

Foliage Plants Improve Concentration and Emotional Condition of Elementary School Students Performing an Intensive Assignment

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Abstract. This study was conducted to compare the concentration and emotional condition of elementary school students performing an intensive assignment in the presence or absence of foliage plants, using electroencephalography (EEG) and a modified semantic differential method (SDM). In a crossover experimental design, 30 elementary students performed a 3-min intensive age-appropriate arithmetic assignment in the presence or absence of foliage plants. Continuous EEG monitoring in the frontal lobe was performed using a wireless dry EEG device. Immediately thereafter, subjective evaluation of emotions was performed using the SDM. The concentration of the male elementary students was significantly higher when the assignment was performed in the presence vs. absence of plants as evidenced by the increase in the ratio of spectral edge frequency of 50 and a decrease in the relative theta power spectrum in the right frontal lobe. The SDM results revealed a significant psychological relaxation when the assignment was performed in the presence of plants. Therefore, the presence of foliage plants in the space where the elementary students performed the intensive assignment led to positive effects on concentration and emotional condition.

As positive effects of contact with nature are known, studies have evaluated the influence of plant arrangement or natural landscapes in workplaces and working environments (Chang and Chen, 2005; Tennessen and Cimprich, 1995). Asaumi (1995a, 1995b) reported that plant arrangement improves

a room's aesthetic quality and makes subjects feel more relaxed. In a hospital, inpatients who were assigned to a room with a natural view recovered faster than those assigned to a room with windows facing buildings (Ulrich, 1984). People arrange plants in their office to reduce or recover from stress from back pain, eyestrain, mental fatigue, and shoulder stiffness (Asaumi et al., 1994; Kondo, 1989).

Previous studies have reported that contact with plants provides a variety of benefits to humans and especially to children. Montessori (2013) reported that because nature directly educates humans, it is necessary to offer nature-based childhood education for a healthy body and mind. The results of EEG and subjective evaluations of emotions under green visual stimuli revealed improved concentration and psychological relaxation in elementary school students when they looked at real foliage plants compared with other visual stimuli (Oh et al., 2019). According to Markevych et al. (2014), as the distance from

residence to green space decreased, the occurrence of behavioral problems (e.g., emotional dysregulation, hyperactivity/inattention, and peer relationship problems) in children decreased. Another study showed that when 25 children, aged 7 to 12 years with attention-deficit/hyperactivity disorder (ADHD), walked in the city or park for 20 min and then performed the Digit Span Backward, the achievement of the task performed after taking a walk in the park was higher than that performed after taking a walk in the city (Taylor and Kuo, 2009).

Children in many countries are under a high level of academic stress in recent years (Bradshaw et al., 2013; Kim, 2015). Students in South Korea have the highest level of academic achievement and graduation rate [Jeon, 2009; Organization for Economic Co-operation and Development (OECD), 2017]. The Program for International Student Assessment reported that the youth in South Korea spend 60 h per week studying. This is the greatest amount of time among the OECD countries (Jeon, 2009; OECD, 2017). In addition, the results of the International Survey of Children's Well-being by the United Nations Children's Fund revealed that the subjective well-being of Korean children was the lowest among the OECD countries (Bradshaw et al., 2013; Kim, 2015). It is reported that children from 0 to 9 years of age spend only 0.53 h outdoors on weekdays; they spend most of their time indoors (Suh et al., 2016). Prolonged time in an artificial indoor environment can increase stress and negatively affect emotions (Dye, 2008). Therefore, indoor environments in which children spend most of their time, especially learning environments, play a significant role in children's stress, emotional condition, and subjective well-being (Sin and Kang, 2001).

However, studies that focus on measuring the psychophysiological and emotional responses of children are limited. Therefore, in this study, we determined the effects of foliage plants arranged in a space where students performed assignments on the concentration and emotional condition of elementary school students.

Materials and Methods

Subjects. Thirty elementary school students, aged 10 to 13 years, participated in this study. To recruit the subjects, a flyer including study information was distributed in elementary schools and churches in Gwangjin-gu, Seoul, South Korea. The subjects who wished to participate in this study were required to complete a consent form for permission from their parents. A previous study reported that there were differences in cortical activity relating to dominant and nondominant hand movement (Tarkka and Hallett, 1990), and thus a criterion for participation was that the subjects should be right-handed. Additionally, the participants were required to fast for 2 h before starting the experiment because ingredients such as caffeine naturally found in various foods

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could stimulate the brain and affect the data (Heckman et al., 2010). The subjects also responded to a questionnaire, which included questions on age; the height, weight, and body mass index (BMI) (ioi 353; Jawon Medical, Gyeongsan, South Korea) of the subjects were measured before the experiment. After completion of the study, the subjects received \$20 as an incentive. This study was approved by the Bioethics Committee of Konkuk University (no. 7001355-201710-HR-206).

Experimental procedure. We employed a crossover experimental study design. Each subject performed the study procedure as presented in Fig. 1 (Oh et al., 2019). Before starting the intensive assignment, subjects rested for 1 min by staring at a white wall. The subjects then performed an intensive assignment for 3 min in the presence or absence of foliage plants (Fig. 2). After finishing the intensive assignment, the subjects completed a questionnaire for reporting their subjective emotional condition. After the first experiment, each subject rested for 1 min and then started another intensive assignment for 3 min in the presence or absence of foliage plants. The male and female students took the test in a random order separately.

Experimental condition. The experiment was conducted from Oct. to Dec. 2017. A space for the experiment (180 cm × 160 cm) was prepared in a room in Konkuk University, Seoul, South Korea. A white hardboard was attached to the wall across from the subject's face, and an ivory-colored curtain was placed on both sides to minimize external stimuli. The room conditions were regu-

lated: average temperature 21.8 ± 3.6 °C (O-257; DRETEC Co., Japan), average relative humidity $24.8 \pm 9.6\%$ (O-257; DRETEC Co.), and average illumination 1244.4 ± 821.1 lx (ST-126; SINCON, South Korea).

The foliage plants, *Scindapsus (Epipremnum aureum)*, were grown in a white-colored container (55 × 15 cm) (Fig. 3A). The total height of the container, including the foliage plants, was 35 cm. It was placed on an experimental table, 50 cm from the sitting position of the subject (Fig. 3B).

Intensive assignment. The intensive assignment involved arithmetic problems such as multiplication and division according to the subject's school grade. Fifteen questions for each grade (third, fourth, fifth, and sixth) were randomly selected from textbooks published in South Korea (e.g., $40 + 160 / (61 - 45) \times 6$; $2345 + 3815$; and 58×20) (Choi, 2015, 2017; Kang and Choi, 2015, 2017). The selected 15 questions for each grade were edited for a consistent format. The subjects solved the questions for 3 min, and the average number of solved questions was 6.2 ± 3.4 .

Measurement. To measure the concentration of each subject while solving the intensive age-appropriate arithmetic assignment in the presence or absence of foliage plants, a wireless dry EEG device (Quick-20; Cognionics, San Diego, CA) was used to detect brain activation (Fig. 4A). The EEG device uses a dry electrode system and not a wet electrode system with an electrolyte gel; therefore, it minimizes the risk of electric shock and allows subjects to remove the electrode from the scalp quickly if they feel uncom-

fortable. The potential difference is determined by placing the dry electrode in contact with the scalp, amplifying the measured electric signals, and collecting the processed data. This device is mainly used in the field of neuroscience (Onton et al., 2016; Stevens et al., 2016) and has been certified for safety by the European Commission and Federal Communications Commission. A brain-mapping program (Bio-scan; Bio-Tech, Daejeon, Korea) was used to map the mean EEG measurements to the subject's brain during the experiment.

The EEG monitoring was performed in two areas of the head by following the 10/20 international electrode arrangement (Fig. 4B) (Jasper, 1958). According to the international electrode method, EEG monitoring was performed at F3 (left frontal) and F4 (right frontal) in this study because the frontal lobe is involved in cognition and judgmental abilities (Lee and Kim, 2017a).

The Korean version of a modified simple SDM was used to measure the subjective emotional conditions of each subject (Osgood et al., 1957). The SDM consisted of three questions for "unpleasant-pleasant," "artificial-natural," and "nervous-easy" with a 13-point Likert scale. Higher scores indicated better emotional conditions.

Data analysis. EEG data were analyzed using Cognionics Data Acquisition (Cognionics) and Telescan 2.2 software (Cognionics). The collected EEG raw data were analyzed using power spectrum analysis to identify theta, beta, and low-beta powers and spectral edge frequency of 50 (SEF50) related to attention ability. The relative theta (RT), beta (RB), and low-beta (RLB) power spectra were calculated by the ratio of power in the 4- to 50-Hz band to power in the 4 to 7, 14 to 30, and 12 to 15 Hz, respectively (Park, 2005). Furthermore, the ratio of beta and theta power (RBT) was calculated by ratio of power in the 4- to 7-Hz band to power in the 14 to 30 Hz. The SEF50 is the frequency of the point on the power spectrum graph in which the area from 4 to 50 Hz occupies 50% of the area in the entire frequency range (Yu et al., 2012).

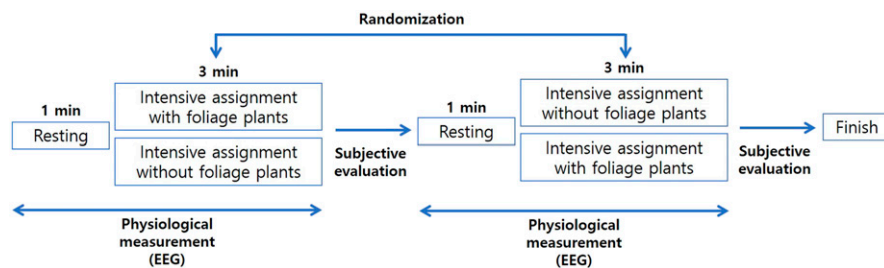


Fig. 1. Study procedure. EEG = electroencephalography.



Fig. 2. Intensive assignment conducted (A) with foliage plants or (B) without foliage plants.

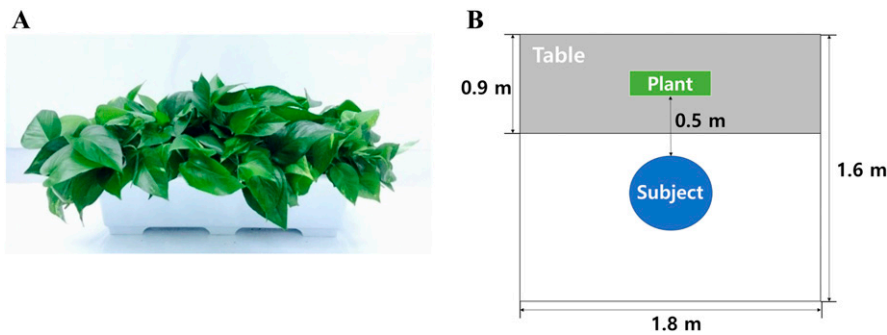


Fig. 3. Experimental setting of the study: (A) plant material and (B) room arrangement for the experiment.

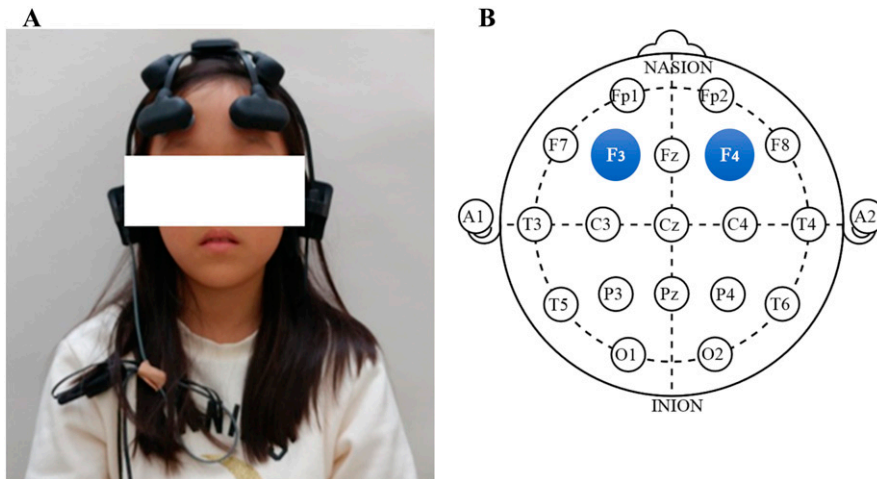


Fig. 4. (A) Wireless dry electroencephalography device (Quick-20; Cognionics, San Diego, CA). (B) International electrode arrangement (Jasper, 1958). The highlighted bolded channels (F3, F4) were measured in this study.

Table 1. Descriptive information of subjects who participated in the study to measure psychophysiological response according to the presence of foliage plants during an intensive assignment (N = 30).

Variable	Male (n = 10)	Female (n = 20)	Total (N = 30)	Significance ^w
	Mean ± SD			
Age (yr)	11.9 ± 1.1	11.5 ± 1.3	11.6 ± 1.2	0.964 ^{NS}
Height ^t (cm)	151.7 ± 10.1	142.9 ± 10.6	145.8 ± 11.1	0.149 ^{NS}
Body weight ^y (kg)	49.2 ± 11.8	37.4 ± 9.9	41.3 ± 11.8	0.053 ^{NS}
Body mass index ^x (kg·m ⁻²)	21.2 ± 3.6	18.0 ± 2.6	19.0 ± 3.3	0.053 ^{NS}

^tHeight was measured using an anthropometer (Ok7979; Samhwa, Seoul, South Korea) without shoes.

^yBody weight was measured using a body fat analyzer (ioi 353; Jawon Medical, South Korea).

^xBody mass index was calculated using the formula [weight (kg)] / [height (m)²].

^wStatistical significance as determined using the independent two-sample *t* test.

^{NS}Nonsignificant.

Table 2. Results of relative theta power spectrum (RT), relative beta power spectrum (RB), and ratio of beta wave and theta wave (RBT) by electroencephalography, according to the presence and absence of foliage plants during an intensive assignment.

EEG	Plant arrangement	RT ^y		RB ^x		RBT ^w	
		F3	F4	F3	F4	F3	F4
		Mean ± SD ^z					
Male (n = 10)	Presence	0.39 ± 0.07	0.38 ± 0.05	0.18 ± 0.05	0.19 ± 0.05	0.40 ± 0.15	0.41 ± 0.14
	Absence	0.43 ± 0.08	0.48 ± 0.15	0.17 ± 0.06	0.17 ± 0.07	0.35 ± 0.18	0.34 ± 0.17
	Significance ^v	0.646 ^{NS}	0.013*	0.715 ^{NS}	0.517 ^{NS}	0.557 ^{NS}	0.295 ^{NS}
Female (n = 20)	Presence	0.46 ± 0.10	0.48 ± 0.13	0.18 ± 0.05	0.18 ± 0.06	0.36 ± 0.16	0.34 ± 0.18
	Absence	0.46 ± 0.11	0.47 ± 0.14	0.18 ± 0.06	0.18 ± 0.07	0.38 ± 0.25	0.42 ± 0.40
	Significance ^v	1.000 ^{NS}	0.766 ^{NS}	0.892 ^{NS}	0.725 ^{NS}	0.957 ^{NS}	0.705 ^{NS}
Total (N = 30)	Presence	0.44 ± 0.10	0.45 ± 0.12	0.18 ± 0.05	0.18 ± 0.06	0.37 ± 0.16	0.37 ± 0.17
	Absence	0.45 ± 0.10	0.47 ± 0.14	0.18 ± 0.06	0.18 ± 0.07	0.37 ± 0.23	0.39 ± 0.34
	Significance ^u	0.701 ^{NS}	0.519 ^{NS}	0.831 ^{NS}	0.852 ^{NS}	0.574 ^{NS}	0.693 ^{NS}

^zStandard deviation.

^yRT was calculated by [theta (4–7 Hz) power] / [total frequency (4–50 Hz) power].

^xRB was calculated by [beta (14–30 Hz) power] / [total frequency (4–50 Hz) power].

^wRBT was calculated by [beta (14–30 Hz) power] / [theta (4–7 Hz) power].

^vStatistical significance as determined using Mann-Whitney test.

^uStatistical significance as determined using the independent two-sample *t* test.

^{NS}, *Nonsignificant or significant at $P \leq 0.05$.

To determine the effect of the presence of foliage plants on assignment performance, the number of questions solved and the number of correct answers per total number of questions were calculated as a percentage using Microsoft Excel (Office 2007; Microsoft Corp., Redmond, WA).

The independent two-sample *t* test and Mann-Whitney test in SPSS (version 22 for Windows; IBM, Armonk, NY) were performed; $P < 0.05$ was considered statistically significant. For demographic information, Microsoft Excel (Office 2007) was used to generate descriptive statistics of the mean, SD, and percentage.

Results

Demographic characteristics. Thirty subjects aged 11.6 ± 1.1 years participated in the study: 10 boys and 20 girls (boys 11.9 ± 1.1 years, girls 11.5 ± 1.3 years) (Table 1). Boys were found to be in the BMI 75th percentile for 11-year-old boys in South Korea and girls in the BMI 50th percentile of the 11-year-old girls in South Korea (Korea Centers for Disease Control and Prevention, 2017). Both were in the normal range.

Comparisons of concentration in the presence or absence of foliage plants during intensive assignment. In the presence of foliage plants, the RT index was significantly decreased to 0.38 in the right frontal lobe of male subjects compared with that in the absence of foliage plants ($P < 0.05$) (Table 2, Fig. 5). This result indicates an increase in attention and concentration due to the reduction in theta power, which is the reverse index of attention and concentration (Han and Hong, 2017). However, for combined male and female students and female students, there were no differences in the RT index according to the presence and absence of foliage plants during an intensive assignment. Furthermore, there were no differences according to the presence of plants in the RB index and RBT index of combined male and female students (Table 2; brain-mapping data

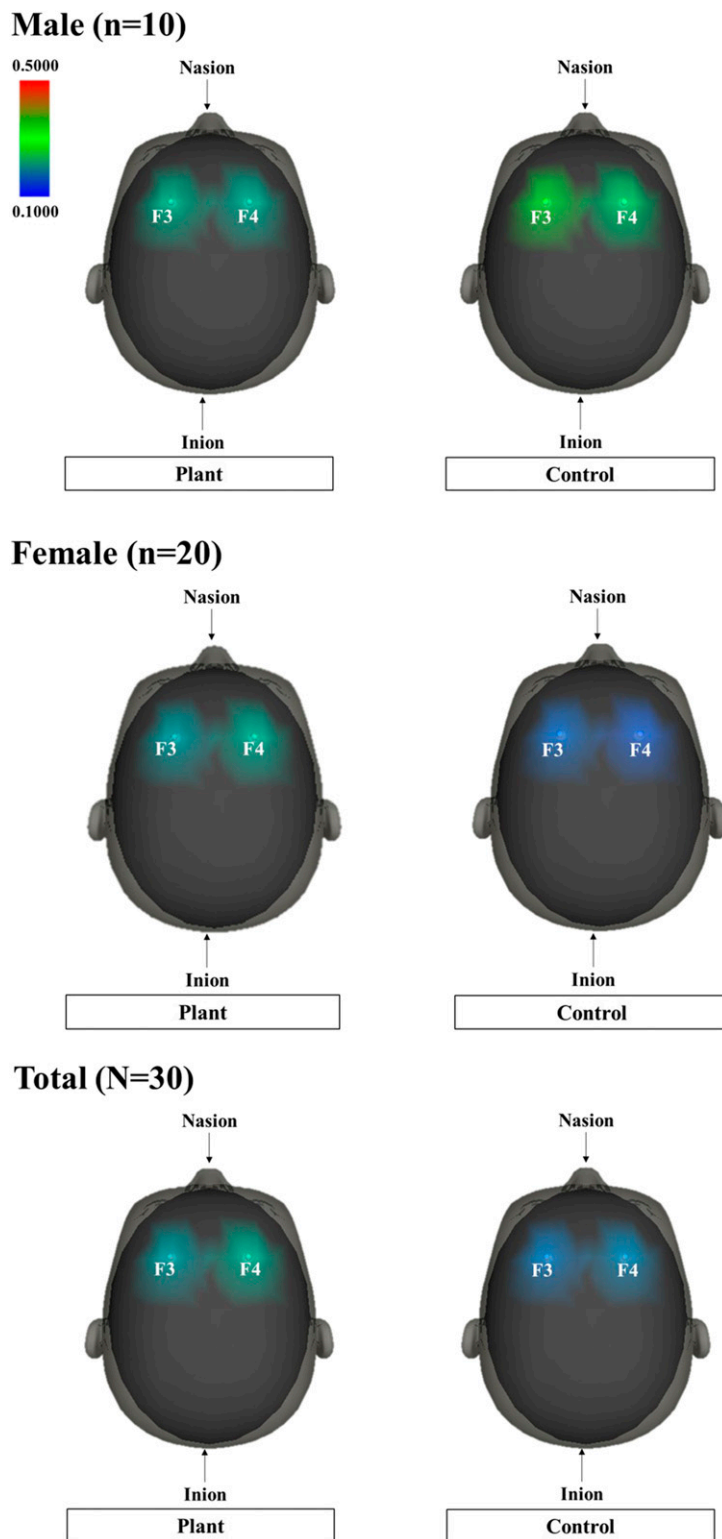


Fig. 5. Relative theta wave intensity using a brain-mapping program according to the presence and absence of foliage plants during an intensive assignment.

not shown). When performing the assignment in the presence of plants, the RLB index in both frontal lobes of male subjects tended to be higher than that when foliage plants were absent; however, the differences were not statistically significant (Table 3; brain-mapping data not shown). When performing the assignment in the presence of foliage

plants, the SEF50 in the right frontal lobe of male subjects was 9.03, which was significantly higher than that when foliage plants were absent ($P < 0.05$) (Table 4, Fig. 6). Because the SEF50 tends to increase with increasing attention and assignment difficulty (Park and Goo, 2007), this result means the brain activity of male subjects when perform-

ing the assignment in the presence of foliage plants was activated (Schwarz et al., 2004). Furthermore, the data for combined male and female students and female students showed that there were no differences in the SEF50 according to the presence and absence of foliage plants during an intensive assignment.

Comparison of emotional condition in the presence or absence of foliage plants under an intensive assignment. Subjective evaluation of emotional condition according to the presence and absence of foliage plants when performing the assignment was performed using the SDM questionnaire. According to the SDM, the feeling of “being relaxed” was significantly higher with foliage plants (the value was ≈ 1.3) than without foliage plants (the value was ≈ 0.3) ($P < 0.05$) (Fig. 7). Furthermore, there were no statistically significant differences in the feeling of “being comfortable” and “being natural” (Fig. 7). The results of classification by gender revealed that there were no statistically significant differences in the SDM according to the presence and absence of foliage plants (data not shown).

Result of intensive assignment performance. The results of the intensive assignment performance according to the presence or absence of foliage plants revealed that the performance of male students in the presence of plants was significantly higher than that in the absence of plants, from 5.70 to 8.20 within the same time ($P < 0.05$) (Fig. 8). Furthermore, the percentage of correct answers in the assignment in the presence of plants was higher than that in the absence of plants, from 36.00% to 52.67% in male students ($P < 0.05$) (Table 5). The results of the intensive assignment performance and percentage of correct answers in the assignment of female students and total students revealed that there were no statistically significant differences according to the presence and absence of foliage plants (Table 5, Fig. 8).

Discussion

To compare concentration and emotional condition of elementary school students who performed an intensive assignment in the presence or absence of foliage plants, the EEG monitoring and a modified SDM were performed. The results revealed that the concentration of male elementary students was significantly higher when the assignment was performed in the presence vs. absence of plants as evidenced by the increase in the ratio of SEF50 and the decrease in the relative theta power spectrum in the right frontal lobe. Per the SDM, significant psychological relaxation was demonstrated when the assignment was performed in the presence of plants.

In the presence of foliage plants, the RT index was significantly decreased in the right frontal lobe of male subjects compared with that in the absence of foliage plants; there were no significant differences in the RB, RBT, and RLB indexes according to the

Table 3. Results of relative low-beta wave (RLB) by electroencephalography, according to the presence or absence of foliage plants during an intensive assignment.

RLB ^y	Plant arrangement	F3	F4
		Mean ± SD ^z	
Male (n = 10)	Presence	0.16 ± 0.04	0.15 ± 0.05
	Absence	0.15 ± 0.05	0.14 ± 0.05
	Significance ^x	0.775 ^{NS}	0.619 ^{NS}
Female (n = 20)	Presence	0.13 ± 0.04	0.13 ± 0.03
	Absence	0.14 ± 0.04	0.13 ± 0.05
	Significance ^x	0.850 ^{NS}	0.534 ^{NS}
Total (N = 30)	Presence	0.14 ± 0.04	0.14 ± 0.04
	Absence	0.14 ± 0.04	0.14 ± 0.05
	Significance ^w	0.870 ^{NS}	0.824 ^{NS}

^zStandard deviation.

^yRLB was calculated by [low-beta (12–15 Hz) power] / [total frequency (4–50 Hz) power].

^xStatistical significance as determined using Mann-Whitney test.

^wStatistical significance as determined using the independent two-sample *t* test.

^{NS}Nonsignificant.

Table 4. Results of spectral edge frequency of 50 (SEF50) using electroencephalography, according to the presence or absence of foliage plants during an intensive assignment.

SEF50 ^y	Plant arrangement	F3 (Hz)	F4 (Hz)
		Mean ± SD ^z	
Male (n = 10)	Presence	8.98 ± 2.44	9.03 ± 2.25
	Absence	7.98 ± 1.13	7.45 ± 1.36
	Significance ^x	0.333 ^{NS}	0.028*
Female (n = 20)	Presence	7.68 ± 1.05	7.64 ± 1.37
	Absence	7.95 ± 1.66	8.08 ± 2.60
	Significance ^x	0.776 ^{NS}	0.839 ^{NS}
Total (N = 30)	Presence	8.11 ± 1.72	8.10 ± 1.80
	Absence	7.96 ± 1.48	7.87 ± 2.26
	Significance ^w	0.720 ^{NS}	0.661 ^{NS}

^zStandard deviation.

^ySEF50 is the area from 4 to 50 Hz, which occupies 50% of the area in the entire frequency range.

^xStatistical significance as determined using Mann-Whitney test.

^wStatistical significance as determined using the independent two-sample *t* test.

^{NS}, *Nonsignificant or significant at $P \leq 0.05$.

Table 5. Percentage of correct answers in intensive assignment according to the presence and absence of foliage plants.

Percentage of correct answers (%)	With foliage plants	Without foliage plants	Significance
	Mean ± SD ^z		
Total (N = 30)	38.89 ± 26.38	34.89 ± 21.28	0.261 ^{NS, y}
Male (n = 10)	52.67 ± 24.64	36.00 ± 16.69	0.031* ^x
Female (n = 20)	32.00 ± 25.00	34.33 ± 23.62	0.377 ^{NS, x}

^zStandard deviation.

^yStatistical significance as determined using Mann-Whitney test.

^xStatistical significance as determined using the independent two-sample *t* test.

^{NS}, *Nonsignificant or significant at $P \leq 0.05$.

presence and absence of foliage plants during an intensive assignment (Tables 2 and 3). Previous findings suggest that theta wave, beta wave, and ratio of beta wave and theta wave are indicators of frontal lobe functional status in relation to attention and concentration (Choi, 2011). Among these, the theta waves in the 4- to 7-Hz range occurs in a shallow sleep state or during rapid eye movement sleep (Han and Hong, 2017). When theta waves are overloaded while studying in adolescence, the brain is in a shallow sleep rather than attention (Byun, 2011). If this condition persists, learning efficiency is reduced, and other problems, such as lack of motivation, occur (Byun, 2011). If the intensity of theta waves is higher than that required by age, it means that the degree of attention and brain activity is low (Clarke et al., 2002). In particular, ADHD can be regarded as a representative disorder of

excess theta waves (Clarke et al., 2002). Thus, when performing the assignment in the space with foliage plants, the decrease in theta wave activity in the right frontal lobe of male students means that frontal lobe activity increased and attention improved (Table 2, Fig. 5). The RLB frequency band is observed in the sensory motor cortex of the brain, also termed “sensorimotor rhythm,” and a high value indicates higher concentration (Barkhatdze et al., 2016). This index measures attention with the theta wave (Lee and Kim, 2017b). Because its enhancement is known to reduce hyperactivity (Monderer et al., 2002; Sterman and Egner, 2006), in several neurofeedback studies, children with ADHD were trained to increase the amplitude of RLB (12 to 15 Hz) to improve their attention and reduce ADHD symptoms (Bakhtadze et al., 2016; Mohammadi et al., 2015).

In the presence of foliage plants, the SEF50 was significantly increased in the right frontal lobe of male subjects compared with that in the absence of foliage plants (Table 4, Fig. 6). Because SEF50 is the frequency below 50% of the total EEG power (Schwender et al., 1996), it is a measure used to investigate the activity of the cerebral cortex and indicates the degree of workload (Yu et al., 2012). The SEF50 is an index for the awake state that shows how much of the brain is active during a task (Schwarz et al., 2004). It is also an indicator of the degree of cognitive load in the brain—the higher the value, the higher the cognitive ability (Tak, 2010). Therefore, male students who performed the assignment in the space where plants were present could improve their attention because the brain was more awake and cognitive activation occurred. Similar results have been reported in previous studies on the benefits of plant arrangement in the work environment. Jang (2013) and Lee and Son (1999) reported that cerebral activity increased when looking at plants. Igarashi et al. (2015) reported that the frontal lobe was activated when looking at living plants rather than plant images. There is evidence that, as a whole, the prefrontal cortex that is the front part of frontal lobe in the cerebral cortex performs a critical role in the organization of behavioral, linguistic, and cognitive actions; therefore, the activation of frontal lobe indicates an improvement in intellectual performance ability and attention ability (Carter, 2009; Fuster, 2002; Marie and Rebecca, 2011).

The results of the intensive assignment performance and the percentage of correct answers in the assignment according to the presence and absence of foliage plants revealed that the assignment achievement and the percentage of correct answers of male students in the presence of plants was significantly higher than that in the absence of plants (Table 5). A similar study revealed that contact with plants has positive effects on intellectual performance ability and that the higher the ratio of natural scenery outside the window, the higher the symbol digit modalities test achievement of girls aged 7 to 12 years (Taylor et al., 2002). According to a study by Tennessen and Cimprich (1995), 72 college students performed attention tasks such as Digit Span Forwards, Digit Span Backward, and Symbol Digit Modalities Test in their dormitories, and the task achievement increased as the ratio of natural scenery outside the window increased. In another study, after 25 children who were diagnosed with ADHD walked 20 min in the city or park, children who walked in the park performed better on an attention task (Digit Span Backward) than those who walked in the city (Taylor and Kuo, 2009).

Based on the SDM, according to the presence and absence of foliage plants when performing the assignment, the feeling of “being relaxed” was significantly higher with plants than without plants (Fig. 7).

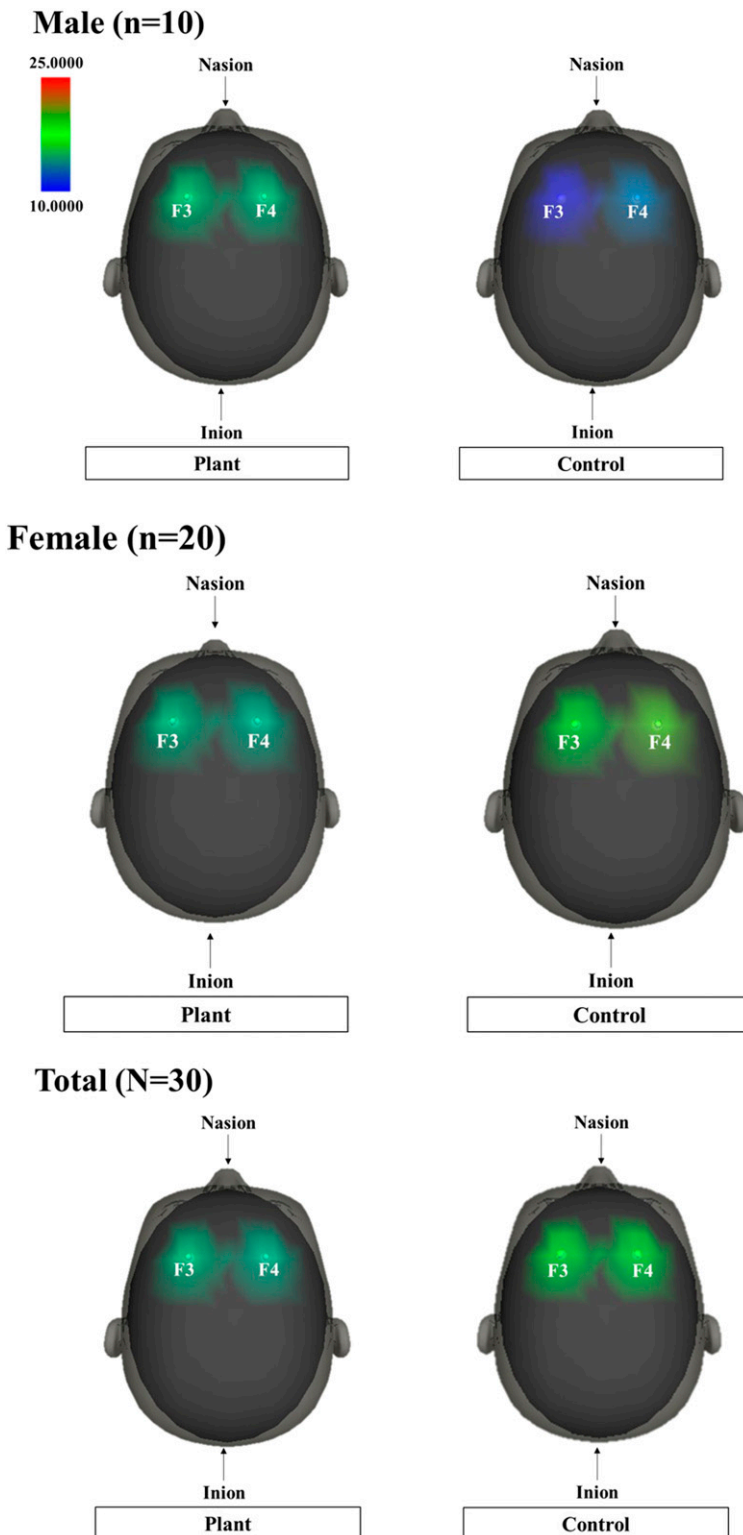


Fig. 6. Relative spectral edge frequency of 50 using a brain-mapping program according to the presence or absence of foliage plants during an intensive assignment (Hz).

Similar findings have been reported in previous studies. When 24 men in their 20s performed the same tasks with and without foliage plants, the oxyhemoglobin concentration in the left prefrontal cortex of the subjects was lowered when performing the task with plants; this result suggests that tasks involving living foliage plants induce more

physiological relaxation than working without foliage plants (Park et al., 2017). Furthermore, they also felt significant positive emotions, such as being more comfortable, natural, and relaxed compared with performing the task without plants (Park et al., 2017). According to Choi et al. (2016), only a 5% index of indoor greenness could provide

benefits in psychophysiological stability by stimulating the autonomic nervous system, such as EEG and heart rate variability, and is associated with positive feelings such as “clean,” “soft,” “bright,” “warm,” “vibrant,” “comfortable,” and “fresh.”

The results of this study reveal that there were differences in children’s EEG response and assignment performance according to the presence or absence of foliage plants during the intensive assignment between genders. According to previous studies, there are large numbers of androgen receptors in the visual cortex of the brain, and males have higher levels of androgens compared with females (Moir, 1992; Nunez et al., 2000). Because of this, neurons in the visual cortex of the brain develop differently, and males show differences in visual function, such as finding changes in minute parts of visual stimuli, compared with females (Abramov et al., 2012). Therefore, in this study, we suggest that male students accepted and responded to the visual stimulation of foliage plants more sensitively according to differences in visual function between genders, which also affected psychophysiological responses and performance on the assignment.

In conclusion, the purpose of the present study was to investigate the effects of exposure to living foliage plants by measuring psychophysiological and psychological indicators when children performed an intensive assignment. The results revealed that the presence of plants in the assignment performance space increased the EEG activity in the frontal lobe and improved concentration for male students. Furthermore, it also made them psychologically stable and promoted positive mood. Further studies should recruit more subjects to analyze more specific psychophysiological and psychological effects of living plants in assignment performance spaces. A follow-up study would be interesting to determine the effect according to the number and types of plants. Moreover, it would be valuable to compare differences among ages and between genders.

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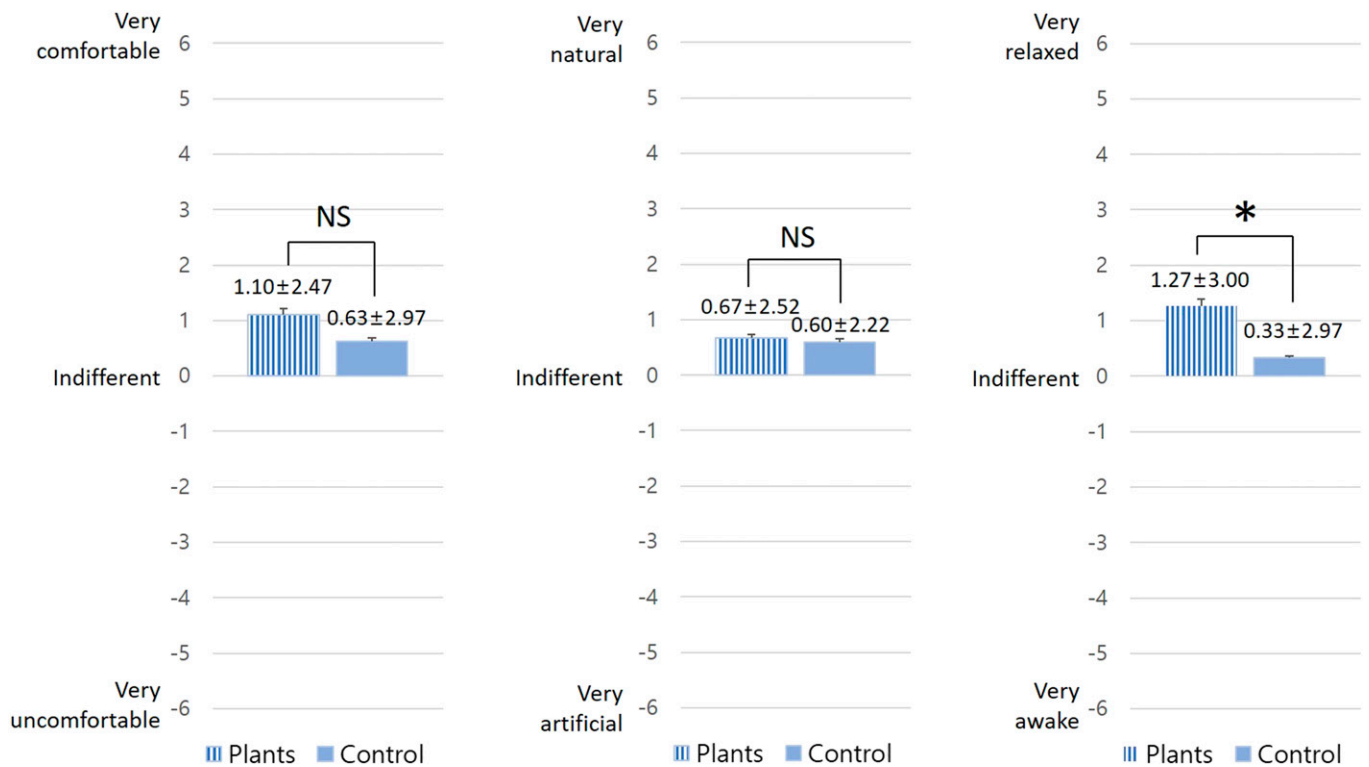


Fig. 7. Results of modified semantic differential method (SDM), according to the presence and absence of foliage plants during an intensive assignment (N = 30). NS = not significant, * $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$ by independent two-sample t test.

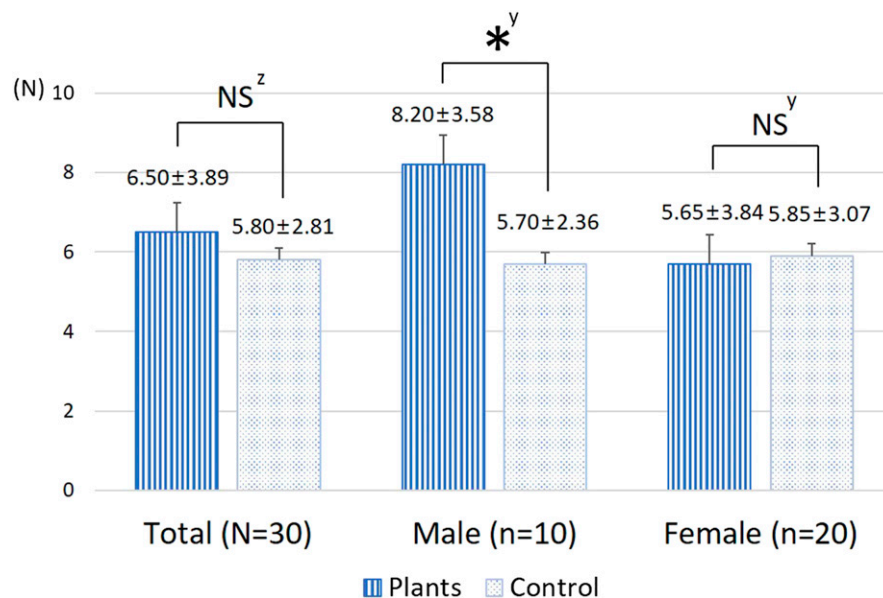


Fig. 8. Results of number of assignments performed according to the presence and absence of foliage plants during an intensive assignment. NS = nonsignificant, * $P < 0.05$. ^zIndependent two-sample t test. ^yMann-Whitney test.

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