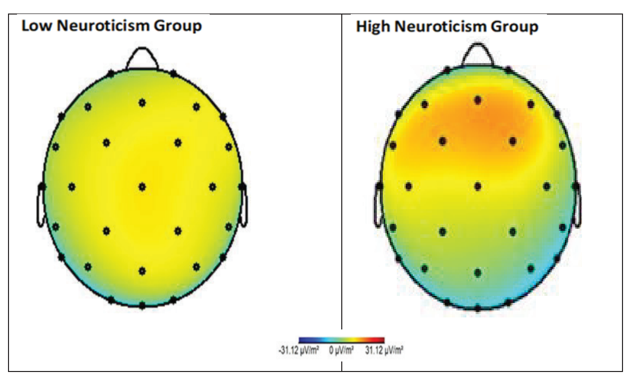

Figure 5: Topological distribution of the ERP components at the maximum peaks of P300 (240 ms – 400 ms) for Low Neuroticism (Left) and High Neuroticism (Right) in incongruent stimuli

Table 2. P300 amplitudes elicited in low and high neuroticism in responses to incongruent condition

Electrode Site	Group	Mean Rank	Sum of Ranks
Fz	Low (N=10)	7.50	75.00
	High (N=10)	13.50	135.00
Cz	Low (N=10)	8.50	85.00
	High (N=10)	12.50	125.00
Pz	Low (N=10)	10.60	106.00
	High (N=10)	10.40	104.00

Discussion

The cognitive flexibility was operationalized based on the Stroop task's underlying concept that the processing of a stimulus feature affects the concurrent processing of a second stimulus attributealso known as the interference effect.[17]Thus, the cognitive process involved in performing this stroop task is understood as cognitive interference control - an ability to resist distracting stimuli that requires selective attention and information processing.

Noted that, a larger value of P300 amplitudes were elicited by high neuroticism than low neuroticism across the midline electrode channels for both stimuli condition. As the P300 amplitudes is reflected as attention resources allocated, it has been manifested that high neuroticism put more attention while performed the Stroop task during the experiment. This concept of attention can be well understood in the theoretical framework of selective attention.

Human's capacity to process information is limited, but by selective attention it enables us to ignore irrelevant stimuli while focusing on relevant stimuli in the environment. Selective attention basically can be classified into two types of process based on aperceptual system named involuntarily (bottom-up) and voluntarily (top-down). Bottom-up process is based on the stimulus feature that is, distinctive features of stimulus express high contrast and this permits them to capture attention more effectively as compared to stimuli whose features are similar.[18] On the other hand, the top-down processing is a cognitive process that focus on relevant information of stimuli to direct current behavioral goals.[19] As the Stroop task demands allocation of attention resources because this task requires information to be selectively processed in the brain while irrelevant information is filtered out, thus top-down attention process looked more compromise to discuss in this paper.

Based on the results, it has been shown that among all the midline site electrodes, only the Fz (frontal region) showed significant difference of P300 amplitude for both congruent and incongruent stimuli between the low neuroticism and high neuroticism. According to 10/20 system, the electrode channel of Fzcorresponds to the frontal region that has basic brain functions including attention, motor planning, judgement, emotional expression, verbal expression and working memory.[20]

Over the years, researchers have done testing and experiments to patients with damage on the frontal cortex and the results showed the patients had specific deficits in the executive functions. All these evidences led to acceptance to the fact that frontal cortex plays crucial role in the executive functions. Furthermore, a vast array of neuroimaging studies have shown activation in the prefrontal cortex (PFC) when the Stroop task was performed, indicating PFC as a region that is responsible to provide signals in the top-down attention process.[21,22] The prefrontal cortex (PFC) provides top-down signals to the extrastriata cortex in order to selectively process relevant sensory information. Larger P300 amplitudes in the frontal region was elicited as a result of the activation in the top-down process and thus, this study reinforced evidence in the role of PFC in the selective attention.

Based on the current results, this study showed that high neuroticism exhibited greater attention resources and greater processing of information when attending both stimuli (congruent and incongruent). Neuroimaging studies had suggested the involvement of amygdala (as part of the limbic system) in attention process.[23,24] Thus, it can be predicted that prefrontal cortical top–down control contributes to the inhibition of responses generated by limbic functioning,[25] which might include emotional responses in which individuals with neurotic personality would appraise the challenge as more stressful and display more negative effect following the experience. Therefore, individual differences in association to limbic system can influence the cognitive process due to stress responses in reaction to stimuli and consequently increase in intensity and high concentration of attention.[24,26] as well as implication on emotional process.[27] However, the finding of the current study should be taken with caution due to the small sample size and the enlightment of cognitive flexibility from the single measure of P300 component without looking at other components. The neural process of the ERP components such as N400-600 should be highlighted in future research to understand conflict monitoring and cognitive control in neuroticism.

Conclusion

High neuroticism indicates incompatible goal in cognitive flexibility from the response inhibition in conflict and non-conflict conditions. Prefrontal cortical top–down control subsidises the inhibition of responses in high neuroticism.

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Conflict of interest

The authors of this manuscript declare that they have no conflict of interest concerning its drafting, publication, or application

Authors’s contribution:

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Data gathering: Norrul Aikma Mohamed

Writing and submitting manuscript: Nasir Yusoff, Norrul Aikma Mohamed

Editing and approval of final draft: Nasir Yusoff, Norrul Aikma Mohamed, Nor Azila Noh

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