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Technical paper

The Significance of Delta Wave Among Athletes

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Abstract

This article reports on the differences between the physiological response of the brain between athletes and non-athletes by using Quantitative Electroencephalography (QEEG). EEG waves were observed using qEEG and analysis were compared between the two groups. This research involved 41 undergraduates of Universiti Malaysia Sarawak (UNIMAS). The qEEG recordings were made during the Eyes opened, Eyes Closed, and Stroop task conditions to find out the dominant wave during each of the conditions in different region of the brain. The results revealed higher EEG Delta and Beta1 at frontal region (Fp1, Fp2), somatosensory, (C3, P4) and visual spatial area (P3, P4). Delta, Beta and Gamma wave were dominant while the participants were performing the Stroop Task. Coupling of delta and beta oscillations might be due to the athletes' anxiety during the Stroop task. In Eyes Closed state, delta and alpha wave were dominant at the fronto-parietal attention network area. This study contributes to the development of training protocol for neurofeedback training for athletes in preparation for training of peak performance in any sports activity. It is recommended that extensive analysis should be done on the interaction of delta-gamma oscillations in different parts of the brain to find out its implication on attention and emotion during the cognitive process.

***Keywords*:** *Athlete; Delta; EEG; qEEG; Sports.*

1. Introduction

Previous literature in sports explained the underlying neuro mechanism of motoric actions and decisions made in facing the challenges in different field of sports activities such as darts' throwing and pistol shooting. Such kinaesthetic moves required quick decisions because it is part of a dynamic strategy to face the continual mix of intricate challenges. Sometimes a slight movement of one arm require quick adjustments in other parts. In most of the sports, athlete's actions are part of a dynamic strategy to deal with an everchanging mix of intricate challenges [1]. For example, raising a gun resulted in a new calculation of movement for a precise shooting. Accumulation of evidence has shown that diet and lifestyle plays a vital role especially in delaying the onset and progression of the age-related health disorders and improve the cognitive function of an individual [2]. In most of the mental tasks, focus and concentration are required which were accompanied by spectrum of delta oscillations to inhibit the other processes which interfere with the resolution of the mental task.

In a study [3] on the neurobiological bases of attention there are separate neural systems that mediate different aspects of attention. Currently, two functionally distinct and potentially competing brain networks have been identified, which can be broadly distinguished by their contrasting roles in attention to the external world vs. the internally directed mentation involving long-term memory [4]. The dorsal attention system is supporting externally directed cognition [5] and the hippocampal-cortical memory system or the ventral system that linked to internally directed cognition often labeled as default network (ventral medial prefrontal cortex, the posterior inferior parietal lobule, the retrosplenial cortex, the posterior cingulate, and the lateral temporal lobe) [6]. The third system is the fronto-parietal control system, which includes many regions identified as supporting cognitive control and decision-making processes, including the lateral prefrontal cortex, the anterior cingulate cortex, and the inferior parietal lobule [7]. Attention has two complementary components: an intensive, selective component which applies to the initiation and execution of action, seems based primarily in dorsolateral frontal cortex, and an exclusionary one, is the equivalent of the inhibitory control of interference primarily based in ventral frontal cortex. Selective executive attention can be understood as a property of frontal networks in operation. In the perceptual and action cycle, executive attention would shift from one domain of action to another as different networks excite one another [8]. Another executive attention subfunction is the interference control primarily based in the orbitomedial prefrontal cortex. By suppressing distraction, executive attention is served. Several neuroimaging studies showed that any task requiring concentrated attention activates areas of the lateral and medial prefrontal cortex in addition to the posterior cortical areas of the perceptual specialization. It was proposed that delta increases during mental calculation, and this increase correspond to what they called "internal concentration"]. These authors later demonstrated that this delta activity is present in many other tasks that require internal concentration [7]. In previous study, it was evaluated the cross-frequency coupling between delta and beta oscillations; increases in the correlation between these two oscillations were present during anxiogenic situations in the orbitofrontal and anterior cingulate cortices [9].

Researchers from John Hopkins University, and John Krakauer of Columbia reviewed studies related to scanning of the brains of healthy and brain-damaged patients who have problems with their movement [10]. Their research revealed that that the brain continues updating the solution and calculation to adjust body movement. Athletes mind are sharp in finding better solution when

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faced with conflict in decision making. Optimal Feedback Control is a recent formulation of the computational motor control framework where it mentions that there are 3 basic foundation of the computation that can be described where first, the need to accurately predict the consequence of the commands of the motor movement, secondly the need of combination of prediction of actual sensory feedback to formulate the judgment regarding our state of body and world, and thirdly, in order for our movements to maximize some measure of performance there will be a need to adjust the gain of our sensorimotor feedback loops to balance the cost and reward of the movement optimally..

In other experiments, athletes and non-athletes were given the same tasks while qEEG were used to record their brainwaves. It was reported that the brain waves of karate champions and ordinary people were recorded with their eyes closed, and differences between the waves were compared [11]. The research team has also measured the brain waves of athletes and non-athletes in actions. It was found that the athlete generates stronger alpha rhythm in as restful state [11] and studies on pistol shooters that fired 120 times and fencers balance on one foot showed that the brains were quieter than the non-athletes. The results suggest that the athletes' devoted less brain activity on motor tasks. The findings suggest that an efficient brain does a better job in sports to improve the cognitive functioning of human brain. When people were involved in running, walking or exercises, these could help to improve their focus and performance in mental activity [12]. Thus, more practices are needed to develop the efficient brain of an athlete. As one's starting to practice new skills in sport, the neuroscience started to communicate change to develop extra grey matter in some of the related area indicating brain plasticity during the duration of the practices. It will continuously change with more practices for peak performance. In this state of mind, the experienced athletes demonstrate big bursts of alpha wave activity compared to novice athletes that shows less alpha brain wave activity.

Exercise can produce and increases several neurons or neurogenesis [13]. Rebirth of new neurons and its activation on the other hands depends on the exercise or brain exercise done by the individual involved. Researchers suggest that the formation of new neural cells and endothelial cells which is used to form a new capillary is derived from the same pool of stem cells [14]. Previous study has demonstrated the relationship between the number of neurons generated in mouse dentate gyrus and the degree of increase in regional CBV which obtained and measured by MR [15]. The result from the study indicates that after 3 months of aerobic exercise, there is a significant increase in regional cerebral blood volume (rCBV). It was concluded that regions of the brain responsible for angiogenesis such as cerebral cortex and cerebellum is capable of neurogenesis [14] It was also mentioned that health is an important factor in fostering the child's ability to learn apart from excelling in academic performance which stems from the child's complex interaction between their intellect and variables surrounding them. It was reported that the basis of the top performance of sports relies on the dynamics of the brain itself [16]. Individuals who exercise and athletic interacted has higher self-control compared to individuals who did not have any interaction with physical activity [17].

In this research, the main objective was to highlight the dominant wave underlying the mechanism of attention networks in cognitive processing of athletes during the quick decision making and mental calculation of movements to be made in response to the external stimuli. Brain wave recordings on the athletes and non-athletes were done while performing the Stroop task which is similar to making the movement or mental calculation during sports. This research utilized qEEG to identify the dominant wave in the athletic and non -athletic brain. The presence and increase of different EEG bands and sub bands in different cognitive tasks indicated the brain plasticity of both groups involved in the study.

2. Methods

This is a quantitative observation study using quantitative electroencephalogram (qEEG) to record the brain wave signals from athlete and non-athlete participants. The results from both group were compared using graphical presentation to observe and analyse the brain wave in the region of interest (ROI). The participants were given tasks to perform and the brain frequencies and waveform were recorded for analysis of different sub-bands.

The instrument used in this study is a neurophysiological assessment that can measure the level of cognition, which is the Stroop test. The Stroop test is a type of neurophysiological assessment which evaluates on the perceptual speed and executive function [18]. The Stroop test is a reliable test that measure a different component of physical fitness such as the level of aerobic fitness, muscle, and body composition. The Stroop task has been vastly used to study the attentional processes. It was described that a task where "a word such as red might appear in green ink, the word brown in red ink, and so on" [19].

In this research, the participants consist of 41 undergraduates of First year and Final year undergraduates from Universiti Malaysia Sarawak (UNIMAS) who volunteered to participate in the research (Table 1). Twenty were athletes and active in sports where 21 were non-athletes selected to find out the difference in brainwave during the Stroop test performance and Eyes closed conditions and the related brain networks involved during the mental tasks.

Table 1: Total number of participants

Participant	Boys	Girls	Total
Athlete	10	10	20
Non-athlete	2	19	21
Total	12	39	41

The procedure of this study begins by using qEEG (Mitsar amplifier) which consists of 19 electrodes Fp1, Fp2, F7, F3, Fz, F4, F8, T3, C3, Cz, C4, T4, T5, P3, Pz, P4, T6, O1, O2 sites in the International 10-20 system) with 250 Hz sampling rate in 0.3 – 70 Hz frequency range in the resting eyes opened (EO) conditions [23]. During the study, the participants sat comfortably on a sofa for approximate from 10-30 minutes to allow the brain wave recordings comfortably in a relax state. This condition is then stored in the computer using EEG. This step is vital to ensure any interference of the artefacts such as the movement of the participant, noise etc. are removed to obtain a clean and raw data. Hence, the steps are visually inspected and Fast Fourier Transform (FFT) are computed to provide spectral analysis output to examine for peculiar patterns. The, the output is then displayed as topographical "map" to identify for differences in cerebral functioning using estimates of absolute and total power.

3. Discussion of Findings

3.1. Brain Networks (Region of interest)

The core cognitive mechanism during the performance of Stroop test was the attention network collectively referred as fronto-parietal attentional control network. EEG delta, beta and gamma were dominant at this region when the subjects are actively engaged in Stroop test. The attention mechanism allows the brain to utilize the limited resources depending on the tasks given.

3.2. Difference in Brainwave Pattern of Athlete versus Non-Athletes in Eyes Closed (EC) and Brainwave Pattern of Athlete during Stroop Effects Task

3.2.1. Brain Wave Pattern of Athlete during Stroop Task versus Eyes Closed (EC) Conditions

In Figure 1, we can see higher delta and Beta1 wave at the Frontal region (Fp1, Fp2), somatosensory area (C3, C4) to reveal the development of the psychomotor skills and visual spatial area (P3, P4). This area is collectively called fronto-parietal attentional control network area that engaged in attentional allocation in humans and non-human primates [7]. It was identified as supporting cognitive control and decision-making processes, including the lateral prefrontal cortex, the anterior cingulate cortex, and the inferior parietal lobule [7]. Another executive attention subfunction is the interference control primarily based in the orbitomedial prefrontal cortex. Delta and Gamma increases correspondingly throughout the attentional allocation over the frontal, parietal and visual areas. The Athletes group performed the Stroop effects tasks where they are required to allocate visual spatial attention to the left and right visual field for the detection of stimuli. We can conclude that athletes need to be calm and relax while facing their challenge so that they can focus on their target. The results highlighted the role of EEG delta and beta2/Gamma in the mechanism of coordination and attention within the Fronto-parietal area (Figure 1) Interactions within or between these bands such as high gamma and delta have been proposed to serve as mechanisms for coordination within and between brain networks engaged in cognitive processing [20].

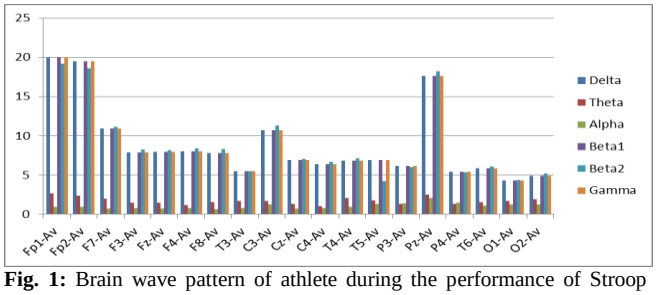


Fig. 1: Brain wave pattern of athlete during the performance of Stroop effects

With practice and exercise, different regions of the brain communicate with each other to strengthen their connections [7]. Neurons in the frontal part of the brain (the prefrontal cortex) are active. The prefrontal cortex or the executive functions region are vital for the decision-making task and focus to enable the athletes to perform well in sports. It was suggested that increased alpha activity was related to an increased accuracy. With practice, the frontal cortex grows quiet and the athletes' calculation and movement becomes accurate [21]. The response becomes automatic as their brain becomes more efficient in adapting and tuning in to make sense of new situation sooner [1].

EEG Delta were still dominant in Eyes Closed conditions among athletes. Beta2 and Gamma were almost not visible (Figure 2). Alpha naturally increases in most of the EEG studies.

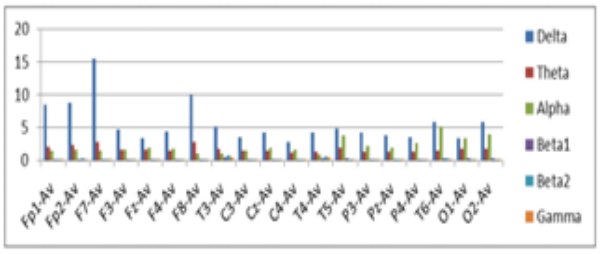


Fig. 2: Brain wave pattern of athlete during the Eyes Closed

3.2.2 Brainwave Pattern of Non-Athletes during the Stroop Task versus Eyes Closed (EC) Condition

Delta dominated the Frontal region (F7), central region (C3, Cz), Temporal region (T3, T4, T5 and T6) and Occipital area (O1, Oz). This is followed by EEG alpha and theta at the occipital and temporal area. Overall the brain waves showed slow cortical activity compared to the Stroop task. The subjects were in a state of calm and relaxed. Figure 3 showed different brainwave pattern of Non-athletes during the Stroop effects task.

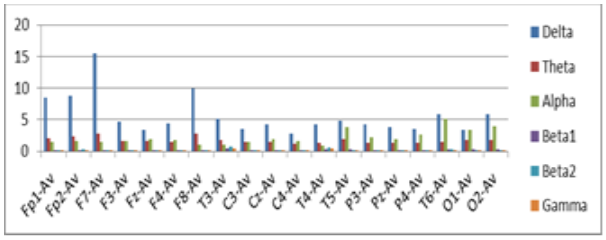


Fig. 3: Brain wave pattern Of non-athlete during the performance of Stroop effects

The brainwave pattern of non-athletes shown in the Figure 4 appeared similar to the conditions during the Stroop effect tasks and during the Eyes closed resting condition with higher alpha at temporo-parietal area and occipital lobe, which is normal for any subjects in a relax and closed eyes conditions. However, EEG gamma did not increase in correspondent with EEG delta as can be seen in the athletes' brain while performing the Stroop task. The difference could be seen in the strength of probable interaction between the low frequency EEG delta and high gamma in the prediction of subjects' attentional behaviour while facing the intricate challenges. The increase of delta corresponds with the internal concentration in any mental tasks [22].

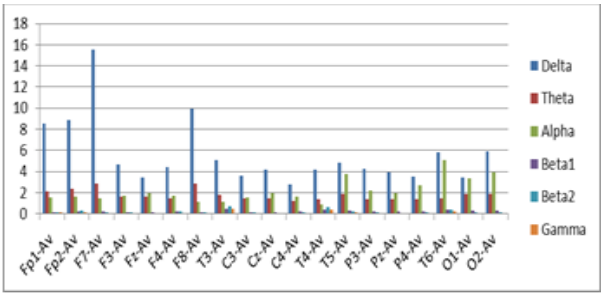


Fig. 4: Brainwave patterns of non-athlete during the Eyes Closed

In the Eyes Closed conditions, the brain wave patterns are similar with higher EEG delta followed by Alpha and theta (Figure 4). EEG gamma were almost non-existence.

4. Conclusion

We found increases in EEG delta, beta and gamma that remained elevated throughout the attentional allocation period over fronto-parietal attention network in the athletes' brain. These results highlight the role of EEG delta and gamma as mechanism for sub-second facilitation and coordination within human fronto-parietal cortex that is guided by momentary attentional demands. The brainwave pattern of athletes was dominated by delta wave which indicates the importance of focus and attention not only during the sports but for the importance of health and intelligent quotient. Hence, this study contributes to the development of training protocol for Neurofeedback training for the athletes in preparation of training for peak performance in any sports activity. In this context, elevating the alpha/theta ratio is the best protocol to suppress high EEG gamma activation that exist in a high anxiety situation. Alpha protocol was originally developed to produce a hypnogogic state for enhancing creativity when benefits were found in enhanced wellbeing and psychic integration stage.

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