TERM PROJECT REPORT

STATISTICAL COMPARISON OF EEG MEAN POWER FOR MALE AND FEMALE SUBJECTS

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ABSTRACT

EEG (Electroencephalography) can be defined as electrophysiological monitoring of the brain activity over a period of time as recorded from the scalp. Nowadays, EEG is widely used in several applications thanks to its advantages over other neuroimaging techniques including functional magnetic resonance imaging (fMRI), magnetoencephalography (MEG), electrocorticography (ECoG), near-infrared spectroscopy (NIRS), and event-related optical signal (EROS). Despite the relatively poor spatial sensitivity, EEG has a very high temporal resolution, on the order of milliseconds, and sophisticated EEG data collection systems are capable of recording at sampling rates up to 20 MHz which makes it a prominent technique not only in brain diagnosis but also in biological signals-based controllers. Furthermore, EEG signals can be compared using some characteristic features. In this work, mean power values have been used to statistically investigate the difference in EEG signals of male and female subjects performing the same tasks over the same period of time. We have shown that there is no significant difference in EEG mean power between male and female subjects while performing right and left hand motor imagery (MI), mental arithmetic (MA), and rest state.

Keywords*: EEG, Mean Power, Motor Imagery, Mental Arithmetic.*

INTRODUCTION

Brain-computer interface (BCI) systems have come into prominence in recent years, and have been a great alternative for paralyzed patients to communicate with several systems [1][2][3]. The purpose of a BCI system is to capture brain activity and turn it into command. Mapping brain signals can be done using EEG, a technique that provides a direct measure of brain activity with a temporal resolution of less than millisecond [4].

In the last years, the gender difference in EEG signals has been extensively studied. Some researches suggest a male superiority in gross motor skills [5] and simple index finger tapping [6][7], while the performance of females was superior in fine motor skills such as handwriting tasks [8] and pegboard tasks [6]. In contrast, other studies have found no significant difference in EEG signals between male and female subjects while performing the same tasks [9][10].

This study aims at comparing EEG signals of 29 male and female subjects while performing left and right hand MI, MA, and rest state using unpaired t-test (also known as Student's test). Comparisons were based on the mean power of signals. Before conducting the t-test, some preprocessing techniques were applied to all signals. First of all, outliers were detected and removed using the quartiles method. Then, signals have been filtered with a passband of 5-50Hz to increase their signal-to-noise ratio. Afterward, the filtered signals recorded from 32 channels were linearly combined into one signal channel using principal component analysis (PCA). Finally, the power spectrum of the resulting signal was computed and its mean value was calculated. Based on the mean values of the power spectrum, male and female EEG were compared.

METHOD

Dataset

In this work, an open-access electroencephalography (EEG) and near-infrared spectroscopy (NIRS) dataset collected by Jaeyoung Shin et. al. have been used (download link: http://doc.ml.tu-berlin.de/hBCI/contactthanks.php) [11][12]. This dataset was collected based on two brain-computer interface (BCI) experiments, left versus right hand motor imagery (MI) and mental arithmetic (MA) versus resting state. Fig.1 shows the general structure of the dataset. Note that the dataset also contains information about electrodes placement and task onset markers which are not mentioned in Fig.1. The figure illustrates only the structure of the EEG data since the NIRS data was not used in this study.

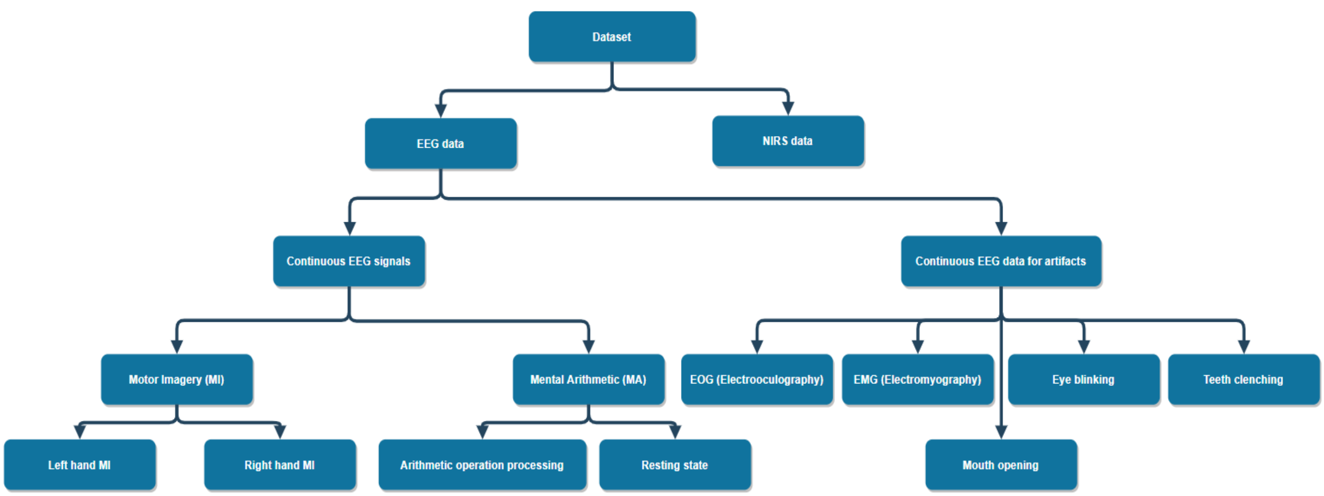

Fig. 1. General structure of dataset

Data acquisition

EEG data were recorded using BrainAmp EEG amplifier with thirty active electrodes (Brain Products GmbH, Gilching, Germany, Fig. 2) at 1000 Hz sampling rate and mastoids were chosen as reference electrodes.

Fig. 2. BrainAmp EEG amplifier, Brain products GmbH, Gilching Germany.

EEG electrodes were placed on a custom-made stretchy fabric cap (EASYCAP GmbH, Herrsching am Ammersee, Germany, Fig. 3) according to the international 10-5 system (AFp1, AFp2, AFF1h, AFF2h, AFF5h, AFF6h, F3, F4, F7, F8, FCC3h, FCC4h, FCC5h, FCC6h, T7, T8, Cz, CCP3h, CCP4h, CCP5h, CCP6h, Pz, P3, P4, P7, P8, PPO1h, PPO2h,POO1, POO2 and Fz for ground electrode, Fig. 4)

Fig. 3. EASYCAP cap product

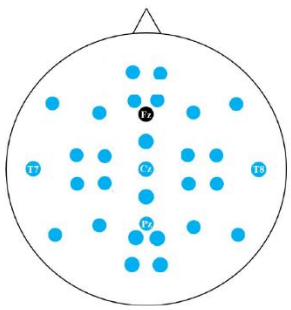

Fig. 4. Placement of EEG electrodes (blue and black (ground) circles) according to the international 10-5 system

Experiments

Experiments were carried on 29 subjects and can be described as follows:

The subjects sat in an armchair in front of a white screen. The experiments consisted of 3 sessions of left and right hand MI (dataset A) and MA and resting state (taking a rest without any thought) (dataset B) each. Also, 5 types of motion artifacts were collected (dataset C).

Dataset A: Left Hand MI versus Right Hand MI:

For MI, subjects were asked to imagine opening and closing their hands as they were grabbing a ball, with about a 1Hz pace with the help of visual instructions displayed on the screen.

Dataset B: MA Versus Baseline Task:

Subjects were asked to perform a simple subtraction of 3-digit number minus 1-digit number (e.g. 126 – 1), then, they were instructed to repeatedly subtract 1 from the previous result.

For the baseline task (i.e. resting state), the subjects were asked to only focus on a black fixation cross displayed on the screen.

Dataset C: Motion Artifacts:

Five types of motion artifacts were measured.

a) Blinking eyes: The subjects were asked to blink their eyes once whenever they heard a short beep sound.

b) Moving eyes: The subjects were instructed to move their eyes at 2 s intervals following the arrow indicating the directions to markers on the wall while not moving their head.

c) Moving head: The subjects moved their heads without moving their eyes.

d) Clenching teeth: The subjects clenched their teeth for 2 s when they hear a beep sound.

e) Opening mouth: The subjects opened their mouth widely for 2 s when they hear a beep sound.

Data processing

The original EEG data were downsampled to 200Hz. Any signal processing method was not applied to the raw data except conversion to Matlab compatible format and re-referencing for linked-mastoid reference. However, we have applied some other preprocessing techniques which are mentioned below using MATLAB R2018b (MathWorks, Natick, MA, USA).

Removing Outliers

Although there is no perfect way to remove all outlier data points from EEG signals, some methods can effectively reduce an important number of these outliers. In this work, we have used the 'Quartiles' method in which outliers are defined as elements more than 1.5 interquartile ranges above the upper quartile (75 percent) or below the lower quartile (25 percent).

This method is useful when the data is normally distributed. Thus, it can be used in our case since the re-referenced EEG signals of different subjects for both MI and MA have such distribution (Fig. 5).

We have removed a significant number of outliers by applying this method to the entire dataset. However, only the result of one channel is represented in Fig. 6 for left and right hand MI, MA, and rest state.

Bandpass Filtering

In order to reduce the effect of the voltage from the galvanic skin response across the head, we need to attenuate frequencies below 5 Hz. We also need to filter high frequencies to reject the noise in EEG signals.

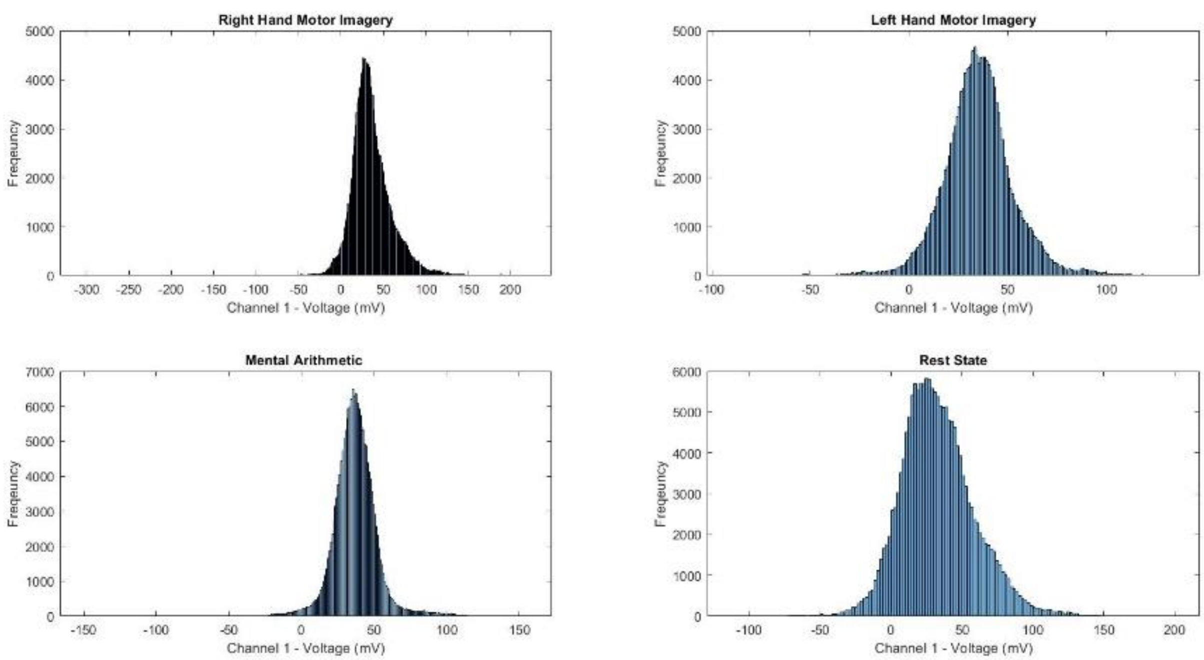

Fig. 5. Data are normally distributed (Gaussian distribution). The distribution of a chunk of data (Only channel 1) is shown for right and left hand MI, MA, and rest state.

Signals have been filtered with a passband of 5-50Hz using Signal Processing Toolbox [13] and no further preprocessing techniques have been applied before linearly combining all the channels into one single channel.

Linear Combination using Principle Component Analysis (PCA)

As mentioned before, 32 channels were used to record brain activity during the experiments. We have combined these 32 channels into one vector which represents a linear combination of all channels. This vector was determined by a linear component analysis (PCA) in which the first principle component PC 1 explained 97.05 %, 97.06 %, 97.12 %, and 96.36 % of the total variance of right hand MI, left hand MI, MA, and rest state EEG signals, respectively. PCA analysis was conducted using Statistics and Machine Learning Toolbox [14].

Power Spectrum

Principle component analysis was followed by computing power spectrum of the combined signals using Signal Processing Toolbox. Then, the mean power values of left hand MI, right hand MI, MA, and rest state were calculated for all the 29 subjects. Results are shown in Table 1.

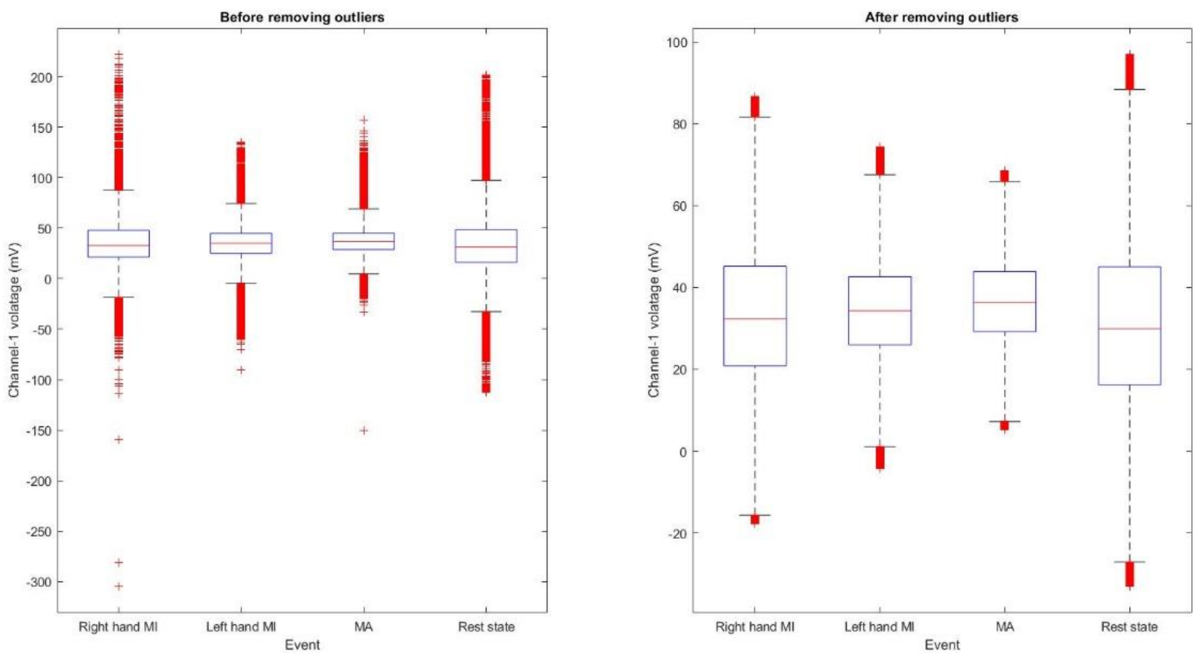

Fig. 6. Box and Whiskers plot of channel-1 data for right hand MI, left hand MI, MA, and resting state before and after 'quartiles' removing outliers. Although outliers are not completely removed due to the EEG signals artifacts, a significant number of outliers was removed.

Table 1. EEG mean power values for right and left hand MI, MA, and rest state. Female subjects are represented in pink color and male subjects are represented in blue.

Subject ID	Mean Power (mdB)			
	Right Hand MI	**Left Hand MI**	**MA**	**Rest State**
S01	13355	13337	12735	13354
S02	1612,2	1575,6	1691,4	1554,7
S03	10482	11481	9100	9147,1
S04	2890,9	3033,2	2839,6	2686,6
S05	2437,4	2510	2250,1	2388,2
S06	2317,6	2276,2	2246,2	2079,7
S07	4435,1	4540,4	4193,2	4173,8
S08	16593	15879	5272,8	5114,8
S09	2870,1	2814,3	2806	2799,9
S10	6198,5	6079,4	5587,8	6252,1
S11	3901,8	3533,9	3667,4	3619,8

S12	3527,2	3843,9	3237,4	3397,3
S13	3362	3142,3	2977,7	2835,8
S14	13355	13337	12735	13354
S15	4458,6	4389,8	4341,4	4436,7
S16	2502,3	2512,1	2165,2	2223,5
S17	2412	2470,1	2595	2445,3
S18	8579,9	8376	8171,6	8666,2
S19	1373,6	1335,7	1410,1	1388,1
S20	2204	2213,9	2475,2	2448,5
S21	4483,7	4514,8	3920,5	4008,9
S22	3294,3	3366	3404,9	3678,1
S23	1776,7	1777,4	1971,8	1959,7
S24	4542,6	4632,1	4178,9	4641,8
S25	2627,6	2720,8	2159,6	2338,4
S26	3827,6	3835,9	3347	3774,9
S27	5887,9	5888,9	5679,3	5971,1
S28	3721,6	3565,9	4782	4988,5
S29	6711,6	6915,2	6806,5	6230,7

Unpaired T-Test

The 29 subjects who participated in the experiments were divided into two groups of male and female, and 4 unpaired t-tests were conducted using “Data Analysis Toolbox” in Excel [15] to investigate the difference between the two groups in mean power for right hand MI, left hand MI, MA, and rest events, with a confidence level of 5%.

RESULTS AND DISCUSSION

We wanted to check whether the mean value of the EEG power of male subjects is different from the mean value of the EEG power of female subjects for left and right hand MI, MA, and rest state. Hence, we have the hypothesis that:

- H0: There is no significant difference in EEG mean power between male and female subjects.
- H1: The mean value of EEG power is significantly different between male and female subjects.

Results of right and left hand MI, MA, and rest state t-tests are shown in Table 2, Table 3, Table 4, and Table 5, respectively.

As indicated in tables 3 to 6, for critical t-values, all p-values are greater than 0.05, which represents the significance level. Thus, we accept the null hypothesis H0, reject the alternative hypothesis H1, and conclude that there is no significant difference between the mean value of EEG power while performing right hand MI, left hand MI, MA, and rest state for male and female subjects.

CONCLUSIONS AND FUTURE WORK

In this work, we compared EEG mean power of right and left hand MI, MA, and rest state

Table 2. EEG mean power .Mean±SD. 13 male subjects for, 16 female subjects

Gender	EEG Mean Power (mdB)			
	Left hand MI	Right hand MI	MA	Rest State
Male	4512,66 ± 2383,21	4624,13 ± 2603,74	4178,04 ± 2123,98	4254,59 ± 2147,63
Female	5442,32 ± 4794,91	5361,50 ± 4679,24	4652,12 ± 3549,02	4790,53 ± 3768,55

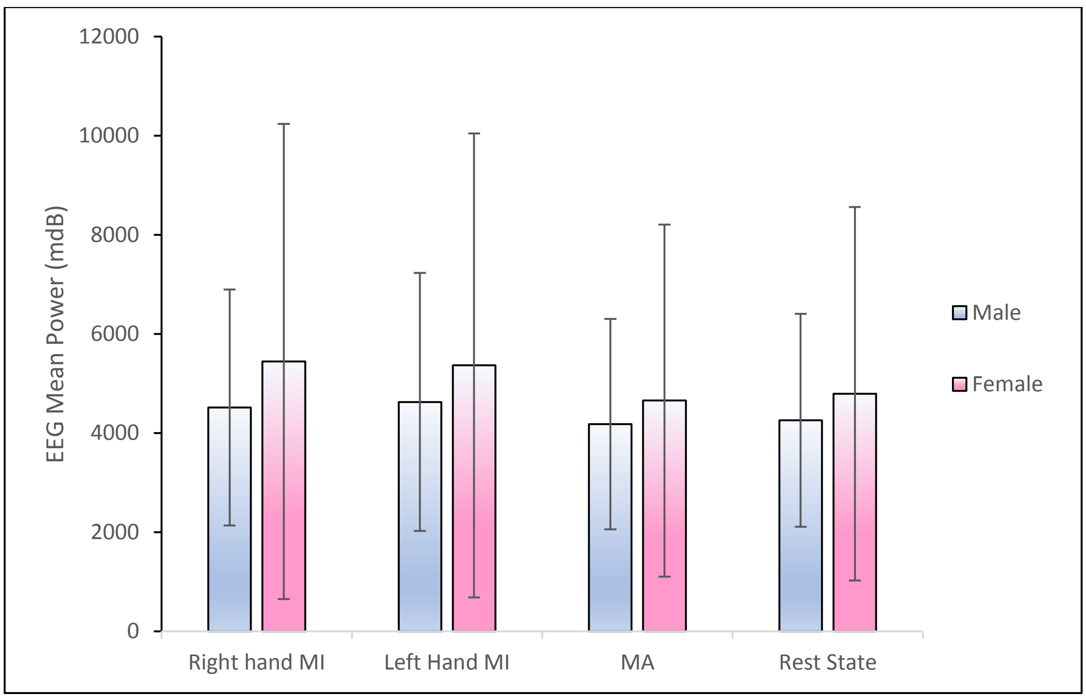

Fig. 7. EEG mean power. Mean±SD, 13 male subjects , 16 female subjects .

Table 3. T-Test results for right hand motor imagery. The value of p shows that there is no significant difference between male and female subjects in EEG mean power for right hand motor imagery

	Right Hand MI Mean Power - Female	*Right hand MI Mean Power - Male*
Mean	5442,325	4512,661538
Variance	22991249,53	5679718,011
Observations	16	13
Hypothesized Mean Difference	0	
Df	23	
t Stat	0,679137687	
P(T<=t) one-tail	0,25191412	
t Critical one-tail	1,713871528	
P(T<=t) two-tail	0,503828239	
t Critical two-tail	2,06865761	

Table 4. T-Test results for left hand motor imagery. The value of p shows that there is no significant difference between male and female subjects in EEG mean power for left hand motor imagery

	Left Hand MI Mean Power - Female	*Left Hand MI Mean Power - Male*
Mean	*5361,50625*	*4624,130769*
Variance	*21895358,93*	*6779465,959*
Observations	*16*	*13*
Hypothesized Mean Difference	*0*	
Df	*24*	
t Stat	*0,536367796*	
P(T<=t) one-tail	*0,298320757*	
t Critical one-tail	*1,71088208*	
P(T<=t) two-tail	*0,596641513*	
t Critical two-tail	*2,063898562*	

Table 5. T-Test results for mental arithmetic. The value of p shows that there is no significant difference between male and female subjects in EEG mean power for mental arithmetic

	MA Mean Power - Female	*MA Mean Power - Male*
Mean	4652,125	4178,046154
Variance	12595546,01	4511321,036
Observations	16	13
Hypothesized Mean Difference	0	
Df	25	
t Stat	0,445140273	
P(T<=t) one-tail	0,330024457	
t Critical one-tail	1,708140761	
P(T<=t) two-tail	0,660048913	
t Critical two-tail	2,059538553	

Table 6. T-Test results for rest state. The value of p shows that there is no significant difference between male and female subjects in EEG mean power for rest state

	Rest State Mean Power - Female	*Rest State Mean Power - Male*
Mean	4790,53125	4254,592308
Variance	14202027,46	4612354,654
Observations	16	13
Hypothesized Mean Difference	0	
Df	24	
t Stat	0,480817796	
P(T<=t) one-tail	0,317500134	
t Critical one-tail	1,71088208	
P(T<=t) two-tail	0,635000267	
t Critical two-tail	2,063898562	

for 2 groups of male and female subjects. We have statistically shown that there is no significant difference between the two groups and we have approved the result of some previous works suggesting the same results [9][10].

As future work, we can compare EEG signals of two genders based on other features extracted from signals. The analysis can be also done separately for delta waves (. 5 to 3 Hz) , theta waves (3 to 8 Hz) alpha waves (8 to 12 Hz), beta waves (12 to 38 Hz), and gamma waves (38 to 42 Hz).

REFERENCES

[1] G. Dornhege, J. R. Millán, T. Hinterberger, D. McFarland, and K. R. Müller, Toward Brain-Computer Interfacing. Cambridge, MA, USA: MIT Press, 2007.

[2] J. R. Wolpaw, N. Birbaumer, D. J. McFarland, G. Pfurtscheller, and T. M. Vaughan, “Brain-computer interfaces for communication and control,” Clin. Neurophysiol., vol. 113, pp. 767–791, Jun. 2002.

[3] J. R. Wolpaw and E. W. Wolpaw, Brain-Computer Interfaces: Principles and Practice. New York, NY, USA: Oxford Univ. Press, 2012.

[4] Pari Jahankhani, Vassilis Kodogiannis and Kenneth Revett,” EEG Signal Classification Using Wavelet Feature Extraction and Neural Networks,” IEEE John Vincent Atanasoff JVA International Symposium on Modern Computing, pp. 120 – 124, Oct. 2006.

[5] Junaid KA, Fellowes S. Gender differences in the attainment of motor skills on the Movement Assessment Battery for children. Phys Occup Ther Pediatr. 2006;26:5-11.

[6] Ruff RM, Parker SB. Gender and age specific changes in motor speed and eye-hand coordination in adults. Percept Mot Skills. 1993;76:1219-30.

[7] Hausmann M, Kirk IJ, Corballis MC. Influence of task complexity on manual asymmetries. Cortex. 2004;40:103-10.

[8] Weintraub N, Drory-Asayag R, Dekel R, Jokobovits H, Parush S. Developmental trends in handwriting performance among middle school children. OTJR. 2007;27:104-12.

[9] Hamstra-Bletz L, Blote AW. Development of handwriting in primary school: a longitudinal study. Percept Mot Skills. 1990;70: 759-70.

[10] Dorfberger S, Adi-Japha E, Karni A. Sex differences in motor performance and motor learning in children and adolescents: An increasing male advantage in motor learning and consolidation phase gains. Behav Brain Res. 2009;198:165-71.

[11] Jaeyoung Shin, Alexander von Lühmann, Benjamin Blankertz, Do-Won Kim, Han-Jeong Hwang and Klaus-Robert Müller, "Open Access Dataset for EEG+NIRS Single-Trial Classification," IEEE Trans. Neural Syst. Rehabil. Eng., online published.

[12] Blankertz B, Tangermann M, Vidaurre C, Fazli S, Sannelli C, Haufe S, Maeder C, Ramsey LE, Sturm I, Curio G, Mueller KR, "The Berlin Brain-Computer Interface: Non-Medical Uses of BCI Technology," Front Neuroscience, 4:198, 2010.

[13] Signal Processing Toolbox. [Online]. Available at

https://www.mathworks.com/products/signal.html

[14] Statistics and Machine Learning Toolbox. [Online]. Available at https://www.mathworks.com/products/statistics.html

[15]. Microsoft Corporation, 2018. Microsoft Excel, Available at: https://office.microsoft.com/excel