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Brain Functional Connectivity and Power Spectrum Analyses during Mental Arithmetic

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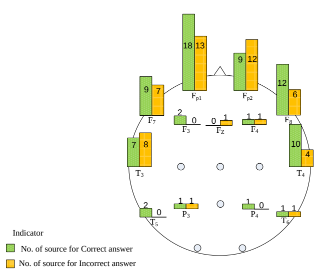
Graphical abstract



Abstract

Mental calculation is one of the skills in executive function where problem solving skill and working memory were needed. The objectives of this study were to determine the directional connection of brain networks using partial directed coherence, and to observe the power spectrum of the brain rhythms during the mental task. Thirteen healthy participants were involved in the mental arithmetic task, where each participant was asked to subtract 1000 with number 7 continuously within 60 seconds. Electroencephalography machine was used to collect the data of brain signal, and the data were analyzed using partial directed coherence and Fast Fourier Transform. There were two possibilities that participants gave an answer; correct or incorrect answer to the calculation. As a result, regardless of correct or incorrect answer, mostly frontal and temporal area has been used in performing the mental task including some part of parietal area. Increasing theta frequency band and decreasing beta frequency band were involved in generating the information needed during mental arithmetic at the frontal area. It generates information of the mental calculation, which is send to other brain areas; i.e. centro-parieto-occipito-temporal area which show decreasing alpha frequency band; an indication of other cognitive processes. In conclusion, fronto-temporal area is activated during mental arithmetic task.

Keywords: Mental arithmetic; functional connectivity; electroencephalography; partial directed coherence; Fast Fourier Transform

Abstrak

Pengiraan mental ialah salah satu kemahiran di fungsi eksekutif di mana kemahiran penyelesaian masalah dan ingatan kerja telah dilakukan. Objektif kajian ini akan menentukan sambungan berhaluan jaringan otak menggunakan *partial directed coherence*, dan memerhatikan spektrum kuasa otak semasa tugas mental. Tiga belas orang peserta sihat terlibat dalam tugas aritmetik congak, di mana setiap peserta diminta untuk tolak 1000 dengan nombor 7 secara berterusan dalam 60 saat. Mesin elektroensefalografi digunakan untuk mengumpul data isyarat otak, dan data di analisis menggunakan *partial directed coherence* dan *Fast Fourier Transform*. Terdapat dua kemungkinan peserta memberikan jawapan; jawapan betul atau tidak betul kepada pengiraan. Hasilnya, tanpa mengambil kira jawapan yang betul atau tidak betul, kebanyakkan kawasan *frontal* dan *temporal* telah digunakan dalam melaksanakan tugas mental, termasuk beberapa bahagian di kawasan *parietal*. Pertambahan jalur frekuensi *theta* dan penurunan jalur frekuensi *beta* terlibat dalam menjana maklumat semasa aritmetik congak di kawasan *frontal*. Ia menghasilkan maklumat pengiraan mental, di mana ia menghantar kepada bahagian otak lain; iaitu kawasan *centro-parieto-occipito-temporal* yang menunjukkan penurunan jalur frekuensi *alpha*; petunjuk proses kognitif lain. Kesimpulannya, kawasan fronto-temporal diaktifkan semasa tugas aritmetik congak dilakukan.

Kata kunci: Aritmetik congak, keterkaitan fungsian, elektroensefalografi, *partial directed coherence*, *Fast Fourier Transform*

1.0 INTRODUCTION

Mental arithmetic is a process of quantitative processing calculation which involves regularly in our life such as simple addition, subtraction, multiplication, and division [1, 2]. In neuropsychology field, mental arithmetic is widely study to determine the ability of a person using their serial order memory [3]. Partly due to people tend to use variety of strategy to get solution for the arithmetical problems, and they cannot use external method to calculate other than their head. Previous studies have done mental arithmetic tasks for single-digit and multi-digit in variety of arithmetic operations [4, 5].

The calculation process when doing mental arithmetic will make people uses their problem solving skill and working memory to give an actual answer [6–8]. Problem solving and working memory are some parts of executive function skills which involve inhibiting, shifting, and updating factor.

Executive function (EF) is a cognitive processing which contains various skills that makes people able to achieve their particular goal in daily life; planning, organizing, problem solving, decision making, and goal setting [9]. In mental arithmetic, inhibition is when we need to abstain from giving the wrong value of calculation, while shifting is when we have to switch the number of calculation into another number to get the exact answer [10]. Meanwhile, updating is a short term storage which needs the working memory to hold the previous information use for the next calculation [11]. Several researches in brain area report that executive function performs at frontal area and mental arithmetic is usually process at frontal and parietal areas, but the process of calculation for other brain area remain unclear [12].

Researches on functional connection of cortical networks have been explored widely these days. The brain activity can be studied using Electroencephalography (EEG), functional Magnetic Resonance Imaging (fMRI), Positron Emission Tomography (PET), and Magneto-encephalography (MEG) [13, 14]. In order to capture the brain signal to observe the cortical networks, researchers preferred to use EEG measurement as it was portable and more conducive to monitor [15].

Connectivity pattern can be determined through directed connectivity measures; coherence, cross-correlation, phase slope index (PSI), transfer entropy (TE), directed transfer function (DTF), and partial directed coherence (PDC) [16]. In electrophysiological signal, PDC has been widely used as it has the ability to detect direct relations for causal connectivity [17, 18].

Power spectrum has been investigated for most studies in brain research in order to observe the brain rhythms. It can be determined by six different frequency bands; delta (1 – 3 Hz), theta (4 – 7 Hz), alpha (8 – 12 Hz), beta (13 – 30 Hz), gamma (31 – 50 Hz) and high-gamma (50 – 120 Hz) frequency bands. Every frequency band has their own operation; delta band associated with deep sleep, theta band appear as from consciousness to drowsiness, alpha band associated with relaxation without attention or concentration or enhance signal-to-noise ratio, beta band appear in active thinking and attention, and gamma band associated with recognizing brain disease. Previous studies discovered that working memory has enhanced the frontal theta and beta waves [19, 20].

Previous researches had done mental arithmetic in single-digit and multi-digit for several operation problems but the functional connection between different brain areas is not fully understood. The aims of this study were to determine the functional connectivity of brain networks between frontal and other brain areas during mental arithmetic task using partial directed coherence (PDC), and to observe the frequency bands of brain rhythms while performing the mental task.

2.0 METHODOLOGY

2.1 Participant

The study was conducted on 13 healthy participants between the ages of 21 to 25 years old. Subjects were postgraduates and undergraduate students from Universiti Teknologi Malaysia. Each subject need to avoid caffeine and excessive exercise within 12 hours before doing the task [21].

2.2 Procedure

There were two conditions that each participant needs to fulfill; Control Condition and Mental Task Condition. In control condition, each participant needed to relax their mind in 60 seconds while their brain signals were recorded. Next, participant would underwent mental task condition, which they needed to subtract 1000 with number 7 (MA07) repetitively within 60 seconds (e.g.: 1000 – 7 – 7 – … – 7 = 951) [22].

Next, participants needed to give the last answer of their mental subtraction. If the answer of their subtraction was incorrect, they would be given the correct answer and were asked to continue to subtract the corrected final answer with number 7 in the trial that follows. The mental subtraction task was continued until fifth trial.

2.3 Data Measurement

The data of brain signal were collected using electroencephalography (EEG) machine (EEG-9100J/K Neurofax, Nihon Kohden). In order to capture the signal, 19-channels electrode cap was attached to participant's scalp according to 10-20 International Electrode Placements (i.e.: $F_{p1}, F_{p2}, F_3, F_4, C_3, C_4, P_3, P_4, O_1, O_2, F_7, F_8, T_3, T_4, T_5, T_6, F_z, C_z$, and P_z) as shown in Figure 1. Electrode gel was injected in every channel with the purpose of recording the electrical activity of the brain. Two external electrodes of Ag/AgCl were attached at participant's ear lobes (i.e.: A_1 and A_2) as a reference. The values of bandpass filter were 0.07 – 120 Hz and the impedance was kept below 20kΩ.

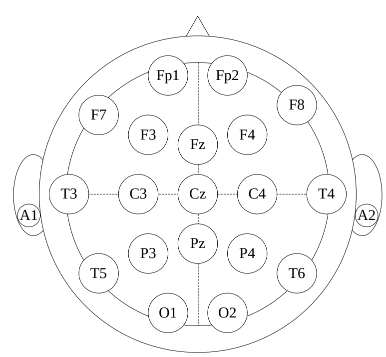


Figure 1 19-channels electrode placement with references (A_1, A_2)

2.4 Data Processing

The raw brain signal data were converted to comma-separated value (.csv) file and were analyzed using partial directed coherence (PDC). PDC was used to determine the functional connectivity of information sources and sinks from the 19-scalp locations. PDC is an extended concept of partial coherence which combines the Granger causality time domain with multivariate autoregressive (MVAR) models and it is defined in frequency domain [23–25]. PDC is defined as in Equation (1).

$$PDC_{ij}(f) = \frac{|\bar{A}_{ij}(f)|}{\sqrt{|\bar{A}_{1j}(f)|^2 + |\bar{A}_{2j}(f)|^2}} \quad (1)$$

where $\bar{A}_{ij}(f)$, $(i, j = 1, \ldots M)$ is a matrix element from a Fourier transform of MVAR model, $\bar{A}(f)$ as in Equation (2):

$$\bar{A}(f) = I - \sum_{r=1}^{p} A_r e^{-i2\pi fn} \quad (2)$$

where p is the order of MVAR model and A_r is the estimation of coefficient matrix.

Next, the PDC data were illustrated in a 19 x 19 matrix graph as shown in Figure 2. X-axis indicates functional connectivity of information sources, where the brain signal produces information to other brain locations; meanwhile Y-axis indicates functional connectivity of information sink, where other scalp locations receive the produce information. To determine the signal pathways, the value of the connectivity must be at 0.4 and above as depicted in Figure 3.

Last but not least, the data of brain signal were analysed using Fast Fourier Transform (FFT) to observe the frequency band of brain signal when participant did the mental arithmetic task; i.e. delta band (1 – 3 Hz), theta band (4 – 7 Hz), alpha band (8 – 12 Hz), beta band (13 – 30 Hz), gamma band (31 – 50 Hz), and high gamma band (51 – 120 Hz).

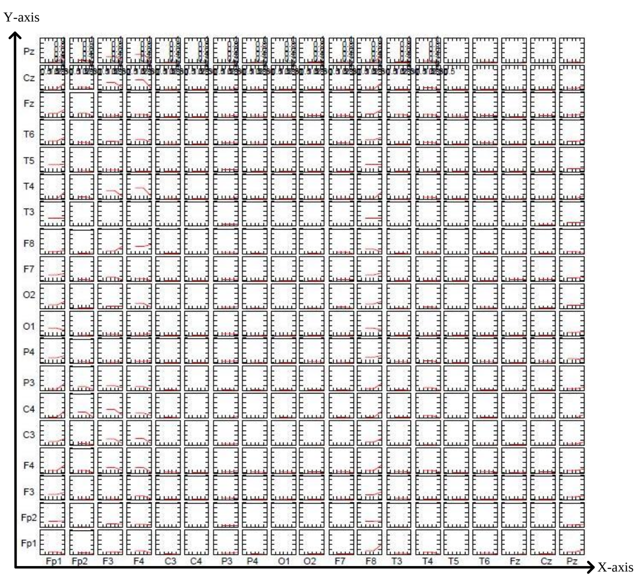


Figure 2 19 x 19 matrix graph of scalp locations

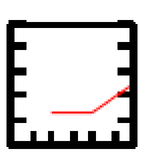


Figure 3 The signal connection between the channels occur

In order to identify the accurate scalp location and definite frequency band when doing the mental task, the data were normalization as in Equation (3).

$$\text{Normalization (\%)} = \frac{\sum \text{frequancy band}}{\sum \text{total frequancy band}} \times 100\% \quad (3)$$

After normalization of the entire frequency band for every scalp locations, *t*-test value was conducted to calculate for the correct and incorrect answers to indicate the significant difference between the findings with control. The values of the significant difference were set at $P < 0.05$.

3.0 RESULTS AND DISCUSSION

For the mental arithmetic task (MA07), there were thirteen participants involved with five trials for each person. Generally, out of 65 trials (13 participants × 5 trials), 37 correct answers were given by the participants while another 28 answers were incorrect.

3.1 Functional Connectivity

Example of signal pathways of the cortical networks for information sources and information sinks during the mental task which can be observed is shown in Figure 4. The results were obtained using PDC which delineate the information sources and sinks according to brain regions. Information source is where information was generated when participant started to calculate while information sink is where information was sent to other brain area for various executive function skills to obtain the answer to the arithmetic task given.

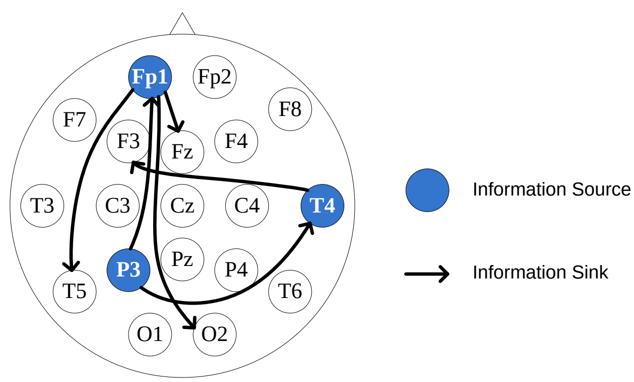


Figure 4 Example of signal pathways of cortical networks

Figure 5 shows the number of information sources for correct and incorrect answer produces within 19 EEG channels. It had been determined by totaling up information sources from the results of cortical networks. Regardless correct and incorrect answers, commonly frontal area (i.e.: F_{p1}, F_{p2}, F_3, F_4, F_7, F_8, and F_z) and temporal area (i.e.: T_3, T_4, T_5, and T_6) were involved in the mental subtraction task. Few information sources were produced in parietal area (i.e.: P_3 and P_4) during mental task. From the figure, scalp locationsF_{p1}, F_8, and T_4 were frequently used by participants in giving correct answers while scalp locations F_{p1} and F_{p2} were frequently used for the incorrect answers.

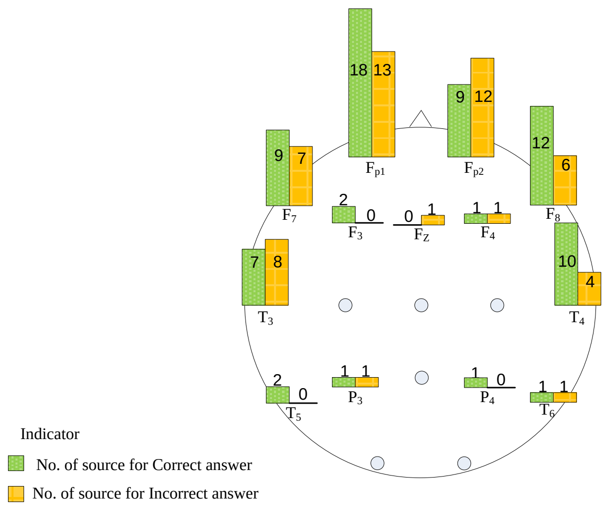


Figure 5 Number of information sources for correct and incorrect answer during mental arithmetic task

Figure 6 shows the number of information sinks for Correct and Incorrect answer of mental arithmetic task. It also had been determined by totaling the information sink up from the results of cortical networks. The process on sending the information when doing the task was varied and distributed to all brain regions for both correct and incorrect answers.

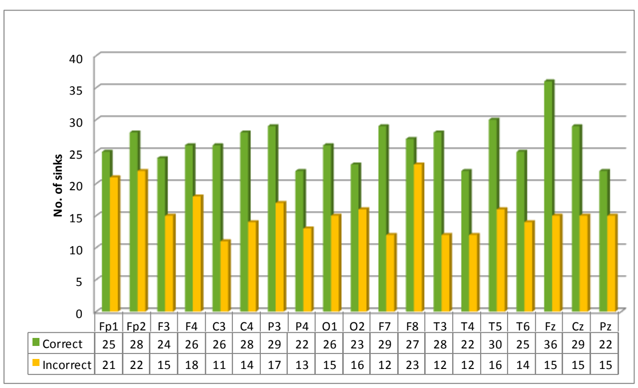


Figure 6 Number of information sinks for correct and incorrect answer during mental arithmetic task

Based on the result in Figure 5, functional connectivity of information sources during mental arithmetic task are usually occur at frontal and temporal area, and with some minimal information coming from parietal area. Frontal area is already known as executive function area which has problem solving skill to do the mental task. Meanwhile, temporal area is part of working memory besides frontal area [26]. According to research by Droes and colleagues, memory problem can occurs at fronto-temporal area, which is called dementia [27].

3.2 Power Spectrum

Tables 1 and 2 show the average ± standard deviation values of frequency bands for every channel between Correct – Control task and Incorrect – Control task, respectively. The bolded area indicates three significant differences; P < 0.05, P < 0.01 and P < 0.001 which are differentiate by number of asterisk at the end of the average ± standard deviation value. When participants gave correct answers, delta band at F_3, F_7, T_5, T_6, and F_Z, theta band at $F_{p1}, F_3, F_4, F_7, F_8, F_z, P_3$, and P_z, and high gamma band at C_z significantly increased. In contrast, alpha frequency band at $F_3, F_4, F_7, F_z, C_3, C_4, C_z, P_3, P_4, P_z, O_1, O_2, T_3, T_4, T_5$, and T_6, beta frequency band at $F_{p2}, F_3, F_4, F_7, F_8, F_z, C_3, C_4, T_3$, and T_5, and gamma frequency band at F_7 significantly decreased when participants gave correct answers.

Meanwhile, when participants gave incorrect answers, delta frequency band at F_7 and F_8, and theta frequency band at $F_{p1}, F_3, F_4, F_7, F_8, F_z, P_3$, and P_z, significantly increased. On the other hand, alpha frequency band at F_z, C_3, C_4, P_3, P_4, P_z, O_1, O_2, T_5, and T_6, beta frequency band at F_{p2}, F_3, F_4, F_7, F_8, and F_z, and gamma band at F_7 and F_8, significantly decreased when participants gave incorrect answers.

Based on the data in Table 1 and Table 2, channel F_7 gives the most significant differences for both correct and incorrect answer at theta and beta frequency bands. Regardless of correct or incorrect answers, theta frequency band significantly increased when compared to control. It is vice-versa for the beta frequency band. Beta frequency band significantly decreased at the same F_7 location for both correct and incorrect answers. From the power spectrum result, regardless of giving correct and incorrect answer, delta and theta frequency bands had increased mostly in frontal area while performing mental calculation. For correct answer during mental arithmetic task, delta and theta frequency bands has increased also at some part of temporal and parietal area. Meanwhile, as can be seen in Table 1, alpha frequency band had decreased in most of brain area, while beta band decreased at the fronto-centro-temporal area for correct answer when compared to control. As for incorrect answer vs. control, alpha frequency band decreased at centro-parieto-occipito-temporal area, while beta band decreased at the frontal area for the incorrect answer given during mental arithmetic task (Table 2).

Theta and beta frequency bands are associated with problem solving and working memory which need us to keep updating our memory information from time to time.

4.0 CONCLUSION AND FUTURE WORKS

Based from our finding, the fronto-temporal area and some part at the parietal area are involved in mental arithmetic task regardless of the outcomes of the calculation (correct/incorrect). The frontal and temporal areas play an important role in executive function as they involve in solving a problem and working memory. The finding is supported by the power spectrum analysis whereby, the increasing theta frequency band and decreasing beta frequency band in the area shows working memory. The location generates information of the mental calculation which is send to the other brain areas; i.e. centro-parieto-occipito-temporal area which has shown decreasing alpha frequency band for other processes. For future research, functional connectivity of brain area can be further explored by doing multi-digit mental calculation; e.g.: subtract with number 13. Furthermore, it can be done with other arithmetical operation (i.e.: addition, multiplication, and division).

Table 1 Percentage distribution of power changes between correct answer of mental arithmetic and control tasks

Channel	Delta 1 – 3 Hz		Theta 4 – 7 Hz		Alpha 8 – 12 Hz		Beta 13 – 30 Hz		Gamma 31 – 50 Hz		High Gamma 51 – 120 Hz	
	Control	Correct	Control	Correct	Control	Correct	Control	Correct	Control	Correct	Control	Correct
F_{p1}	43.40±9.76	47.71±13.55	**13.5±3.18**	**16.03±3.20***	9.90±3.18	8.59±3.27	**17.27±4.97**	**13.55±6.61***	7.93±2.82	6.62±3.82	8.00±2.59	7.50±3.95
F_{p2}	43.19±8.52	46.01±13.96	13.37±2.94	15.54±3.71	10.16±3.77	8.39±3.22	**17.15±4.46**	**14.31±6.78***	7.78±2.27	7.24±4.15	8.35±2.62	8.50±4.97
F_3	**30.11±5.95**	**35.97±10.52***	**12.49±1.48**	**14.60±2.61****	**14.19±5.53**	**10.99±4.95****	**23.51±3.01**	**19.74±4.81****	9.74±2.17	8.80±2.66	9.97±3.66	9.90±3.45
F_4	31.39±10.07	34.50±10.02	**12.14±2.50**	**14.26±2.65****	**13.56±6.75**	**11.17±5.64***	**22.75±5.22**	**20.55±5.21***	9.63±2.75	9.13±2.45	10.53±3.83	10.39±3.14
C_3	22.60±11.03	26.19±8.31	11.19±1.88	12.32±2.41	**16.21±6.85**	**12.92±5.20****	**27.40±6.16**	**24.97±4.88***	10.74±3.57	10.76±2.56	11.88±5.63	12.85±4.02
C_4	22.32±9.86	25.89±7.84	11.42±1.69	12.26±2.56	**16.21±6.35**	**13.19±5.59****	**27.76±5.34**	**24.98±4.33****	10.68±3.47	10.91±2.55	11.61±5.75	12.78±4.28
P_3	28.38±10.70	29.89±9.33	**11.13±1.20**	**12.56±1.88***	**19.04±9.90**	**15.41±7.73***	24.85±5.47	23.82±5.19	8.29±2.90	8.72±2.23	8.32±3.91	9.61±3.18
P_4	28.10±10.90	30.59±9.59	11.50±1.36	12.51±2.33	**20.08±9.41**	**15.75±7.52****	24.58±5.16	23.72±5.82	7.75±2.68	8.25±2.31	7.99±4.38	9.18±3.35
O_1	25.89±9.58	28.44±7.83	10.68±1.69	11.62±1.67	**19.06±9.28**	**14.73±6.51****	25.19±4.60	24.52±4.13	9.43±3.46	9.94±2.70	9.75±4.05	10.75±3.41
O_2	26.61±8.65	29.57±8.12	11.35±1.43	11.99±1.91	**20.47±9.41**	**15.37±8.08****	24.36±3.80	23.48±4.40	8.43±2.55	9.24±2.52	8.78±3.47	10.35±3.31
F_7	**33.93±8.23**	**40.02±8.90***	**11.78±1.31**	**14.46±2.59*****	**10.92±4.17**	**9.20±3.60****	**21.02±2.70**	**17.41±4.06*****	**10.08±2.79**	**8.58±2.39****	12.28±5.59	10.33±3.45
F_8	35.39±6.67	40.13±8.95	**12.14±1.67**	**13.87±2.46****	11.11±4.01	9.42±3.78	**20.93±4.14**	**17.79±4.43****	9.59±2.77	8.71±2.54	10.84±3.62	10.09±3.20
T_3	19.16±6.98	21.47±6.14	9.55±2.50	10.76±3.93	**11.74±5.77**	**9.67±4.06***	**27.44±2.93**	**25.39±3.60****	14.56±4.41	14.27±2.68	17.56±6.81	18.45±4.82
T_4	21.74±10.89	22.35±7.44	9.20±2.81	10.15±3.41	11.01±5.19	10.09±4.80	27.06±5.86	26.49±5.49	14.36±4.95	14.26±3.63	16.63±6.62	16.67±4.48
T_5	**23.40±6.85**	**26.46±7.59***	11.02±1.52	11.85±1.83	**18.77±9.49**	**14.62±7.19****	**25.87±4.50**	**24.72±4.61***	10.01±3.59	10.49±2.36	10.93±4.81	11.87±3.25
T_6	**22.94±5.08**	**27.05±8.56***	11.12±2.06	11.93±2.23	**20.11±9.63**	**15.23±7.46****	25.45±4.22	24.43±5.42	9.67±3.55	9.87±2.59	10.72±5.68	11.49±3.47
F_Z	**31.61±6.72**	**35.93±8.80***	**13.68±2.19**	**15.67±3.37***	**15.93±7.66**	**12.39±5.55****	**22.45±3.10**	**19.57±4.11****	8.33±1.92	7.83±2.04	8.00±2.99	8.61±2.61
C_Z	24.92±5.40	27.21±7.93	13.83±1.67	13.85±2.56	**15.93±5.21**	**13.50±4.56***	25.57±3.01	23.94±4.44	9.95±2.27	10.05±2.29	**9.81±4.09**	**11.45±3.58***
P_Z	28.83±5.90	33.06±9.64	**11.66±1.27**	**13.19±2.20***	**18.02±7.91**	**14.03±6.64****	24.90±3.20	21.98±5.31	8.33±2.33	8.33±2.44	8.26±3.52	9.41±3.29

Data presented as mean±SD. *, **, and *** are $p<0.05$, $p<0.01$, and $p<0.001$, respectivel

Table 2 Percentage distribution of power changes between incorrect answer of mental arithmetic and control tasks

Channel	Delta 1 – 3 Hz		Theta 4 – 7 Hz		Alpha 8 – 12 Hz		Beta 13 – 30 Hz		Gamma 31 – 50 Hz		High Gamma 51 – 120 Hz	
	Control	Incorrect	Control	Incorrect	Control	Incorrect	Control	Incorrect	Control	Incorrect	Control	Incorrect
F_{p1}	42.45± 9.70	46.81± 12.17	13.87± 3.33	16.49± 3.38*	9.90± 3.06	9.08± 3.78	17.62± 5.27	14.31± 6.59	8.04± 3.01	6.30± 3.53	8.13± 2.74	7.01± 3.14
F_{p2}	41.93± 8.06	46.73± 12.48	13.62± 3.15	16.15± 3.75	10.27± 3.81	8.73± 4.17	17.60± 4.63	14.35± 6.60*	7.98± 2.38	6.58± 3.81	8.60± 2.75	7.47± 3.94
F_3	29.68± 5.83	35.09± 10.69	12.59± 1.60	15.18± 3.17**	14.31± 5.75	11.62± 6.26	23.77± 3.22	20.21± 5.46*	9.68± 2.36	8.32± 2.63	9.98± 4.00	9.57± 4.17
F_4	30.96± 10.93	33.75± 11.33	12.21± 2.72	14.87± 3.64**	13.71± 7.24	11.55± 6.99	22.91± 5.70	21.07± 6.39	9.61± 3.01	8.82± 3.12	10.60± 4.19	9.95± 4.02
C_3	23.42± 11.85	25.52± 9.48	11.24± 2.01	13.04± 3.04	16.65± 7.25	13.21± 5.35*	27.22± 6.65	25.89± 5.74	10.29± 3.59	10.41± 2.33	11.19± 5.82	11.94± 4.34
C_4	23.13± 10.54	25.62± 8.50	11.50± 1.78	13.02± 2.79	16.65± 6.67	13.68± 6.05*	27.61± 5.74	25.69± 5.38	10.22± 3.48	10.25± 2.13	10.88± 5.91	11.73± 4.16
P_3	29.23± 11.47	30.86± 9.71	11.13± 1.31	13.15± 2.75*	18.75± 9.96	15.65± 8.90*	24.64± 5.82	23.89± 5.44	8.11± 2.94	8.02± 2.20	8.13± 4.07	8.43± 2.71
P_4	29.10± 11.35	30.95± 11.41	11.52± 1.39	13.50± 3.14	19.95± 9.25	15.90± 9.12*	24.48± 5.55	23.38± 6.62	7.46± 2.76	7.66± 2.74	7.49± 4.53	8.62± 3.76
O_1	26.69± 10.11	27.76± 10.86	10.70± 1.80	11.62± 2.47	18.88± 9.12	14.73± 7.66*	25.09± 5.00	25.02± 5.10	9.28± 3.64	9.97± 3.39	9.36± 4.04	10.89± 4.02
O_2	27.47± 8.64	29.17± 11.62	11.46± 1.53	12.34± 2.67	20.20± 8.88	16.11± 9.59*	24.27± 4.10	23.81± 5.81	8.21± 2.65	8.77± 3.30	8.39± 3.54	9.80± 4.21
F_7	32.96± 8.13	40.20± 8.70**	11.72± 1.41	14.65± 2.79***	10.85± 4.28	9.54± 4.05	21.52± 2.59	17.63± 4.68***	10.26± 3.00	7.95± 2.38**	12.69± 6.02	10.02± 4.07
F_8	34.30± 6.69	40.69± 7.22*	12.21± 1.81	14.70± 2.49**	11.17± 4.34	9.59± 4.01	21.39± 4.37	17.76± 4.81**	9.81± 2.97	7.95± 2.22*	11.11± 3.87	9.33± 2.38
T_3	19.33± 7.45	22.18± 9.62	9.64± 2.64	11.82± 4.91	11.51± 5.90	9.91± 5.02	27.75± 2.89	25.69± 5.33	14.47± 4.65	13.36± 3.85	17.30± 7.11	17.04± 6.43
T_4	22.12± 11.22	23.82± 8.17	9.52± 2.74	11.15± 3.13	11.46± 5.47	10.53± 4.73	26.96± 5.88	25.87± 4.41	13.97± 5.00	13.23± 3.49	15.98± 6.84	15.41± 4.84
T_5	24.05± 7.30	27.16± 7.66	11.08± 1.48	12.36± 2.38	18.57± 9.40	14.56± 8.88*	25.80± 4.58	24.90± 4.85	9.76± 3.50	10.04± 2.58	10.75± 5.01	10.98± 3.28
T_6	23.21± 5.36	27.15± 7.89	10.99± 1.97	12.33± 2.34	20.13± 9.65	15.69± 9.35*	25.50± 4.36	24.58± 5.08	9.60± 3.74	9.61± 3.02	10.57± 6.03	10.64± 3.68
F_Z	31.35± 7.06	34.95± 9.07	13.82± 2.35	16.32± 4.16*	16.26± 8.08	13.05± 6.95*	22.62± 3.36	20.44± 4.42**	8.16± 2.05	7.49± 2.18	7.80± 3.23	7.75± 2.74
C_Z	26.01± 5.04	27.68± 7.73	14.09± 1.65	15.18± 3.16	15.95± 5.12	14.31± 5.71	25.28± 3.04	23.95± 4.45	9.43± 1.99	9.05± 1.95	9.24± 4.20	9.83± 3.38
P_Z	29.32± 6.15	31.76± 9.47	11.79± 1.34	13.64± 3.18	18.05± 7.84	15.20± 7.47*	24.85± 3.35	23.54± 5.74	8.09± 2.39	7.71± 2.13	7.91± 3.68	8.15± 2.85

Data presented as mean±SD. *, **, and *** are p<0.05, p<0.01, and p<0.001, respectively

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