Eur. J. Hortic. Sci. *85*(4), 279–283 | ISSN 1611-4426 print, 1611-4434 online | https://doi.org/10.17660/eJHS.2020/85.4.9 | © ISHS 2020

Original article

Do plants affect brainwaves? Effect of indoor plants in work environment on mental stress

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Summary

Objectives – **The use of different technologies, such as mobile phones, internet, social media networks, and computer-based electronic devices cause a great deal of mental stress. However, few evidence-based studies have investigated ways to overcome this stress. In the present study, we examined the physiological and psychological effects of working environments containing indoor plants on stress.** *Methods* – **In total, 50 participants (age 20 years) were recruited. Experiments were performed to evaluate the physiological and psychological responses during a 5-min computer task in the presence or absence of indoor plants. Psychophysiological evaluations were based on blood pressure, electroencephalography (EEG) results, and State-Trait Anxiety Inventory (STAI) scores.** *Results* – **EEG analysis revealed that the presence of plants induced a significant change in brain activity, relative to that observed in the absence of plants. The participants exhibited lower STAI scores for tasks performed in the presence of plants than that performed in their absence.** *Conclusions* – **Thus, performing tasks in the presence of indoor plants for 5 minutes may lower mental stress.**

Keywords
anxiety, electroencephalography, indoor florae, technology

Significance of this study

What is already known on this subject?

- The presence of natural vegetation can reduce stress and anxiety in individuals.

What are the new findings?

- Presence of indoor plants in workplace enhanced brainwave activity and reduced anxiety compared with task completion in the absence of plants.

What is the expected impact on horticulture?

- Stress levels among Chinese students are high because of excessive computer use. Horticultural therapy provides a way to eliminate this stress.

Introduction

Plants are most commonly used for indoor recreational and aesthetic purposes; however, experiments assessing human behavior in response to certain types of indoor ornamental plants, in particular, regarding their beneficial effects on physiological and mental health are limited. Plants may lower air contaminants, including nitrogen dioxide, formaldehyde, carbon monoxide, benzene, and trichloroethylene (Stec et al., 2005). Furthermore, a green vegetative environment can reduce psycho-physiological stress and anxiety levels (Ulrich, 1979; Ulrich et al., 1993). Importantly, heavy workloads and long working hours increase the daily discomfort in individuals who live and work in modern buildings. One of the factors for this discomfort may be building materials as well as an increased focus on financial gains for family and for a better quality of life (Skov et al., 1990). Therefore, the use of indoor plants may be beneficial for individuals working in modern buildings. Individuals working in rooms with interior plants have demonstrated full recovery from anxiety and stress symptoms (Lohr et al., 1996). Moreover, there is a strong link between response to pain and exposure to plants in humans (Hartig et al., 1991; Ulrich, 1984); hospital windows with a view of plants can reduce pain in patients as compared to that with a view of a brick wall with no plants. These studies indicate that more evidence-based systemic studies are required to confirm the link between pain and stress reduction. Stress refers to an organism's response to a threat, challenge, or physical/psychological barrier (stressor). Although some types of stress can be favorable, such as those during certain educational settings (Linn and Zeppa, 1984), unfavorable stress has been associated with sleep disorders, anxiety, interpersonal conflicts, depression, increased alcohol and drug consumption, reduced concentration, and academic dishonesty (Flaherty and Richman, 1993). Favorable stress can promote learning, whereas unfavorable stress suppresses it (Solomon et al., 1991). In addition, unfavorable stress has been linked to the inhibition of personal development and academic achievement (Solomon et al., 1991). Electroencephalography (EEG) is a non-invasive, inexpensive instrument to record neural activity in the form of electrical waves (Lei and Roetting, 2011). Subsequently, changes in EEG patterns are associated with neurophysiological responses to external stimuli. Some EEG studies have measured the neurophysiological response in certain environments to various sensory inputs, including hearing, taste, vision, and smell (Ajiro et al., 2009). Additional new approaches using EEG have included experiments assessing human reactions to plants (Ajiro et al., 2009). Further, EEG has been used in the management of stress or anxiety issues (Angelucci et al., 2014) and is useful for assessing different mental states. EEG brainwaves are categorized on the basis of their frequency ranges, and further defined as alpha (8–13 Hz), beta (>13 Hz), delta (4 Hz), theta (4–8 Hz), and gamma (31–42 Hz) brainwaves. Brainwaves are functionally distinct; higher workloads and stress reduce alpha brainwaves in humans (Angelucci et al., 2014). In addition, beta waves are associated with changes in various task difficulty. Alpha and beta waves have different temporal patterns that are associated with brain volume and complexity. Brookings et al. (1996) used EEG to measure the relative impact of stress or workload on brainwave activity. They found that EEG activity changes during exposure to outdoor environments.

Previous studies have measured the impact of plants on human physiological and psychological responses, including heart rate, electromyography, galvanic skin response; and psychological responses, including the Profile of Mood States and Shared Decision Making questionnaire score (Nishii, 2011). However, studies assessing the effect of indoor plants on EEG measurements, blood pressure, and the State-Trait Anxiety Inventory (STAI) method are rarely used. Moreover, the individual effects of indoor plant activity on comfort have not been investigated using EEG. In addition, no experiments have investigated the effects of exposure to plants on relaxation using EEG in the context of Chinese population. University students may feel unsatisfied and inadequate because of excessive stress; therefore, there is a growing need for the early diagnosis of stress-related conditions and the application of psychological services for stress prevention in this population. In the present study, we investigated the EEG changes and other psychophysiological stress responses in Chinese adults performing a mental task in the presence or absence of indoor plants.

Materials and methods

Experimental location

The experiment was performed in a laboratory at the College of Forestry (building #5) with one window, which was covered by curtains. The light intensity, temperature, and humidity of the room were maintained at 500 lux, 24°C, and 55%, respectively. The room was approximately 9 m long, 6 m wide, and 5 m high. All measuring instruments were placed behind the participant to avoid any disturbance in the experimental procedure. The whole experiment was performed in silence; the basic instructions and experimental methods were provided to the participants in a written format.

FIGURE 1. Experimental design. (a) Participant reading the instructions before performing the tasks; (b-c) Participant performing a horticultural task; (d-e) Participant performing a control task; (f) Post-test STAI questionnaire.

Participants

The present study included 50 Chinese students from the College of Finance and Economics (mean age, 20.2±1.63 years; mean weight, 56.3±8.48 kg; mean height, 167.7±7.59 cm). Volunteers from the Sichuan Agricultural University recruited the on-campus students face-to-face or via email. The participants were selected based on their availability and none of them had any mental or physical health problems. All food and liquid intake was controlled throughout the course of the experiment. The participants were informed of the study details, and a simple demonstration of the EEG headset was conducted to ensure that the experiment ran smoothly. Participants provided written informed consent for the publication of the study images. This study was approved by the Ethics Committee of the College of Forestry and Landscape at the Sichuan Agricultural University, China.

Materials

A daily, computer-based written assignment task while observing indoor ornamental plants (horticultural activity) for 5 minutes was chosen. For the control activity, a similar computer task (daily written assignment task) without observation of indoor ornamental plants was used for 5 minutes. Before starting the tasks, complete written instructions were provided to each participant. In this experiment, two common, identical, red-colored indoor ornamental plants were placed on the left and right side near the computer. Indoor ornamental plants in approximately similar plastic pot (diameter 5 mm) was used for the horticultural activity and placed at the same distance from the computer. Both the tasks were performed in a sitting position (Figure 1).

Protocol

The students were divided into two groups (P or C group). On the first day, group P (n=25) performed the task in the presence of an indoor plant, while group C (n=25) performed the control task. On the following day, each group completed the opposite task.

Measurements and data recording

First, participants were administered with pretest questionnaires to collect the data on their height, weight, and age. In addition, STAI questionnaire was administered. Following a complete briefing regarding the experimental methodology, they were sent to the study location and rested for 5 minutes. Baseline blood pressure measurements were obtained from the right arm with the participant in the seated position. Next, the NeuroSky MindWave-EEG headset (Beijing Oriental Creation Technology Co., Ltd., China) was attached to the participant's head, and the participant was guided to perform the given task for 5 minutes in the seated position. The alpha and beta EEG activities were measured throughout the experiment using a Mind Wave EEG headset (MW001) (Hassan et al., 2018b), which detects EEG data at a rate of 512 Hz. Raw EEG data were captured from the forehead position (Fp1) (Robbins and Stonehill, 2014). The device consists of 4 different parts such as: 1) a sensor arm containing EEG electrodes, 2) a Bluetooth USB device, 3) an ear clip, and 4) headband. Two dry sensors are utilized to detect and filter the raw EEG signals, and the sensor tip recognizes electrical brainwave signals of the human brain from the forehead at the Fp1 position. Moreover, the sensor observes ambient noise created by electrical sockets, human muscles, light bulbs, computers, and other electrical instruments. The ear clip acts as a reference and ground, which permit the ThinkGear chip to filter the background electrical noise. The device has thin microchips for data preprocessing and to forward the recorded electrical signals to a computer using Bluetooth. Systolic blood pressure, diastolic blood pressure, and pulse rate data were collected using a sphygmomanometer (Omron, HEM-7011, China). The participants were asked to complete the self-rated STAI questionnaire (Spielberger, 1970) to examine their anxiety levels before and after performing the tasks.

Statistical analyses

Paired t-tests were used to compare physiological variables that included blood pressure and the EEG high alpha and high beta brainwaves. For these analyses, statistical significance was set at P<0.05. Wilcoxon signed-rank tests were used to compare STAI scores as psychological variables. For these analyses, statistical significance was set at P<0.01.

Results

The results show (Figure 2) no significant differences in the systolic (P=0.20) or diastolic (P=0.07) blood pressures or pulse rates (0.77) were observed between the two experimental groups. Although there were no significant differences in the baseline STAI scores between the two experimental groups, the STAI scores significantly decreased following the plant task (40.64±4.88) when compared with the control task (44.88±5.07; P<0.01; Figure 3). Furthermore, during the 1-to-5-minute analysis of high alpha and beta activities, the mean values of most brainwaves increased during the plant

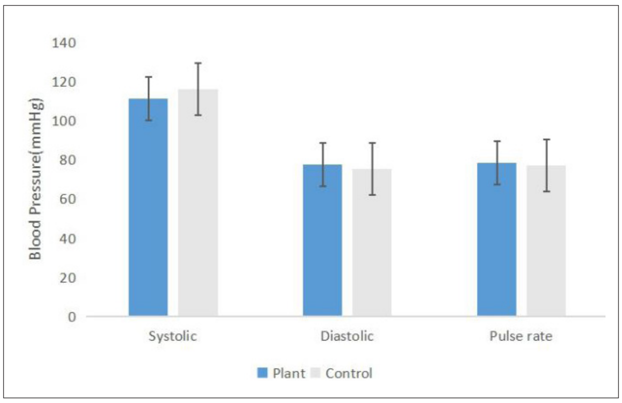

FIGURE 2. Comparison of blood pressure during the control and plant tasks. $N=50$; mean ± SD; $P<0.05$; paired t-test.

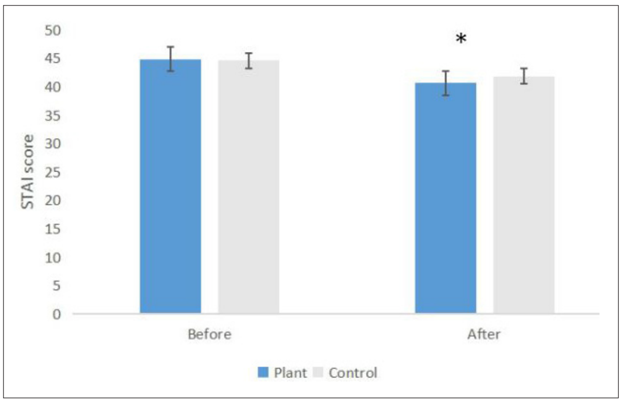

FIGURE 3. Comparison of State-Trait Anxiety Inventory (STAI) scores before and after the control and plant tasks. $N=50$, mean ± SE, $^*P<0.01$; Wilcoxon signed-rank test.

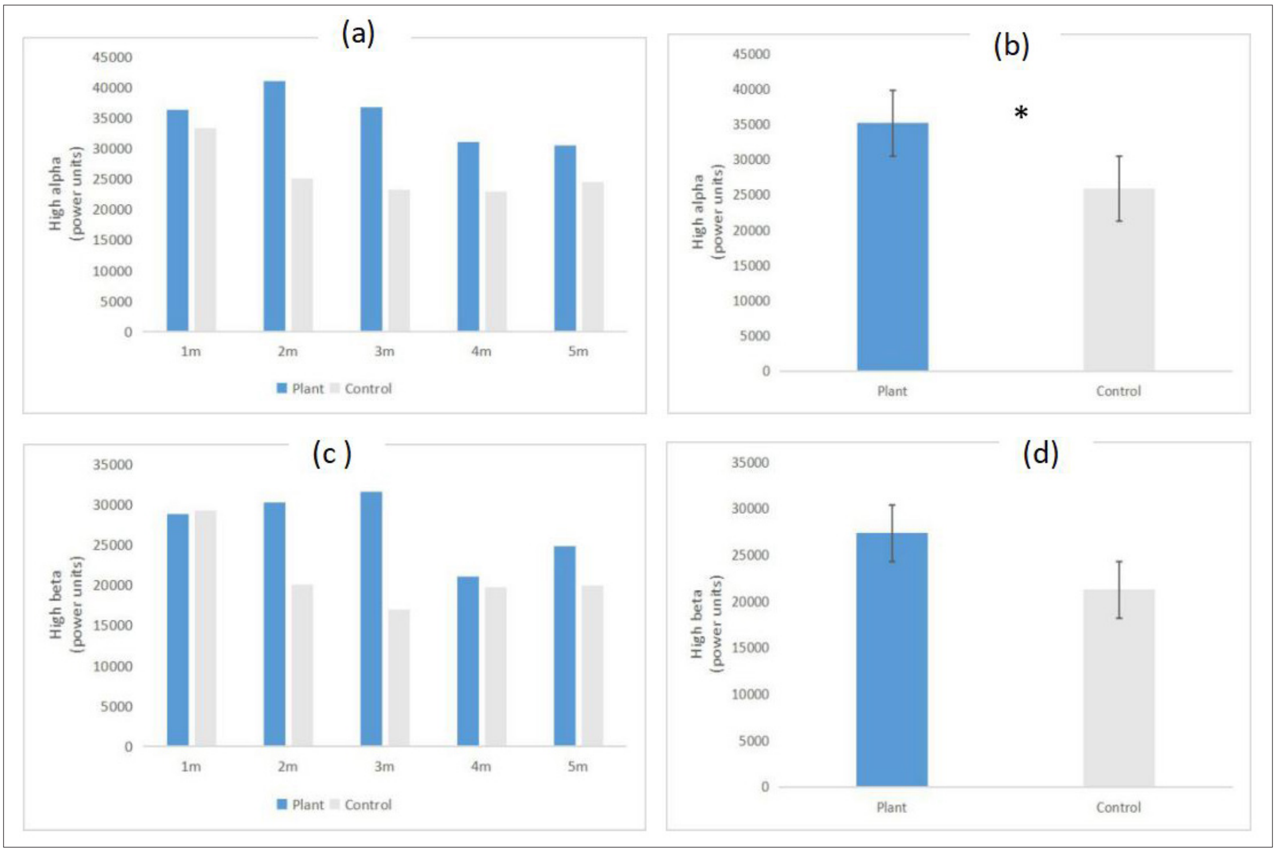

FIGURE 4. Comparison of brain activity during the control and plant tasks. (a) Mean high alpha activity per minute for five minutes; (b) Overall mean values for high alpha activity; (c) Mean high beta activity per minute for five minutes; (d) Overall mean values for high beta activity. $N = 50$, mean ± SE, *$P < 0.05$; paired *t*-test.

task when compared to that during the control task. Paired *t*-tests revealed a significant difference in mean high alpha activity between the two tasks (plant, 35140.36±4357.17; control, 25851.50±4292.37; P=0.01). In contrast, there was no significant difference in high beta activity during the total working period between the two tasks (plant, 27329.43±4329.97; control, 21233.28±4670.92; P=0.09; Figure 4).

Discussion

In the present study, we examined the stress-reducing effects of the presence of indoor plants during a 5-minute task by measuring the physiological response of students using EEG. Our results indicated no significant difference in systolic and diastolic blood pressures between the tasks conditions, indicating that the presence of an indoor plant did not affect blood pressure. Interestingly, our EEG analysis revealed that the presence of indoor plants exerted a positive effect on mental stress by increasing both the high alpha and high beta activities as compared to that in the absence of indoor plants. In our study, the increased high alpha waves were indicative of increased relaxation levels during work in the presence of indoor plants. Our results are comparatively consistent with the results of a previous study, which showed that performing horticultural activities, such as transplanting indoor plants, increases high alpha and beta waves when compared with a mental task (Hassan et al., 2018a). A calming effect of greenery-based natural vegetation has been supported by previous EEG studies. Unstressed individuals who view photos of natural landscapes, such as bamboo plants (Hassan et al., 2017) or those who walk in bamboo forests (Hassan et al., 2018b), or those with single natural components, such as potted plants with flowers (Nakamura and Fujii, 1990) had higher brain alpha wave activity. Furthermore, increased alpha brainwaves are associated with lower/reduced levels of wakeful calmness and physiological arousal (Ulrich, 1981). Stress/anxiety is associated with low alpha waves and enhanced arousal. These studies suggest that participants are highly calm but wakeful, and are less physiologically aroused when interacting with natural stimuli. The findings of our study are consistent with that of a previous study; Nakamura and Fujii (1992) indicated that visual stimulation from different natural stimuli containing natural hedges created a higher alpha to beta wave activity ratio compared with that on viewing images of a concrete wall. Our study results were also comparatively consistent with a study performed on horticultural activity involving transplanting non-flowering plants (pansy), which showed higher alpha brainwave power compared with non-plant settings (Yamane et al., 2004). These findings suggest that increases in high alpha and beta activities reflect relaxation (Liu et al., 2000). Furthermore, high beta brainwaves were increased after participants began working on computer tasks in the presence of indoor plants, and decreased when the tasks were performed in the absence of indoor plants. Thus, our study concluded that participants were more attentive and alert when they performed the horticultural task than when performing the control task. These results were consistent with a previous study indicating that increased high beta brainwave activity is correlated with a highly active mental state, whereas relatively lower beta brainwave activity was associated with drowsiness (Lee et al., 2014). Similarly, STAI scores in the present study indicated significant differences after performing continuous work on a computer task in the absence of plants, indicative of the negative effects exerted on psychological state. Further, our results suggested that participants felt more anxious when performing the control task compared with the plant task. However, there are some limitations in our study. For example, a limited sample size comprising young Chinese university students in their 20s were included. In future experiments, the use of different types of indoor plants and different age groups and nationalities are required.

Conclusion

This experiment indicated that observing indoor ornamental plants (horticultural activity) in a working environment for 5 minutes can decrease mental stress by enhancing brainwave activity and lowering anxiety.

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Received: Apr. 15, 2019
Accepted: Oct. 18, 2019

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