Statistical Analysis of Balanced Brain and IQ Applications

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***Abstract*— EEG signal research had been studied massively in such balanced brain and IQ applications. This paper focuses on correlation between balanced brain and Intelligence Quotient (IQ) applications. At first, the raw EEG signals from both applications need to pre-process to remove artefact and unwanted frequency. Then, the EEG signals will go through statistical processes which are Scatterplot and Correlation test. As a result, there is correlation between the balanced brain and IQ application with strong and significant Pearson correlation.**

***Index Terms*—EEG signals, Balanced brain, IQ, Pearson correlation.**

I. INTRODUCTION

Human brain consists of two hemispheres, which are the right hemisphere and left hemisphere. The right hemisphere refers to abstract and artistic thinking while the left hemisphere refers to analytical and logic thinking [1]. The behaviour of the both hemispheres can be studied and measured using brainwaves. Electroencephalogram (EEG) is a well-known device used to measure human brainwaves since 1929. The EEG device does the brainwave analysis based on frequency band. There are four frequency bands (Delta-band, Theta-band, Alpha-band and Beta band). When compared to other bands, Delta-band has very large amplitude and slowest frequency oscillation while, Beta-band has very small amplitude and highest frequency oscillation [2].

The human brainwaves has been studied in immense applications such as Epilepsy, brain-computer interfacing (BCI), Intelligence Quotient (IQ) but very few studies were done on balanced brain [3]. This works focused on two applications, which are balanced brain and IQ.

The exploration of balanced brain started with the research of brain dominance that specifically examined language dominance [4]. A good mathematician is claimed to be of left dominance while amazing artist is claimed to be the opposite, but there is little study for people with both, right and left dominance. The study for equal use of right and left brain optimally is termed balanced brain. It has been reported that a person who used both brain equivalently produce a healthy life [5]. In contrast imbalanced brain may cause physical pain and stress [6]. A balance brain is important because it provides natural treatment to human in order to achieve healthy life. One study uses visual and audio in 3D games application to generate a balance brainwave [7]. In another studies, EEG biofeedback was used to help a person restore the pattern of a balanced brain [8].

The IQ test module has been used widely by psychologist, to test human intelligence subjects such as Mathematics, Music and Language. Each individual possesses personal intelligence therefore, not all test modules are suitable to test the IQ. The examples of most popular and established IQ modules are Raven test and Wechsler test [9, 10]. The IQ EEG signals analysis is another technique to assess human intelligence. However, this technique requires validation with the established IQ test module that developed by psychologist. In order to implement this technique, the samples must be controlled, for example, the participant must be relaxed throughout the EEG signals recording process. Failure to control the situation when the data collected will lead to invalid relationship between IQ and EEG signals [11].

There were several techniques that can be implemented to analyse EEG signals, among them is statistical analysis. Correlation test is the most often technique used in order to find the relationship between two or more variables. It has been reported that a correlation test can be done if the scatterplot of data is in linear shape [12]. There are researches done in EEG signals using correlation test. For example, EEG signals can be correlate with questionnaire [13], the experts [14], and other applications such as Functional Magnetic Resonance Imaging (fMRI) [15].

Based on the studies reviewed, it was found that the relationship between balanced brain and IQ is still new in EEG signals. Motivated by this findings, statistical correlation test has been performed to confirm the relationship between balanced brain and IQ applications. This paper focuses to examine the correlation of balanced brain and the IQ applications.

II. METHODS

The EEG signals recorded with reference at earlobe A1, A2 and Fpz and two channels Fp1 (left channel) and Fp2 (right

channel). The signals were collected using g.MOBIlab and transferred wirelessly to the computer (Figure 1). The sampling rate is 256 Hz. The experiments were set up at Biomedical Research and Development Laboratory for Human Potential, Faculty of Electrical Engineering, Universiti Teknologi MARA.

A. Subject.

The EEG signals were collected in two different sessions for balanced brain and IQ applications. 51 participants (20 males, 23 females) EEG signals were collected for balanced brain applications. The EEG signals were recorded for 5 minutes with eyes-closed. Prior to experiment, the participants need to answer 15 questions in Brain Dominance Questionnaire. The calculated score of questionnaire will determine the balanced brain index. There are 5 indices, in which Index 1 refers to imbalanced brain and Index 5 refers to highly balanced brain. However, Index 1 and Index 2 contain no sample; as a result, synthetics EEG signals were generated. The synthetics were developed based on Event Related Potentials (ERP) theories [16].

Fig. 1. EEG signals recording process

50 participants (21 males, 29 females) contributed in the collection of EEG signals for the IQ application. Initially, the participant needs to close their eyes during the 5-minute EEG signals recording process. Then, the participant has to answer 20 IQ test questions with open eyes for 10 minutes. The score of IQ test is calculated and the IQ index for each participant is determined. There are 7 indices, with Index 1 referring to extremely low IQ while Index 7 referring to very superior IQ.

B. Statistical analysis.

Prior to statistical analysis, the EEG signals were filtered to remove artefacts (noise) by using threshold value. The EEG signals need to maintain signals of not more than 100 µV and less than -100 µV. Band-pass filter was used to filter unwanted EEG signals frequency. The required frequency is 0.5 Hz to 30 Hz. The Delta-band was set from 0.5 Hz – 4 Hz, the Theta-band was set from 4 Hz – 8 Hz, Alpha-band was set from 8 Hz - 13 Hz and Beta-band was set from 13 Hz – 30 Hz.

Figure 2 shows statistical analysis of this experiment. Statistical analysis starts with calculating mean and standard deviation of EEG signals for both applications. Then, histogram is generated to visualise the data distribution. The histogram pattern must be in normal curve before proceeding Scatterplot. If the histogram skewed right or skewed left, then the mean and standard deviation is reviewed. Next, Scatterplot is generated for each variable. The linear Scatterplot shows that there is correlation between the variable, while curvilinear pattern of Scatterplot shows that there is no relationship between the variable. If the Scatterplot shows curvilinear pattern, the process is terminated. Only the linear Scatterplot pattern will be go through the Pearson correlation test. The correlation test will produce positive or negative relationship between variables and the strength of values is measured between value of 0 and 1. The perfect value of correlation is 1, while 0 mean there is no relationship.

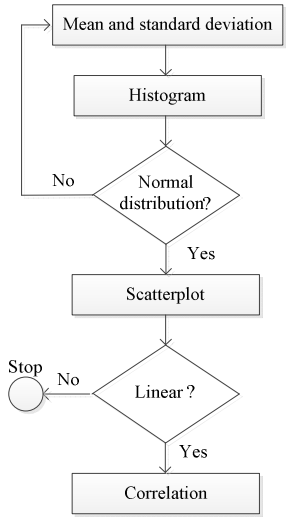


Fig. 2. Statistical analysis flow chart.

III. Result and Discussion

The Table I denotes the samples per index for balanced brain application and Table II denotes the sample per index for IQ application.

TABLE I. Number of Balanced Brain Applications Participants

Group	No. of participants
Index 1	23
Index 2	5
Index 3	9
Index 4	37
Index 5	5
TOTAL	79

TABLE II. Number of IQ Applications Participants

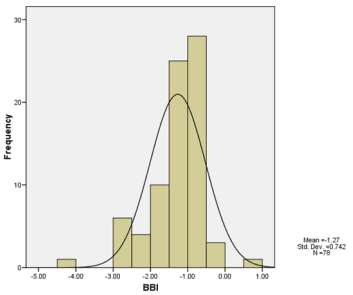
Group	No. of participants
Index 1	5
Index 2	4
Index 3	10
Index 4	12
Index 5	4
Index 6	14
Index 7	1
TOTAL	50

Table III shows the result of descriptive statistics for BBI (balanced brain application), IQ application with eyes-closed state (IQCE) and IQ application with eyes-opened state (IQOE). This analysis resulted from the combination of average reading of both right and left channels of EEG signals. The mean for the three variables is in the range of -1.1638 to -2.8006. It is observed that the value of standard deviation for the three variable do not exceed the mean value. It is important to observe the value of mean and standard deviation before proceeding to analyse the statistics.

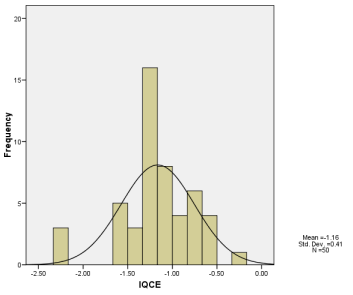
TABLE III. THE MEAN AND STANDARD DEVIATION VALUE

	Mean	Standard deviation
Balanced brain	-1.2680	0.74198
IQ (eyes-closed)	-1.1638	0.41005
IQ (eyes-open)	-2.8006	1.96445

Figure 3 (a) to (c) shows the histogram of PDF (Probability Density Function) EEG signals from the combination of average reading of both right and left channels for the balanced brain application and IQ application with eyes-closed state and eyes-opened state. It is observed that the histograms showed normal distribution and skewed to the right for all application. Again, balanced brain EEG signals were recorded during eyes-closed state, while IQ EEG signals were recorded during eyes-closed and eyes-open state. The histograms patterns for eyes-closed or eyes-open state were mostly right-skewed. It is found that most histogram pattern for participants in both close and open eyes condition skewed to the right [17].



(a)



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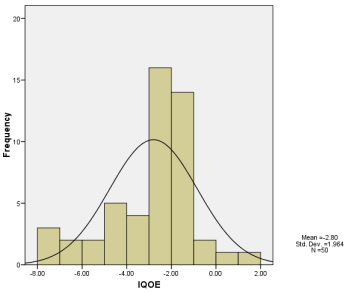
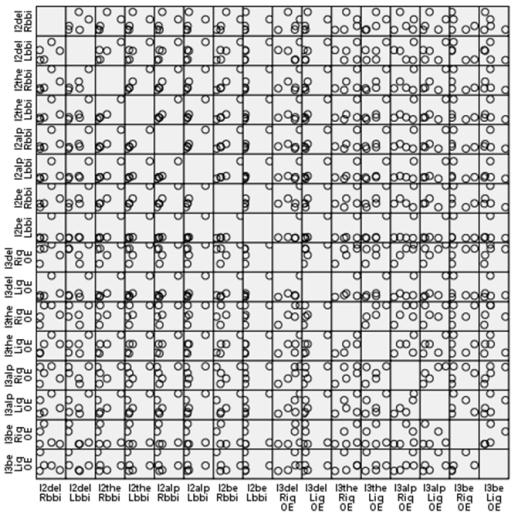


(c)

Fig. 3. Histogram for (a) balanced brain application, (b) IQ application with close eyes state, and (c) IQ application with open eyes state.

The relationship between Index 2 of balanced brain application and Index 3 of IQ application with eyes-opened state is explored through matrix scatterplot as shown in Figure 4. It is observed that the variables *I2theRbbi* to *I2beLbbi* showed positive correlation with variable *I3delLiqOE*.



The acronym:
I2 or I3 – Index 2 or Index 3
del, the, alp, be – Delta-band, Theta-band, Alpha-band, Beta-band
R or L – right channel EEG or left channel EEG
bbi or iq – balanced brain application or IQ application
OE – eyes-opened state
CE – eyes-closed state

Fig. 4. Matrix scatterplot for Index 2 from balanced brain application and Index 3 from IQ application with eyes-opened state.

The results of correlation test indicate that there is strong and positive significant Pearson correlation between *I2beLbbi* (Index 2 of beta left channel from balanced brain application) and *I3delLiqOE* (Index 3 of delta left channel from IQ application with eyes-opened state), with $r = 0.991$, $n = 5$, $p < 0.05$. Moreover, it is observed that there is a strong correlation between *I2alpLbbi* (Index 2 of alpha left channel from balanced brain application) with *I3delLiqOE* (Index 3 of delta left channel from IQ application with eyes-opened state), $r = 0.990$, $n = 5$, $p < 0.05$. Moreover, there is a strong correlation

between *I2alpRbbi* (Index 2 of alpha right channel from balanced brain application) with *I3delLiqOE* (Index 3 of delta left channel from IQ application with eyes-opened state), r = 0.983, n = 5, p< 0.05. Finally, it is seen that there is a strong and positive correlation but with a slight significant difference between *I2theLbbi* (Index 2 of theta left channel from balanced brain application) with *I3delLiqOE* (Index 3 of delta left channel from IQ application with eyes-opened state), r = 0.987, n = 5, p< 0.05.

The relationship between Index 3 of balanced brain application and Index 3 of IQ application with eyes-closed state is explored through matrix scatterplot as shown in Figure 5. It is observed that the variable *I3beRbbi* shows positive correlation with variable *I3beLCE*. It is also observed that the variable *I3delRbbi* shows positive correlation with variable *I3beLCE*.

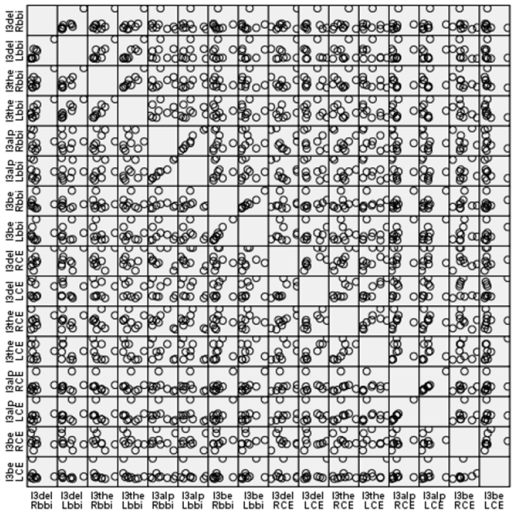


Fig. 5. Matrix scatterplot for Index 3 from balanced brain application and Index 3 from IQ application with eyes-close state.

The results of the correlation test indicate that there is a significant Pearson correlation observed between *I3beRbbi* (Index 3 of beta right channel from balanced brain application) and *I3alpRCE* (Index 3 of alpha right channel from IQ application with eyes-closed state), with r = 0.877, n = 9, p< 0.05. Also, it is seen that there is a positive correlation between *I3beRbbi* (Index 3 of beta right channel from balanced brain application) and *I3alpLCE* (Index 3 of alpha left channel from IQ application with eyes-closed state), with r = 0.860, n = 9, p< 0.05.

The relationship between Index 5 of balanced brain application and Index 6 of IQ application with eyes-opened state is explored through matrix scatterplot as shown in Figure 6. It is observed that the variables *I5alpRbbi* and *I5alpLbbi* show positive correlation with variables *I6alpRiqOE* to *I6beLiqOE*.

The results of the correlation test indicate that there is a significant Pearson correlation between *I5alpRbbi* (Index 5 of alpha band right channel from balanced brain application) and *I6alpRiqOE* (Index 6 of alpha right channel from IQ application with eyes-opened state), with r = 0.990, n = 5, p< 0.05. Also, it is seen that there is a strong correlation between *I5alpRbbi* (Index 5 of alpha band right channel from balanced brain application) and *I6alpLiqOE* (Index 6 of alpha right channel from IQ application with eyes-opened state), with r = 0.981, n = 5, p< 0.05. Furthermore, there is a strong and positive correlation between *I5alpRbbi* (Index 5 of alpha band right channel from balanced brain application) and *I6beRiqOE* (Index 6 of beta right channel from IQ application with eyes-opened state), with r = 0.985, n = 5, p< 0.05. Finally, there is a strong and positive correlation with a slight significant difference noticed between *I5alpRbbi* (Index 5 of alpha band right channel from balanced brain application) and *I6beLiqOE* (Index 6 of beta left channel from IQ application with eyes-opened state), with r = 0.986, n = 5, p< 0.05.

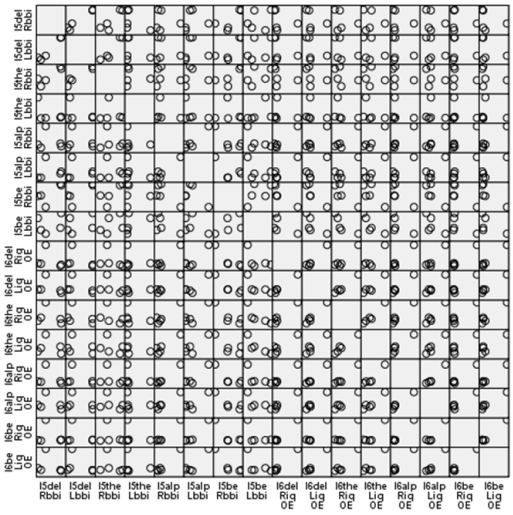


Fig. 6. Matrix scatterplot for Index 5 from balanced brain application and Index 6 from IQ application with eyes-opened state.

IV. Conclusion

As been discussed above, there is correlation between balanced brain and IQ applications. The correlation test showed that there are strong and significant correlation between low and high index of balanced brain and IQ. The results show that the r value ranging from 0.866 to 0.991 with p < 0.05.

Acknowledgment

The authors would like to thank Universiti Malaysia Pahang and Minister of Higher Education for approving this research and the financial support. Also special thanks to researchers of Biomedical Laboratory, UiTM for guidance and support.

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