Dynamics of Scalp Potential and Autonomic Nerve Activity during Intelligence Test

Hafeez Ullah Amin[1], Aamir Saeed Malik[1,*], Ahmad Rauf Subhani[1], Nasreen Badruddin[1], and Weng-Tink Chooi[2]

[1] Centre for Intelligent Signal and Imaging Research (CISIR), Department of Electrical and Electronics Engineering, Universiti Teknologi PETRONAS, Perak, Malaysia
{aamir_saeed,nasreen.b}@petronas.com.my
[2] Advanced Medical and Dental Institute (AMDI), Universiti Sains Malaysia
wengtink@amdi.usm.edu.my

Abstract. The main objective of this study was to examine the changes in autonomic nervous system (ANS) and scalp potential during intelligence test (IQ). Electroencephalogram (EEG) and Electrocardiogram (ECG) signals were recorded simultaneously from eight healthy participants during IQ and resting states (eyes–closed and eyes-open). Heart rate (HR) and heart rate variability (HRV) were derived from ECG signal. EEG mean power was computed for five frequency bands (delta, theta, alpha, beta, and gamma) and analyzed in 12 regions across the scalp. The EEG frequency bands showed significant ($p<0.025$) changes between IQ test and rest states. Delta and theta at frontal (PF, AF, F) and temporal regions (FT, T, TP) and alpha activity at parietal (P), parieto-occipital (PO) and occipital (O) regions were significant. In beta and gamma bands, highly reduced mean power was found at P, PO, and O regions as compared to PF, AF, and F regions in IQ test. HR and low frequency in normalized unit (LFnu) were increased significantly ($p<0.05$ and $p<0.025$, respectively) in IQ test. Further, high frequency in normalized unit (HFnu) was decreased ($p<0.11$). Results showed parallel changes in scalp potential and automatic nervous activity during IQ test compared to rest conditions.

Keywords: EEG frequency bands, asymmetry, intelligence test, autonomic nervous system.

1 Introduction

In neurophysiological research, brain imaging techniques such as magnetic resonance imaging (MRI) [1] and electroencephalography (EEG) [2] allow researchers to view human brain activities non-invasively. EEG power analysis in different frequency bands indicates the number of neurons that activate or de-activate simultaneously during certain mental states [3]. EEG power is a measure that reflects the cortical

* Corresponding author.

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activity or cortical information processing. EEG power was positively correlated with performance in intelligence test [4]. Mostly, alpha and theta activities were associated with intelligence related tasks in previous studies. Positive connection was reported between intelligence and alpha power [5]. Alpha activity desynchronization and theta activity synchronization were explored in intelligence and complex cognitive tasks [6]. Increased sample entropy value was reported in intelligence test as compared to eye-closed condition [7].

Brain cortical activity is inversely related to alpha power, i.e., higher alpha power represents lower cortical activity and vice versa [8]. Inter-hemispheric EEG cortical activities during different mental and stress environment are investigated using alpha asymmetry index [4]. It is stable and widely accepted measure which inversely associates cortical hemispheric activity, i.e., positive alpha asymmetry value reflects greater relative left than right activity, and negative alpha asymmetry value indicates greater relative right than left activity [8].

Autonomic nervous system (ANS) consists of sympathetic nervous system (SNS) and parasympathetic nervous system (PSNS). These are responsible for heart-brain relationship [9, 10]. Heart behaves excitation and inhibition under SNS and PSNS influence, respectively. Heart rate variability (HRV) is a measure of heart SNS/PSNS innervation. The associated components of HRV power spectrum includes very low frequency (VLF: 0.04Hz), low frequency (LF: 0.04 to 0.15Hz), and high frequency (HF: 0.15 to 0.4Hz) [10]. HF component is influenced by parasympathetic activity, while LF follows both sympathetic and parasympathetic involvements. Further, the LF and HF can be expressed in normalized unit (nu), where nu is equal to LF or HF divided by total power minus VLF value. LF in normalized unit (LFnu) is attributed to sympathetic and the ratio of LF and HF is representation of sympathetic to parasympathetic distribution [9]. Recent ECG and EEG studies reported changes in ANS activity with mental arithmetic task [11].

Individuals who are strong in analytical and cognitive abilities are conventionally viewed as smart and intelligent [12]. Raven's Advance Progressive Matrices (APM) test is a psychological standardized cognitive ability test, which is used to measure an individual's higher order mental reasoning ability, logical thinking, and general intelligence. It is designed to discriminate among individuals of "superior intellectual ability". It is routinely used as a selection methodology for high stakes situations such as defense training, research, and medical education [13].

The purpose of this work is to study the behavior of EEG and ECG signal simultaneously in university students while performing intelligence test (IQ). Two research questions were investigated: 1) are there any changes in ANS during complex mental reasoning process? 2) Which brain regions show discrimination in EEG frequency bands between IQ test and rest states?

The paper is organized as follows: the material and method is described in section 2. Section 3 presents the EEG and ECG results and discussion, while conclusion and future work is given in Section 4.