Effects of Planting on the Prefrontal Electroencephalogram Activity of University Students

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ABSTRACT

Background and objective: This study was conducted from June 1 to August 30, 2021 with 33 students at Daegu Catholic University to investigate the effect of planting on the theta, alpha, beta, and gamma waves of the prefrontal cortex.

Methods: For the experiment, the subjects wore electroencephalogram (EEG) sensors and proceeded through the following three steps: 1) preparation stage: looking at the wall (2 min), 2) work stage: planting plants (5 min), and 3) appreciation stage: looking at and appreciating the plants they planted (3 min).

Results: As a result of analyzing the total relative values of the preparation, work, and appreciation stages in the raw data (excluding the delta wave, which increases during sleep), the alpha wave increased in the work stage of planting activity (Left: \( p = .000 \), Right: \( p = .000 \)). Alpha waves are brain waves that are activated in states of relaxation, rest, and euphoria. In male students, alpha waves (Left: \( p = .001 \), Right: \( p = .001 \)) were activated in the work stage. In female students, there was a significant difference in all EEG activity between the stages. Theta wave (Left: \( p = .046 \), Right: \( p = .029 \)) was most activated in the appreciation stage, and the alpha wave (Left: \( p = .000 \), Right: \( p = .000 \)) was most activated in the work stage. Beta waves (Left: \( p = .016 \), Right: \( p = .013 \)) and gamma waves (Left: \( p = .015 \), Right: \( p = .011 \)) were found to be inactivated in the work stage.

Conclusion: The study results facilitated the investigation of planting effectiveness according to the type of activity by measuring the EEG for each activity stage.

Keywords: alpha wave, appreciation, EEG, preparation, work

Introduction

Due to the spread of COVID-19, most people, including people who are quarantined, are subjected to many restrictions and sanctions in their daily life, such as quarantine and remaining indoors. Unable to relieve the accumulated anxiety and depression, people are suffering from severe depression or lethargy, and a new term describing this phenomenon has arisen: “Corona Blue”. “Corona blue”, a compound word of ‘Coronavirus disease’ and ‘blue,’ a color that symbolizes depression, is emerging as a serious social problem as it affects many people (Kim, 2021). In particular, university students feel a sense of deprivation of opportunities due to the limitations of face-to-face activities, and are faced with problems of adjusting to university life, such as academic achievement, career path, and new interpersonal relationships. In addition, in the process of rapid social change, they are facing constant life stressful situations (Lee, 2012). It is known that the stress experienced by university students and their maladaptive coping decrease academic achievement and life satisfaction (Suldo et al., 2008).

Currently, people are searching for various healing methods to relieve the stress and depression that occur during
city life; the use of companion plants as one such method is now receiving attention. A companion and an animal living with a person is called a companion animal, a companion plant is a plant that lives with a person like a companion animal. This term has begun to be used by the mass media as well as on the Internet. The birth of such a neologism reflects the increase in the number and social interest of people who want to achieve psychological satisfaction through emotional communion with plants (Kim, 2018). Gardening activities with living plants are particularly effective in psychological and emotional aspects. Recently, various studies have been conducted to investigate physiological changes in emotional function. Among the objective tests for examining human physiology, the electroencephalogram (EEG) test provides quantitative data for psychophysiology research of quantitative brain function (Chang and Chen, 2005). In the brain, as part of the central nervous system, spontaneous electrical changes occur in response to stimulation and these changes are measured by EEG. EEG is an objective and non-invasive method that can measure the continuously changing brain activity by recording electrical changes generated in real time by the activity of brain neurons (Yoon, 2010). These studies show that a simplified device produces consistent measurements repeatedly, which are also highly consistent with those of the traditional multi-channel EEG device (Rogers et al., 2016; Ratti et al., 2017). It is reported that various cognitive states such as relaxation, attention, sleep, and arousal can be effectively measured and classified by simplified EEG devices (Kang et al., 2015; Peng et al., 2019; Fernandez-Blanco et al., 2020). In a study on college students, when green plants are placed indoors, positive physiological changes occur in emotional function due to a decrease in delta waves in the frontal and temporal lobes, an increase in alpha waves in the occipital lobe, and a decrease in beta waves in the parietal lobe (Park et al., 2014). It was reported that the actual plant stimulation group experienced a higher level of stabilization and relaxation than the artificial color stimulation group in middle-aged people (Jang et al., 2019). Various psychological mechanisms work in the process of restoring human nature through plants. It is said that growing plants helps to acknowledge one's worth, which leads to improved self-esteem and emotional stability, as well as consideration for others and cooperation (Woo and Park, 2012). There is a report that horticultural activities applying the rational emotive behavior therapy technique for college students reduce irrational beliefs and job stress and have a positive effect on improving career maturity (Jo et al., 2019).

Therefore, in this study, the psychophysiological effect of horticultural activity was investigated by analyzing the effect of planting on the brain wave activity of university students. The purpose of this study was to analyze the difference in EEG activity between planting and plant appreciation to establish a basis for designing a horticultural activity program according to the purpose of healing for each subject.

Research Methods

Study subjects

This study was conducted with 33 students from June 1 to August 30, 2021 enrolled in Daegu Catholic University who gave consent to participate in the study after being explained the purpose, method, and duration of the experiment. The average age of the subjects was 22.8 ± 1.5 years, and there were 14 male (42.4%) and 19 female students (57.6%). The study was conducted in the laboratory (area: 30 m², illuminance : 300-400 lux) of Daegu Catholic University under limited conditions in which external stimuli were excluded and the subject could concentrate on the experiment. All participants were in their twenties (an age when the prefrontal cortex is being completed; Ha and Park, 2018), not currently taking any medications for disease, and had no particular brain disease or color perception problems. Among the subjects, those who ate food containing alcohol or caffeine two h before the experiment were excluded.

Research tools

Program design

The planting program was designed as a set of activities where each subject transplanted a table palm (Chamaedorea
elegans) and appreciated the plant. As an indoor plant, table palm has the advantage of being air purifying, easy to obtain, and easy to care for. The program was 10 min long in total and divided in three stages as follows: 1) preparation stage: looking at the wall (2 min), 2) work stage: planting plants (5 min), 3) appreciation stage: looking at and appreciating the plants (3 min) (Table 1).

Table 1. Composition of planting program

<table>
<thead>
<tr>
<th>Stage</th>
<th>Time (min)</th>
<th>Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preparation</td>
<td>2</td>
<td>Looking at the wall</td>
</tr>
<tr>
<td>Work</td>
<td>5</td>
<td>Planting Chamaedorea elegans</td>
</tr>
<tr>
<td>Appreciation</td>
<td>3</td>
<td>Viewing the plant</td>
</tr>
</tbody>
</table>

Program run

Subjects who voluntarily consented to the experiment participated in the experiment after filling out the consent form, reading the experiment manual, and familiarizing themselves with the precautions for EEG measurement. Before starting the experiment, the students were given a brief explanation of the role of cobble-stone soil, culture soil, clay sand, and the planting process so that the planting work could be carried out smoothly. Wearing an EEG measuring device, each subject transplanted a table palm (25-30 cm tall, 10 cm in diameter) into a flowerpot (12 × 12 × 15 cm), and then appreciated the plant. At the beginning of each stage, they were given signals of ‘start,’ ‘plant,’ and ‘stop and look’ with a small sound (Fig. 1).

Assessment tools

In this study, the EEG of the prefrontal lobe was measured at each activity stage (preparation-work-appreciation stage) using an EEG measuring device (NeuroNicle E1, LAXTHA Inc., Korea). The reference electrode and ground electrode were attached to the right earlobe in the form of tongs, and a band-type measuring device with two measuring electrodes was worn to be placed on Fp1, Fp2 (prefrontal lobe) according to the 10/20-International Electrode Placement System to measure 2-channel EEG (Seol, 2020).

The frequency of the EEG was analyzed for theta waves ($\theta$ wave: 4-8 Hz), alpha waves ($\alpha$ wave: 8-13 Hz), beta waves ($\beta$ wave: 13-30 Hz), and gamma waves ($\gamma$ wave: 30-50 Hz) (Lee, 2011), and excluded the delta wave, which increases during deep sleep. The theta wave reflects a state of deep meditation (Park, 2002), the alpha wave is activated when there is relaxation and rest, happiness, and no stress (Kim et al., 2005) and the beta wave is activated during states of attention, tension, and an active mental state. In addition, gamma waves are brain waves that are activated when solving difficult problems in a highly cognitive state (Kim et al., 2005). For the analysis, the frequency value (Hz) is displayed on the horizontal axis, and the power value ($\mu$V; indicating the degree of appearance of the corresponding frequency) is displayed on the vertical axis. The relative power, which is the ratio of the absolute power of each frequency band divided by the absolute power of the entire frequency band, was compared and analyzed as a dependent variable.

Fig. 1. Three stages of the experiment.
Effects of Planting on the Prefrontal Electroencephalogram Activity of University Students

Table 2. Changes in electroencephalogram of the subjects by each activity stage (N = 33, unit: $\mu$V)

<table>
<thead>
<tr>
<th>EEG</th>
<th>Activity stage</th>
<th>$\text{Activity Stage}$</th>
<th>$p^\beta$</th>
<th>$p^\gamma$</th>
<th>$p^\delta$</th>
<th>$p^\epsilon$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\theta$ wave (4-8Hz)</td>
<td>Preparation</td>
<td>0.65±0.20</td>
<td>0.67±0.10</td>
<td>1.000</td>
<td>0.70±0.14</td>
<td>0.094</td>
</tr>
<tr>
<td></td>
<td>Work</td>
<td>0.66±0.18</td>
<td>0.67±0.12</td>
<td>1.000</td>
<td>0.70±0.15</td>
<td>0.122</td>
</tr>
<tr>
<td></td>
<td>Appreciation</td>
<td>0.12±0.05</td>
<td>0.16±0.04</td>
<td>0.000 $^{***}$</td>
<td>0.12±0.03</td>
<td>1.000</td>
</tr>
<tr>
<td>$\alpha$ wave (8-13Hz)</td>
<td>Preparation</td>
<td>0.12±0.05</td>
<td>0.16±0.04</td>
<td>0.000 $^{***}$</td>
<td>0.12±0.03</td>
<td>1.000</td>
</tr>
<tr>
<td></td>
<td>Work</td>
<td>0.15±0.11</td>
<td>0.12±0.06</td>
<td>0.340</td>
<td>0.12±0.09</td>
<td>0.076</td>
</tr>
<tr>
<td></td>
<td>Appreciation</td>
<td>0.14±0.11</td>
<td>0.12±0.07</td>
<td>0.476</td>
<td>0.12±0.09</td>
<td>0.029 $^*$</td>
</tr>
<tr>
<td>$\beta$ wave (13-30Hz)</td>
<td>Preparation</td>
<td>0.08±0.08</td>
<td>0.05±0.03</td>
<td>0.147</td>
<td>0.06±0.06</td>
<td>0.170</td>
</tr>
<tr>
<td></td>
<td>Work</td>
<td>0.07±0.07</td>
<td>0.05±0.05</td>
<td>0.235</td>
<td>0.06±0.06</td>
<td>0.095</td>
</tr>
<tr>
<td>$\gamma$ wave (30-50Hz)</td>
<td>Preparation</td>
<td>0.65±0.20</td>
<td>0.67±0.10</td>
<td>1.000</td>
<td>0.70±0.14</td>
<td>0.094</td>
</tr>
<tr>
<td></td>
<td>Work</td>
<td>0.66±0.18</td>
<td>0.67±0.12</td>
<td>1.000</td>
<td>0.70±0.15</td>
<td>0.122</td>
</tr>
<tr>
<td></td>
<td>Appreciation</td>
<td>0.12±0.05</td>
<td>0.16±0.04</td>
<td>0.000 $^{***}$</td>
<td>0.12±0.03</td>
<td>1.000</td>
</tr>
</tbody>
</table>

$^a$Pairwise comparison of preparation and work stages by Bonferroni.
$^b$Pairwise comparison of preparation and appreciation stages by Bonferroni.
$^c$Pairwise comparison of work and appreciation stages by Bonferroni.
$^d$Pairwise comparison of appreciation and work stages by Bonferroni.
$^e$Comparison by activity stages by repeated measures design ANOVA.
$^*p > .05$, $^{**}p < .01$, $^{***}p < .001$.

Fig. 2. Changes in EEG of students in three activity stages, i.e., preparation, work, and appreciation (unit: $\mu$V). (A) $\theta$ wave (4-8 Hz), (B) $\alpha$ wave (8-13 Hz), (C) $\beta$ wave (13-30 Hz), (D) $\gamma$ wave (30-50 Hz). n = 33; *** = $p < .001$, $\text{ns} = p > .05$; significant by repeated measures design ANOVA.
Data analysis

The data were analyzed using the SPSS (version 19.0, IBM, USA, 2012) program. The average difference in the activity stage was analyzed by repeated measures ANOVA. A post-hoc analysis by Bonferroni was performed to examine the average estimate of the effect size for each stage.

Results and Discussion

Changes in EEG of subjects by activity stage

From the raw data of 33 university students, the relative values were compared between the stages of preparation (2 min), work (5 min), and appreciation (3 min). The left \( \alpha \) wave values were 0.12 ± 0.05 for the preparation stage, 0.16 ± 0.04 for the work stage, and 0.12 ± 0.03 for the appreciation stage \((p = .000)\), while the right \( \alpha \) wave values were 0.12 ± 0.05 for the preparation stage, 0.16 ± 0.04 for the work stage, and 0.12 ± 0.03 for the appreciation stage \((p = .000)\), showing a significant change for each stage. It was observed that the activity of alpha wave significantly increased when planting the plant directly. In the study of Son et al. (1998), when plants were placed indoors, there was no statistically significant difference overall, but alpha waves increased and delta waves decreased, showing the usefulness of indoor plants in the arousal and stable state of the brain. In this study, when plants were directly planted, the alpha wave activity increased with a high degree of significance. There were no significant differences between the stages in the theta, beta, and gamma waves (Table 2 and Fig. 2).

It was reported that gardening improved the mental stability and depressed state of college students and also maintained an active and enterprising psychological state (Kim and Cho, 2018). As a result of analyzing the effects of plant color stimuli on human brain waves and emotions, viewing green plants in an indoor environment has a positive effect on the improvement of psychophysiology, and there is a study result that the cerebral activity is increased (Jang, 2013). Also, alpha waves are generated when the body and mind are in harmony as the muscles are also relaxed at the same time as the relaxed state (Kim et al., 2005). As shown in the results of this study, it is judged that the activity of planting green plants directly relaxes the mind and body and is effective in improving mental physiology.

Changes in EEG by activity stage according to gender

EEG changes were analyzed according to the activity stage by gender. The left \( \alpha \) wave values for male students were 0.12 ± 0.04 for the preparation stage, 0.15 ± 0.03 for the work stage, and 0.13 ± 0.04 for the appreciation stage \((p = .001)\), while the right \( \alpha \) wave values were 0.11 ± 0.04 for the preparation stage, 0.15 ± 0.03 for the work stage, and 0.12 ± 0.03 for the appreciation stage \((p = .001)\), showing significant differences between the stages. The activation was particularly significant in the work stage. There were no significant differences between the activity stages in the theta, beta, and gamma waves (Fig. 3).

In female students, there were significant differences in all EEG between the activity stages. First, the left \( \theta \) wave values were 0.62 ± 0.20 for the preparation stage, 0.69 ± 0.09 for the work stage, and 0.71 ± 0.11 for the appreciation stage \((p = .046)\), and the right values were 0.66 ± 0.18 for the preparation stage, 0.71 ± 0.09 for the work stage, and 0.73 ± 0.12 for the appreciation stage \((p = .029)\), showing significant changes in both sides. The activation was particularly significant in the appreciation stage. The left \( \alpha \) wave values were 0.13 ± 0.06 for the preparation stage, 0.17 ± 0.05 for the work stage, and 0.12 ± 0.03 for the appreciation stage \((p = .000)\), and the right values were 0.12 ± 0.06 for the preparation stage, 0.16 ± 0.05 for the work stage, and 0.12 ± 0.03 for the appreciation stage \((p = .000)\), showing significant changes in both sides. The inactivation was particularly significant in the work stage. The left \( \beta \) wave values were 0.16 ± 0.11 for the preparation stage, 0.11 ± 0.05 for the work stage, and 0.12 ± 0.07 for the appreciation stage \((p = .016)\), and the right values were 0.14 ± 0.10 for the preparation stage, 0.09 ± 0.05 for the work stage, and 0.10 ± 0.08 for the appreciation stage \((p = .013)\), showing significant changes in both sides. The inactivation was particularly significant in the work stage. The left \( \gamma \) wave values were 0.09 ± 0.09 for
Effects of Planting on the Prefrontal Electroencephalogram Activity of University Students

the preparation stage, 0.04 ± 0.02 for the work stage, and 0.05 ± 0.05 for the appreciation stage \((p = .015)\), and the right values were 0.07 ± 0.08 for the preparation stage, 0.04 ± 0.03 for the work stage, and 0.05 ± 0.05 for the appreciation stage \((p = .011)\), showing significant changes in both sides. The inactivation was particularly significant in the work stage (Fig. 4).

It was confirmed numerically that alpha waves increased in the work stage rather than the preparation stage, regardless of gender, reducing stress and increasing emotional stability during the process of planting. In the case of female students, theta wave activity increased stepwise as they proceeded from the preparation stage to the work stage and to the appreciation stage, and the beta wave and gamma wave both decreased significantly. Theta waves reflect a state of deep meditation (Kim et al., 2005), alpha waves are well generated in a healthy and stress-free state, and occur when the body and mind are in harmony as the brain is relaxed and the muscles are also relaxed (Kim et al., 2005). In the case of female students, it was found that they were more active in the work stage compared to the preparation stage, and in the appreciation stage compared to the work stage. It was found that planting a plant or appreciating it was effective in increasing inner concentration because it can help relaxation. In the brain, there is a study result that creativity and telepathy increase when theta and alpha waves cross (Klimesch, 1995). In the case of female students, it was observed that theta wave activity increased and alpha wave activity decreased during the appreciation stage. The results of analyzing the physiological responses of adult men and women to the appearance of alpha waves in the frontal and occipital lobes of the brain according to the level of index of greenness in Choi (2016), there was no significant difference because the mean values

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**Fig. 3.** Changes in EEG in male students in three activity stages i.e., preparation, work, appreciation (unit: µV). (A) \(\theta\) wave (4–8 Hz), (B) \(\alpha\) wave (8–13 Hz), (C) \(\beta\) wave (13–30 Hz), (D) \(\Upsilon\) wave (30–50 Hz). \(n = 14; ** = p < 0.01, ns = p > 0.05\): significant by repeated measures design ANOVA.
for each area were similar. On the other hand, as a result of comparing the differences between men and women, it was found that the number of women was generally higher than that of men. In this study, it was also found that the EEG activity of female students increased more in the horticultural activity of planting.

Given the findings of the studies indicating that beta waves appear when studying or performing tasks under low tension or stress (Lee et al., 2019) and that gamma power values are associated with negative emotional processes (Luo et al., 2007), planting activity seems to have positive effects on stress reduction in female students. These results are in line with the research findings that gardening helps mental health, such as helping to recover from anxiety or tension, and helping to think positively (Chung and Sim, 1992).

It is reported that in the process of growing plants, people have a sense of responsibility along with expectations and affection for the plants as a life and feel psychological stability and flexibility through green plants, in addition to reduced tension and anxiety (Kim, 2019). Ikei et al. (2014) measured changes in heart rate variability according to the presence or absence of plants in an indoor space, and found that parasympathetic nerves were activated, which ultimately led to the stabilization of the autonomic nervous system. In particular, the horticultural treatment program using planting reduced the stress of mothers of children with disabilities who are subjected to daily stress due to practical difficulties and restrictions, which have different characteristics from ordinary families (Han et al., 2012).

This experiment was to analyze the difference in EEG activity between planting and plant appreciation, and to
Effects of Planting on the Prefrontal Electroencephalogram Activity of University Students

prepare the basis for designing a horticulture activity program according to the healing purpose of each subject. Cha (2001) reported that horticultural activities differ according to the social characteristics of college students. Therefore, it was analyzed whether there was a difference in brainwave changes between men and women. In this study, it was confirmed that planting activity increases alpha wave activity compared to plant appreciation. Compared to male students, it was confirmed that female students not only increased alpha waves, which represent relaxation and rest, but also decreased beta waves and gamma waves related to concentration and tension. In addition, it was found that theta wave was activated in the appreciation stage, and inner concentration of attention was increased. This difference is believed to be due to female students' higher interest and preference for horticultural activities. The horticultural activity program was effective in improving emotional intelligence and stress coping in nursing students (Yang and Park, 2018). It is thought that planting plants during horticulture activities will help college students relax and relieve stress. These results are significant in that they provide quantitative evidence of the effect of plant gardening, which has begun to take root as a new trend in emotional wellbeing in horticultural and “green” culture with the increase in single-person households. It can also contribute to establishing planting as a stress management program for college students. It is believed that it will help the foundation for program design according to the purpose of healing for each type of horticultural activity and subject.

Based on the results of this study, limitations and suggestions for follow-up studies are indicated. First, it was confirmed that planting has a significant effect on the brain wave activity, especially alpha waves. A comparative analysis is needed with various plant materials, such as indoor plants and succulents; planting methods, such as hydroponic and soil culture; and smart horticultural planting using coding. Second, we propose a repeated study that can generalize the research results by expanding the research subject group and number of subjects. Third, a detailed analysis on the continuous interaction with plants, along with qualitative evaluation, is necessary.

References


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