Analyses of the Effects of Humanities Education on Brain Waves of the Frontal, Parietal, and Temporal Regions

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Received: May 23, 2022 Accepted: June 30, 2022 Online Published: August 10, 2022

doi:10.5430/jct.v11n5p289 URL: https://doi.org/10.5430/jct.v11n5p289

This work was supported by the Ministry of Education of the Republic of Korea and the National Research Foundation of Korea (NRF-2019S1A5C2A04081101).

Abstract

This study was conducted targeting college students majoring in science and engineering, who were divided into an experimental group who took a humanities course and a control group who did not. After the experimental group took a humanities course, the brain wave activity of the frontal, parietal, temporal, and central regions of the two groups was measured using electroencephalography systems, and the electroencephalogram (EEG) waveforms of the anterior cerebrum were comparatively analyzed. A total of 67 subjects participated in the experiment, with 36 in the experimental group and 31 in the control group. According to the International 10-20 system, an international standard for EEG measurement, 7 electrodes (Cz, F3, F4, P3, P4, T3, T4) were attached to the cerebral scalp, and 2 reference electrodes were attached to both earlobes. These were attached after adjusting the resistance to the minimum value. The experimental group took a humanities course called "Understanding Beauty" for two hours twice a week over a period of 15 weeks. This course aimed to develop students' imaginations to overcome a fact-centered world. After each lecture, the experimental group was asked to sit in a comfortable position with their eyes closed in a dark and quiet environment, and EEG measurements were started when their brain waveforms became stable. EEG measurements were also taken for the control group who did not take the course, at the same time and in the same manner. The measurements were conducted for about 10 minutes. The pattern in EEG changes between the two groups over time was analyzed by dividing them into alpha waves (8-13 Hz), theta waves (4-8 Hz), and beta waves (13-3 Hz). Based on the analysis results, for relative alpha waves, the difference between the mean vectors of all 7 variables was significant depending on the treatment (lecture attendance) ($F(7, 59)=11.790$, $p<0.001$). The variation over time between the experimental and control groups was significant ($F(21,45)=3.575$, $p<0.001$), indicating that there was an interaction effect between repeated measures and the groups. For relative beta waves, the difference between the mean vectors of all 7 variables was significant depending on the treatment ($F(7, 59)=12.628$, $p<0.001$). The variation over time between the two groups was significant ($F(21,45)=3.388$, $p<0.001$), suggesting that there was an interaction effect between repeated measures and the groups. For relative theta waves, the difference between the mean vectors of all 7 variables was significant depending on the treatment ($F(7, 59)=5.301$, $p<0.001$). The variation over time between the two groups was significant ($F(21,45)=3.388$, $p<0.001$), which means that there was an interaction effect between repeated measures and the groups.

Keywords: humanities, electroencephalogram (EEG), frontal lobe, parietal lobe, temporal lobe

1. Introduction

The human brain plays an integrative role of a central nerve system in regulating all behaviors and as an information processing organ for learning, memory, thinking, and problem solving (Kutlu & Gould, 2016; Sara & Hars, 2006). In particular, in infancy, neural pruning of numerous neurons and increase in myelin sheath thickness improve the speed of information transfer between neurons through external stimuli, which especially accelerates learning; in addition, the left and right brains are utilized flexibly and evenly, allowing the brain to quickly accept new functions (Gros, Veyrac, & Laroche, 2015; Schultz, 1998; Hyman, 2005). In particular, the manner in which stimuli are received from

the outside varies from person to person depending on the intensity and type of such stimuli. With the recent rapid development of research areas of brain science, various studies based on brain research are being conducted in the field of education or art (Pepperell, 2018; Cela-Conde & Ayala, 2018). Brain-based learning analytics is attempting to improve education based on brain-related responses by promoting brain function and applying it to learning or education. Humanities, a field of modern studies, is known to affect human sentiment, ethics, and psychological states (Takeuchi et al., 2015, Compston, 2010). In particular, spontaneous learning upholds hippocampal theta oscillations of participants (Pacheco Estefan et al., 2021). Conrad and Newman (2021) employed electroencephalography (EEG) to gauge participants' mind wandering while they were taking a 75-minutes-lecture online. They revelaed that higher level of mind wandering is germane to lower learning performance, backing up the findings of previous studies on downsides of e-learning due to factors outside that prevent from full attention. Using brainwave analyses measured by electroencephalography (EEG), Park and Hahm (2019) explored changes in mindset regarding stress after e-healthcare-based education.

It is also known to affect the formation of personality and smooth interpersonal relationships by acting on brain physiology (Davis & Panksepp, 2011; Hamid, Sulaiman, Murat, & Taib, 2015; Liao, Chen, & Tai, 2018; Rabinowitz, 2021). Tracking the location of excitatory neurons according to human cognitive processes is the most important area in brain research in relation to the localization of brain function. The brain's response to working memory through learning is encoded in the cerebral cortex through the 3rd and 4th stages of the slow wave system during sleep after temporarily storing the external stimuli for daytime learning through the hippocampus. In particular, it is stored in the prefrontal, parietal, and temporal regions of the brain by the sleep spindle wave generated in the 3rd and 4th stages of the sleep stage. It is known to act on emotions and emotions by being stored as specific actions and semantic memories through comparison, prediction, reasoning, and judgment in the prefrontal region. The International 10–20 system is globally applied for the area where 21 electrodes are attached to the cerebral scalp in electroencephalography (Homan, Herman, & Purdy, 1987). Regarding signals generated in the scalp of the cerebral region, measuring the release rates of α, β, δ, and θ waves in the parietal, frontal, temporal, and occipital lobes enables us to gain an understanding the characteristics of electrical signals generated in the cerebral scalp (Homan, Herman, & Purdy, 1987; Desai, Tailor, & Bhatt, 2015; Kang, Handayani, Chong, & Acharya, 2020). This study analyzed the activity of subjects' brain waves in the frontal, parietal, temporal, and central regions after they had taken a course in the humanities, where the importance of education is recently emphasized in South Korea, for 15 weeks. South Korea's education system is distinctively divided into science/engineering and liberal arts based on the content of learning, and students in science and engineering are relatively less likely to study the humanities or liberal arts. In particular, it was predicted that the humanities would affect the way the brain was used, and the changes in brain waves that may occur after taking a course in the humanities for 3 consecutive months were analyzed for each frequency. The effect of humanities education on changes in brain wave reactivity were analyzed by comparing the electrical signals of the left and right brains. It is expected that the findings of this study can be used as basic data in the future direction of education.

2. Method

2.1 Research Subject

This study was conducted only on those who wish to participate among students of D university in area B. A total of 67 healthy 20-year-olds participated in the study as subjects. The participants, who were college students majoring in science and engineering, were all determined through a baseline survey to be healthy people who had never suffered from cardiovascular disease, metabolic disease, musculoskeletal disease, respiratory disease, or neurological disease. Individuals who had undergone surgery in the last 6 months were restricted from participating in the experiment. All participants, including 36 subjects in the experimental group who would take a humanities course, and 31 subjects in the control group who would not, gave their consent to participate in the experiment after being sufficiently informed about the method and purpose of this study. This study was conducted after obtaining approval from the Institutional Review Board (IRB).

2.2 Experiment Schedule and Electroencephalogram (EEG) Measurement

The subjects took a course titled "Understanding Beauty" for 2 hours at the same time twice a week for 15 weeks. This course was a part of university education that aims to raise one's imagination to overcome the fact-centered world, and improve one's ability to discover and solve problems. After taking the course, EEG measurements of the subjects in the experimental and control groups were sequentially taken. Groups of participants were measured a total of four times during the 15-week-course. Participants (control group) who did not take the course were

measured at the same days with the course takers (experimental group). BIOTECH's Cognionics Quick-20 was used as the EEG machine. After the electrodes of the EEG machine were placed along the subjects' cerebral scalp, and the electrode resistance was adjusted to the minimum, their EEGs were recorded. Seven electrodes (Cz, F3, F4, P3, P4, T3, T4) were attached to the cerebral scalp focused on the central, frontal, parietal, and temporal lobes, according to the International 10–20 system, and two reference electrodes were attached to both earlobes after adjusting the resistance to the minimum value. To remove EEG artifacts caused by ambient noises, the subjects were asked to sit in a comfortable position with their eyes closed in a dark and quiet environment, and EEG measurements were started when their brain waveforms became stable. Measurement was carried out for 10 minutes. The analysis was performed on the experimental group and the control group, and alpha waves (8-13 Hz), theta waves (4-8 Hz), and beta waves (13-3 Hz) were analyzed in the left and right brains. The International 10-20 system was applied for EEG measurement of the cerebral scalp, and the electrode labeling is shown in Fig.1. Electrical signals of the regions marked in red were analyzed.

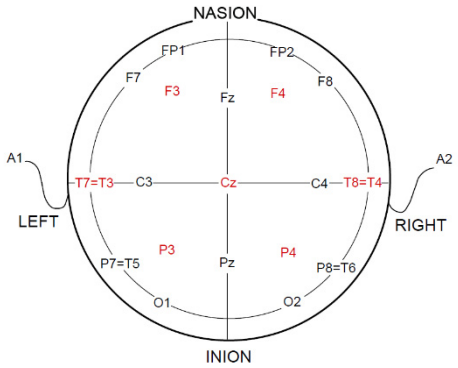


Figure 1. International 10-20 System (Electrode labeling)

Note. 3: Left brain; 4: Right brain; CZ: Central Zone; F: Frontal lobe; C: Central lobe; T: Temporal lobe

2.3 Statistical Processing

The analysis results for the three modules are presented in the order of relative alpha, relative beta, and relative theta. The results of each module are presented in the order of multivariate tests, tests of within-subject effects (including contrast analysis between repeated measures), tests of between-subjects effects, and profile plots. The within-subject effects were to determine whether there was variability in dependent variables according to repeated measures, and an interaction effect between the two groups (experimental and control groups) and the repeated measures. The between-subjects effects represented the variability in dependent variables between the experimental and control groups. Here, repeated measures multivariate analysis of variance (RM-MANOVA) approach was considered because it is suited for experimental design where the multiple groups of participants are being compared repeatedly (RM) on the multiple measures (MANOVA) of interest. The analytic model (i.e., RM-MANOVA) was applied to all three modules divided according to the experimental design: relative alpha, relative beta, and relative theta. All data were analyzed using SPSS Statistics Version 26.0.

3. Results

3.1 Relative Alpha

The results of multivariate F tests are summarized in Table 1. 1) The difference between the mean vectors of all 7 variables was significant depending on the treatment (i.e., taking a humanities course) ($F(7, 59)=11.790$, $p<0.001$). 2) The variation in 7 variables according to repeated measures was significant ($F(21,45)=4.570$, $p<0.001$). 3) The variation over time between the two groups was significant ($F(21,45)=3.575$, $p<0.001$), indicating that there was an interaction effect between repeated measures and the groups. In other words, it can be seen that the pattern of change over time differed in the experimental group that took the humanities course compared to the control group that did not.

Table 1. Multivariate F Tests of between- and within-subject Effects for Relative Alpha

Effect		Value**	F	Hypothesis df	Error df	p-value
Between-subjects (groups)		0.417	11.790	7	59	< 0.001
Within-subject	rep*	0.319	4.570	21	45	< 0.001
	rep*group	0.375	3.575	21	45	< 0.001

* rep: repetition; ** value: based on Wilk's lambda

The results of tests of within-subject effects are as follows. Mauchly's Test of Sphericity was performed, and it was found that all 7 variables did not satisfy the sphericity assumption. The results presented in Table 2 below reflected the degrees of freedom corrected using methods including Greenhouse-Geisser, Huynh-Feldt, and Lower-bound. Based on the analysis results, the variation according to repeated measures was significant in all measurement variables (for all cases, $p<0.001$).

Table 2. Univariate F Tests of Within-Subject Effects for Relative Alpha

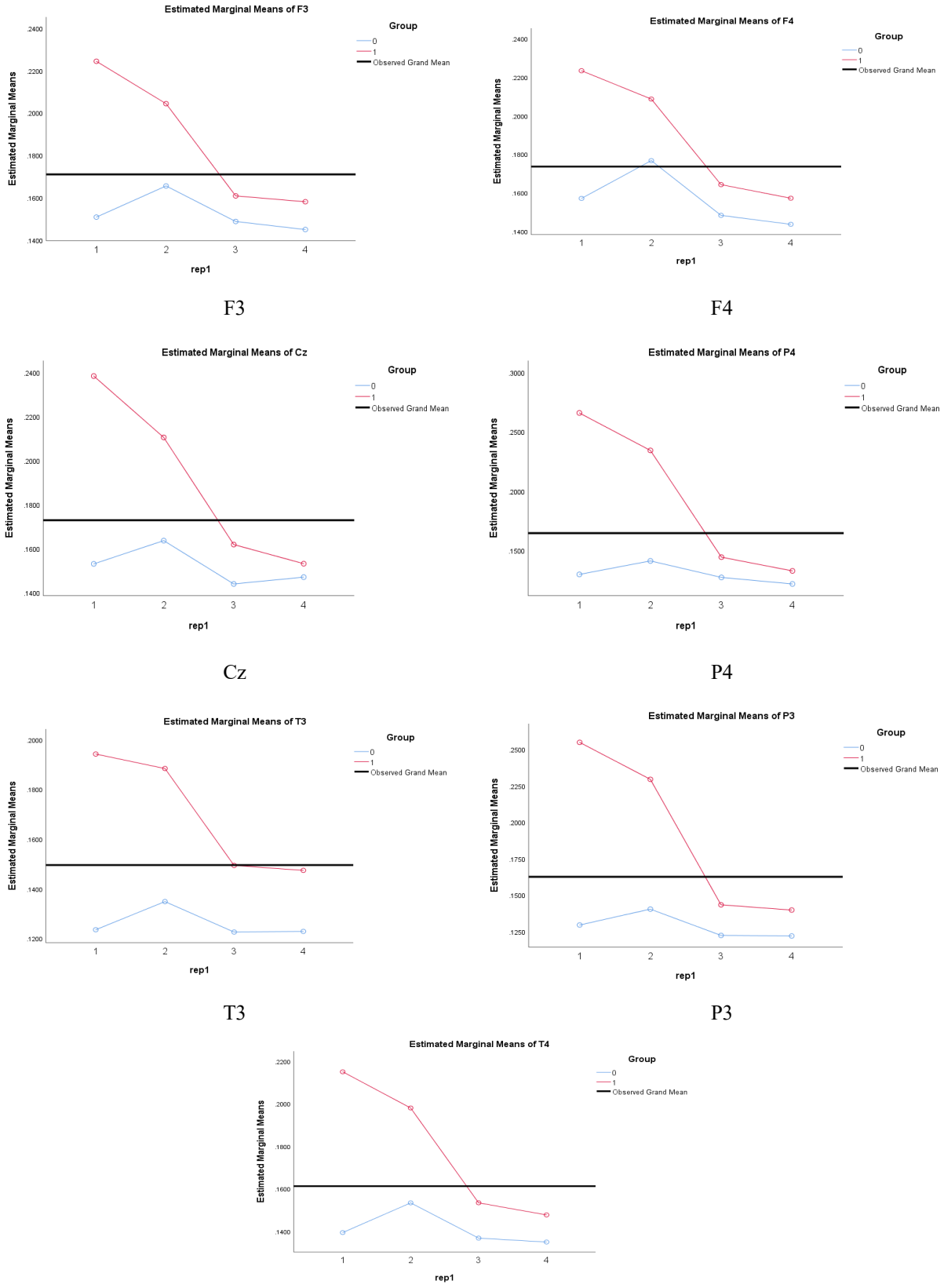
Measure	Type III Sum of Squares	df	Mean Square	F	Sig.
F3*	0.074	2.144	0.034	26.784	< 0.001
F4*	0.098	2.135	0.046	28.684	< 0.001
Cz*	0.108	2.322	0.047	26.508	< 0.001
P4*	0.255	2.122	0.120	32.230	< 0.001
T3*	0.041	2.394	0.017	11.214	< 0.001
P3*	0.216	2.104	0.103	30.777	< 0.001
T4*	0.074	2.412	0.031	19.778	< 0.001

* Measures that do not meet the sphericity assumption. We just present the Greenhouse-Geisser correction method. However, alongside the Greenhouse-Geisser method, Huynh-Feldt, Lower-bound corrections are also checked. Unless otherwise stated, three methods indicate the same significance flag.

On the other hand, the results of a contrast analysis between repeated measures showed significant differences between the first and second measures, and between third and fourth measures, which were common to all measurement variables. The results of tests of between-subjects effects are presented in Table 3. Similar to the results of tests of within-subject effects, the between-subjects effects were found to be significant in all variables ($p<0.001$). Finally, a profile plot for each measurement variable is presented (Figure 2).

Table 3. Univariate F Tests of between-Subjects Effects for Relative Alpha

Measure	df	Mean Square	F	Sig.
F3	1	0.020	56.729	< 0.001
F4	1	0.017	42.211	< 0.001
Cz	1	0.025	48.255	< 0.001
P4	1	0.069	68.452	< 0.001
T3	1	0.032	57.774	< 0.001
P3	1	0.067	76.273	< 0.001
T4	1	0.023	47.238	< 0.001



F3 F4

Cz P4

T3 P3

T4

Figure 2. Profile Plots for Relative Alpha (0: non-course-takers; 1: course-takers)

3.2 Relative Beta

The results of multivariate F tests are summarized in Table 4. 1) Depending on the treatment, the difference between the mean vectors of all 7 variables was significant ($F(7, 59)=12.628$, $p<0.001$). 2) The variation in 7 variables according to repeated measures was significant ($F(21,45)=3.423$, $p<0.001$). 3) The variation over time between the two groups was significant ($F(21,45)=2.039$, $p=0.023$), indicating that there was an interaction effect between repeated measurements and the groups. In other words, it can be seen that the pattern of change over time differed for the group that took the humanities course and the group that did not.

Table 4. Multivariate F Tests of Effects of Between- and Within-Subject for Relative Beta

Effect		Value**	F	Hypothesis df	Error df	p-value
Between-subject (group)		0.400	12.628	7	59	< 0.001
Within-subject	rep*	0.385	3.423	21	45	< 0.001
	rep*group	0.512	2.039	21	45	0.023

* rep: repetition; ** value: based on Wilk's lambda

The results of tests of within-subject effects are presented in Table 5. According to Mauchly's Test of Sphericity performed, all 7 variables satisfied the sphericity assumption. Based on the analysis results, the variation according to repeated measures was significant in all measurement variables (for all cases, $p<0.001$).

Table 5. Univariate F Tests of Within-Subject Effects for Relative Beta

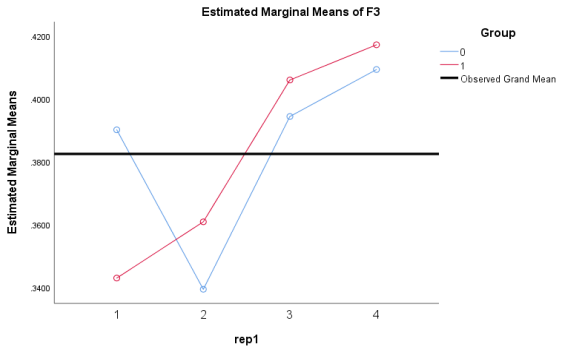
Measure	Type III Sum of Squares	df	Mean Square	F	Sig.
F3	0.170	3	0.057	16.825	< 0.001
F4	0.234	3	0.078	20.771	< 0.001
Cz	0.206	3	0.069	20.430	< 0.001
P4	0.301	3	0.100	19.452	< 0.001
T3	0.105	3	0.035	13.485	< 0.001
P3	0.287	3	0.096	20.267	< 0.001
T4	0.146	3	0.049	15.651	< 0.001

On the other hand, the results of the contrast analysis between repeated measures showed a significant difference between the second and third measures, which was common to all measurement variables.

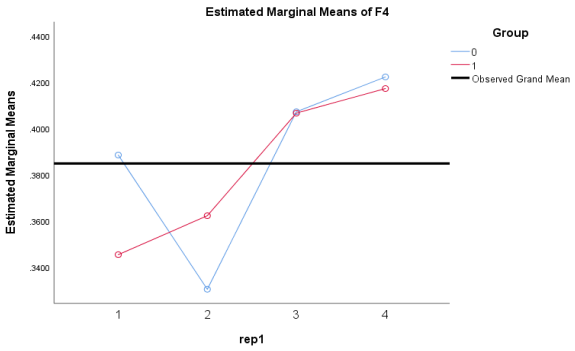
The results of tests of between-subjects effects are presented in Table 6. The between-subjects effects were found to be significant in all measurement variables, excluding F3 and F4 (at the p-value of 0.05). Finally, a profile plot for each measurement variable is presented (Figure 3)

Table 6. Univariate F Tests of Between-Subjects Effects for Relative Beta

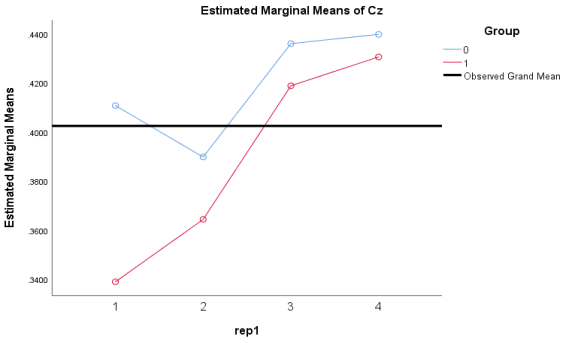
Measure	df	Mean Square	F	Sig.
F3	1	0.000	0.031	0.860
F4	1	0.000	0.237	0.628
Cz	1	0.016	11.663	0.001
P4	1	0.015	7.954	0.006
T3	1	0.009	7.316	0.009
P3	1	0.016	8.440	0.005
T4	1	0.004	4.170	0.045



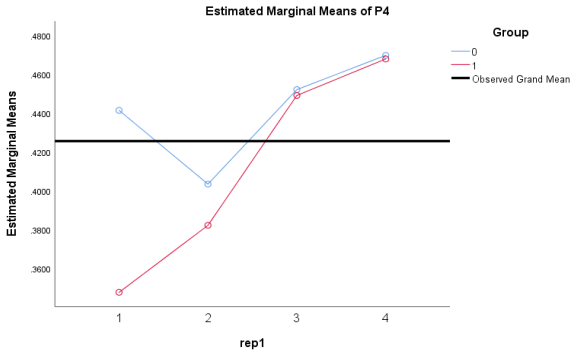
F3



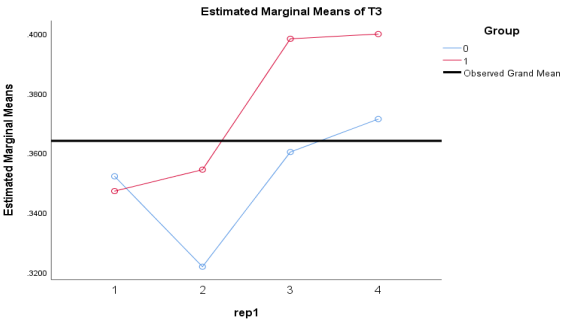
F4



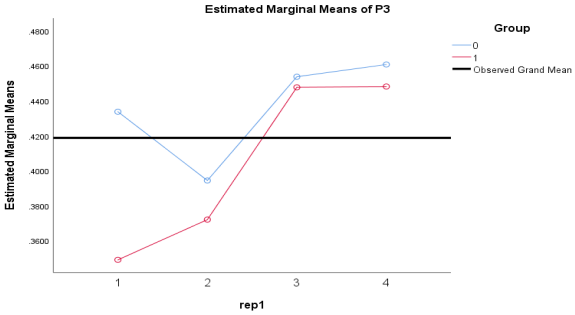
Cz



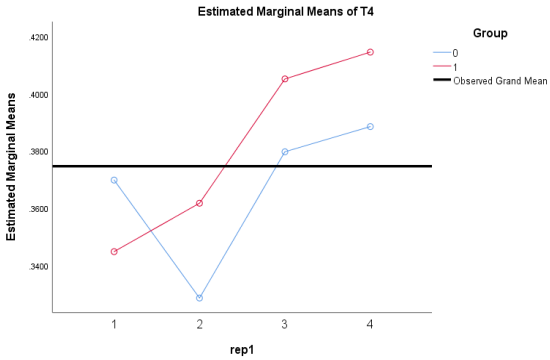
P4



T3



P3



T4#

Figure 3. Profile Plots for Relative Beta (0: non-course-takers; 1: course-takers)

3.3 Relative Theta

The results of the Multivariate F Tests are summarized in Table 7. 1) The difference between the mean vectors of all 7 variables depending on the treatment was significant ($F(7, 59)=5.301$, $p<0.001$). 2) The variation of 7 variables according to repeated measures was significant ($F(21,45)=3.219$, $p<0.001$). 3) The variation between the two groups over time was significant ($F(21,45)=3.388$, $p<0.001$), suggesting that there was an interaction effect between repeated measures and the groups. That is, it can be seen that the pattern of change over time for the group that took the humanities course differed from the group that did not.

Table 7. Multivariate F Tests of Effects of Between- and Within-Subject for Relative Theta

Effect		Value**	F	Hypothesis df	Error df	p-value
Between-subject (group)		0.614	5.301	7	59	< 0.001
Within-subject	rep*	0.400	3.219	21	45	< 0.001
	rep*group	0.387	3.388	21	45	< 0.001

* rep: repetition; ** value: based on Wilk's lambda

The results of tests of within-subject effects are as follows. Mauchly's Test of Sphericity was conducted, and it was found that three variables of F3, Cz, and P4 did not satisfy the sphericity assumption. The results presented in Table 8 below reflected the correction of degrees of freedom using methods such as Greenhouse-Geisser, Huynh-Feldt, and Lower-bound. Based on the analysis results, variations according to repeated measures were significant in all measurement variables other than T4 (at a p-value of 0.05).

Table 8. Univariate F Tests of Within-Subject Effects for Relative Theta

Measure	Type III Sum of Squares	df	Mean Square	F	Sig.
F3*	0.152	2.772	0.055	14.689	<0.001
F4	0.187	3	0.062	16.914	<0.001
Cz*	0.119	2.820	0.042	14.372	<0.001
P4*	0.059	2.765	0.021	7.320	<0.001
T3	0.029	3	0.010	3.560	0.015
P3	0.066	3	0.022	8.959	<0.001
T4	0.047	3	0.016	2.489	0.062

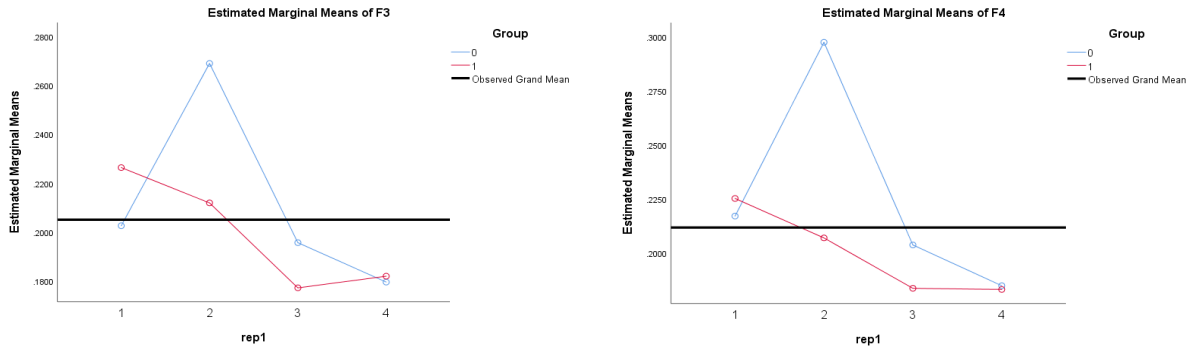
* Measures that do not meet the sphericity assumption. We just present the Greenhouse-Geisser correction method. However, alongside the Greenhouse-Geisser method, Huynh-Feldt, Lower-bound corrections are also checked. Unless otherwise stated, three methods indicate the same significance flag.

Meanwhile, for the measurement variables other than T4, the results of the contrast analysis between repeated measures mainly showed a significant difference between the second and third measures.

The results of tests of between-subjects effects are presented in Table 9. Between-subjects effects were significant only in F4 ($p=0.002$). Finally, a profile plot for each measurement variable is presented (Figure 4).

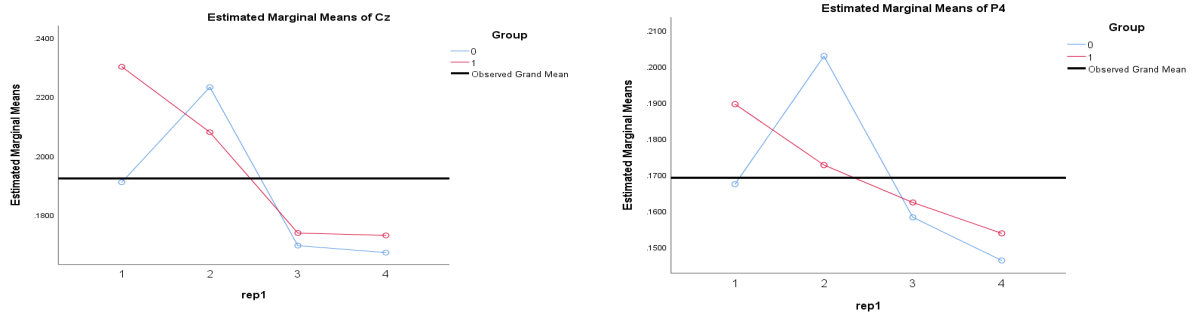
Table 9. Univariate F Tests of between-subjects Effects for Relative Theta

Measure	df	Mean Square	F	Sig.
F3	1	0.003	2.772	0.101
F4	1	0.011	10.604	0.002
Cz	1	0.001	1.665	0.201
P4	1	0.000	0.020	0.887
T3	1	0.000	0.060	0.807
P3	1	0.000	0.355	0.553
T4	1	0.000	0.087	0.768



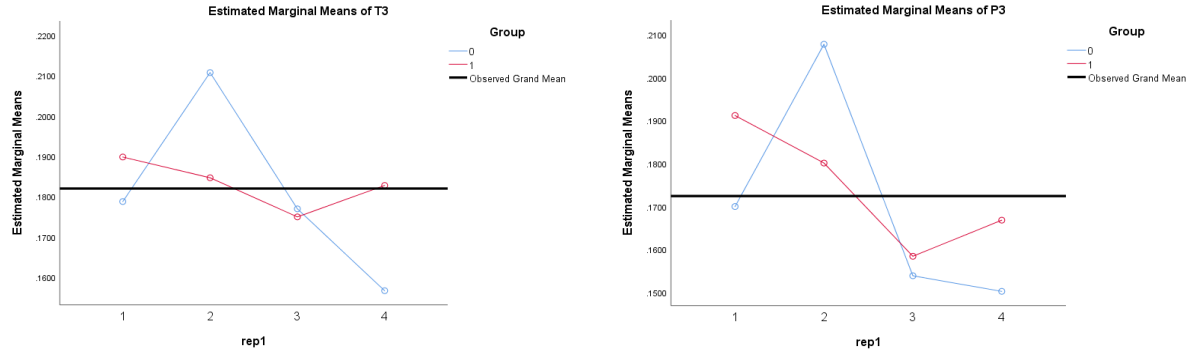
F3

F4



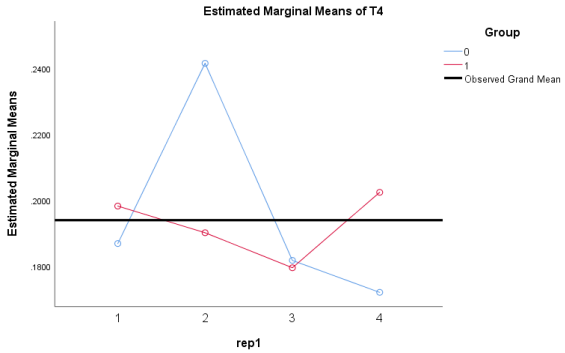
Cz

P4



T3

P3



T4

Figure 4. Profile Plots for Relative Theta (0: non-course-takers; 1: course-takers)

4. Disscussion

With regard to the observed relative alpha waves in the cerebral lobe, alpha waves in the experimental group were relatively more active in the frontal, parietal, temporal, and central lobes compared to those in the control group. For Alpha waves, which are a basic brain wave in the 8-13 Hz band (Leite, 2020; Molina del Río, Guevara, Hernández González, Hidalgo Aguirre, & Cruz Aguilar, 2019), it is considered that an idle brain state was induced in the experimental group, in which the brain can be prepared for a state of comfortable relaxation or concentration.

Relative Beta waves showed a tendency to be activated in the experimental group in the frontal lobes (F3, F4) and temporal lobes (T3, T4) compared to the control group. Beta waves are fast waves and can be broadly divided into three frequency bands. Low Beta waves (12-14.99H) are dominant when you are alert regarding your surroundings, Mid-range Beta waves (15-19.99Hz) are dominant when you are focused on a topic (Molina del Río, Guevara, Hernández González, Hidalgo Aguirre, & Cruz Aguilar, 2019; Hsu, Cheng, & Chiu, 2017), and High Beta waves (20-29.99 Hz) are dominant when you are greatly nervous or anxious (Hsu, Cheng, & Chiu, 2017; Kraus et al., 2020). Low and Mid-range Beta waves showed a dominant tendency, although they were not subdivided in this study. In particular, the frontal lobe is a cerebral lobe that is active in states associated with morality, conscience, learning, or concentration, and this study also found such a tendency for the frontal lobe to become active. The temporal lobe is involved in hearing (Cope et al., 2020), and it is considered that it was activated together with the frontal lobe due to the stimulation of sound waves while taking a humanities course.

Relative theta waves are dominant in a slightly sleepy or meditative state, with a frequency range of about 4-7.99 Hz (Yamsa-Ard & Wongsawat, 2015; Malhotra et al., 2021). As the number of humanities lectures attended increased, the frequency range of about 6-7 Hz showed a tendency to appear dominantly, and the frontal and temporal lobes showed stable patterns without significant fluctuations; however, the details of this are not presented in this study. As a result, it is judged that the humanities course significantly affected the attendees' psychological stability and their ability to focus on a topic. However, since this study was only conducted for a short period of about 3 months, there are limitations in generalizing the findings of this study. In the future, it is considered necessary to conduct follow-up research by extending the experimental period and applying more diverse educational contents.

5. Conclusion & Recommendations

Through all the research results, the relative alpha waves of the frontal, parietal, and temporal regions of the brain map through humanities education showed an increasing tendency, and the relative theta wave showed a decreasing trend. In addition, although it is not shown in this data, it is recognized that the humanities lecture was helpful for psychological stability, such as human emotions and emotions, as the relative gamma wave showed a decreasing tendency. However, as mentioned above, it is necessary to consider the limited classes and the short period of time, and it is considered that additional research on various lectures is needed to overcome the limitations of not considering the individual characteristics of the participants' humanities lectures.

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