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Original article

Effects of indoor foliage plants on college students' work attention recovery: An experiment focusing on plant characteristics

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Summary

Contact with nature helps people maintain their physical and mental balance. It has been proven that placing plants in an office space can help to relieve individuals' stress and improve their work efficiency. This study aimed to determine whether there is a difference in the influence on individuals' work attention when the appearance of foliage plants differs in characteristics such as the size or color of the leaves. Ninety college student volunteers were recruited and divided into 5 different groups (1 control group and 4 different plant groups). Volunteers were asked to relax by observing the plants assigned to their particular group after completing a challenging task, and then complete the task a second time. The correct rate, time spent and EEG α and β waves of each volunteer were recorded each time the task was completed. The result shows that when the volunteers of the five groups finished the second task after relaxing, the accuracy of the task was improved; however, no significant difference existed in the time spent compared with the time spent completing the task the first time. Compared with volunteers in the control group, volunteers in the experimental groups observing plants with larger leaves with a green- or red-dominated mixed color showed higher active α wave values. Therefore, observing plants with larger leaves with a green- or red-dominated mixed color for 5 min between work tasks is more helpful for college students in alleviating the pressure of work tasks and improving work efficiency.

Keywords
EEG, attention capacity, restorative environment, learning space, desktop task

Significance of this study

What is already known on this subject?

- It has been proven that placing plants in an office space can help to relieve individuals' stress and improve their work efficiency.

What are the new findings?

- The leaf size and color of foliage plants can affect individual brain waves and the recovery level of working attention.

What is the expected impact on horticulture?

- Observing green and red plants with larger leaves for 5 minutes between work tasks is more helpful for college students in alleviating the pressure of work tasks and improving work efficiency.

Introduction

College students around the world are facing unprecedented pressures and challenges (Cunningham et al., 2017). There is evidence that the main reason for the lack of learning ability and the decline in the academic performance of college students is the lack of attention caused by mental fatigue (Chang and Chen, 2005; Cohen and Spacapan, 1978; Mantzicopoulos and Morrison, 1994; Nuechterlein et al., 1983; Parasuraman, 1986).

A large number of studies have proven the benefits of contact with nature to the well-being of humans (Kaplan and Kaplan, 1989; Kaplan et al., 1998; Kaplan, 1995; Ulrich and Parsons, 1992). In a broad sense, contact with nature is defined as the existence of natural elements within the line of sight; moreover, people are visually stimulated by natural elements, which can help individuals to achieve a certain degree of recovery in their physical and mental health (Jo et al., 2019; Kaplan et al., 1998; Li and Sullivan, 2016; Ulrich and Parsons, 1992). On the other hand, if people stay inside a building for a long time, the building hinders people's contact with nature, which will cause people to have a negative reaction (Bringslimark et al., 2009; Ulrich and Parsons, 1992). Based on this benefit of experiencing nature, an increasing number of studies have been carried out to investigate the presence of indoor green plants and people's physical and mental health, For example, green plants in the office can ease the anxiety of employees (Chang and Chen, 2005; Larsen et al., 1998), restore their work attention (Raanaas et al., 2011), increase their satisfaction and reduce the number of sick leave days (Bringslimark et al., 2007; Lohr and Pearson-mims, 1996). In the same way, green plants in a university learning space should be able to help students reduce negative emotions, reduce stress, enhance work attention, and experience other positive effects (Han, 2009). Therefore, our study further explores the effect of indoor plants on college students' sustained attention on their work.

However, is the recovery effect the same for all plants? At present, the research on the benefits of indoor plants is mostly focused on the restoration effect. When designing stimuli, the most common choices are a single green foli-

age plant (Hassan, 2019), green foliage plants and potted flowers (Nakamura and Fujii, 1990a; Raanaas et al., 2011), and a plant wall with complex plant species (Stiles, 1995), among others. Most studies have chosen foliage plants as the research object because they have advantageous characteristics, such as easy maintenance and high green efficiency. Moreover, compared with potted flowers, foliage plants do not need to be replaced frequently, and the cost of maintenance is lower over the long term (Han, 2009). Therefore, foliage plants are often used when studying the relationship between plants and human physical and mental health (Hassan, 2019; Han, 2009; Lohr and Pearson-mims, 1996). Most studies have focused on the location of plants with respect to indoor furnishings, and few reports have pointed out differences in the restorative effect of plant characteristics in conjunction with the location. Researchers have used the physiological index measurement and psychological questionnaire testing methods to explore the effects of plant color characteristics on human physiology and psychology (Chang, 2002; Kim and Mattson, 2002). Li (2012) found that the recovery effects of the same green foliage plants on human physiology and psychology were different because of their different leaf shape characteristics (Xia, 2012) such as Schefflera (*Schefflera octophylla*) and Chang Ivy (*Hedera nepalensis* var. *sinensis*), which can help people relax their bodies and more effectively reduce anxiety, anger, and fatigue than *Epipremnum aurum*. Leng et al. (2013) found that the odor, color, leaf size, and number of plant characteristics were significantly related to the subjects' satisfaction with the indoor environment. However, in their study, all of the subjects were at rest when they participated in the experiment and did not perform any mental activity; this lack of activity may render the data insignificant. Therefore, we aimed to conduct in-depth research on the basis of this study.

Our study aimed to obtain quantitative data on work attention in order to further measure the relationship between foliage plants and subjects' work attention. In previous studies by Berman et al., it has been shown that the central executive function of human beings is the most vulnerable to mental fatigue, and this function is also the most likely to benefit from the environment (Berman et al., 2008). Therefore, many studies of the effects of indoor plants on cognitive performance start with measuring the central executive function of individuals, such as key response tasks (Berman et al., 2008; Lohr and Pearson-mims, 1996) and the reading span task (Raanaas et al., 2011). The reading span task is a dual processing task, which requires memory and information processing (Raanaas et al., 2011). An increasing amount of evidence shows that working memory representation can produce an attention guiding effect (Soto et al., 2011; Kumar et al., 2009); using a working memory-guided visual search task could effectively cause and test the degree of fatigue of the individual's central executive function (Kumar et al., 2009; Li et al., 2018; Soto et al., 2012). On this basis, this study draws lessons from the color digital target search task of Cong et al. (2011). Therefore, we used the dual task of a working memory-target search to arouse and evaluate the attention to work and memory of participants.

In addition, some studies have shown that when human beings deal with stress, the sympathetic nervous system can activate the potential functions of many organs to adapt to the internal and external environment; on the other hand, the parasympathetic nervous system plays a role in processes that protect the body, repair processes and recovery processes. Concurrently, the cardiovascular system, skeletal muscle system and neuroendocrine system change rapidly and directly under pressure. These physiological changes can be used as objective indicators to identify the healing environment in the experiment (Zhao and Wu, 2010). Many years ago, Ulrich used electrocardiography (EEG), the pulse conduction interval (PTT), the spontaneous skin conduction response (SCR), and other indicators to confirm the decompressive effect of a specific external environment (Ulrich et al., 1991). Later, Harting et al. (2003) and Yamaguchi et al. (2006) expanded their research methods to include more comprehensive and sensitive physiological indicators, such as those of EEG and ambulatory blood pressure monitoring (ABPM), to prove the effects of the environment on people. Studies have shown that these methods can reveal an individual's stress and recovery state more intuitively and quickly (Hartig et al., 2003; Laumann et al., 2003; Yamaguchi et al., 2006). In our study, EEG data were also used to reflect the physiological indicators of participants when they were stimulated or affected by the environment. We aimed to explore whether plants' appearance characteristics (such as leaf size, color, and others) could affect an individual's work attention and fatigue recovery.

Methods

Design

This study was divided into two stages. In the first stage, we invited 90 randomly chosen self-study students in the teaching building who were in high spirits to visit the laboratory and complete three consecutive digital judgment tasks that we installed on the computer ahead of schedule. We collected their completion records, sorted them according to the final score, and then arranged them into five groups to ensure that the baseline of participants' ability to focus on work remained consistent in each group during the second phase of the test; we did not perform random grouping, which may have led to uneven numbers of participants with high or low correct rates in a certain group. Instead, we allowed all participants to complete a desktop operation task, and according to the correct rate, we ranked the participants from high to low and then divided them into 5 groups. The second stage was the formal experimental stage, in which we invited volunteers to enter the experimental cubicle to complete a color digital search task for which the data would serve as the attention baseline. This test also made them experience work attention fatigue. After the first session of data collection, the testers took off the white cloth in front of the plants in the group and asked the volunteers to relax and observe the plants. During this period, we completed the second session of data collection to evaluate the recovery effect of volunteers' attention.

Materials

Our study aimed to explore the relationship between plants and subjects' attention to work from the perspective of the dominant visual characteristics of plants. To achieve this aim, we chose four kinds of plants that are often used as indoor potted plants: (a) S*cindapsus aureum*; (b) *Trachelospermum jasminoides* (Lindl.) Lem.; (c) *Aglaonema* sp.; and (d) *Codiaeum variegatum* (L.) A. Juss. To strengthen the visual stimulus effect of plants on participants and make participants' physical and psychological responses more obvious, we used more plants. The color, leaf size, quantity, and crown width of these plants are shown in Table 1 and Figure 1.

Table 1. Description of the physical characteristics of the experimental materials.

Group no.	Plant	Color	Leaf size	Number	Crown width plant^{-1} (mm)
Group 1	Control group				
Group 2	*Scindapsus aureum*	Green	15–20 cm^2	4	300
Group 3	*Trachelospermum jasminoides* (Lindl.) Lem.	Green	1– 2 cm^2	6	150
Group 4	*Aglaonema* sp.	Red-dominated mixed color	20–36 cm^2	5	250
Group 5	*Codiaeum variegatum* (L.) A. Juss.	A mixture of colors with yellow and green as the main colors	25–40 cm^2	3	350

The experimental site was a vacant classroom with five experimental cubicles with the same area and shape. Each cubicle had a table and a stool 0.5 m away from the test bed in each cubicle. A group of stimuli was on the table (see Figure 1), as well as a notebook computer equipped with the program E-Prime 2.0. The screens in all cubicles were the same size and had a display ratio of 16:9. During the experiment, the physical environment in the laboratory was maintained as follows: the noise was 30 decibels, the temperature was 24°C, and the air humidity was 45%.

Participants

Volunteers were randomly invited college students. They were informed in advance of the purpose of the experiment, the data to be collected and the entire process of the experiment. Additionally, they could withdraw from the study at any time if they so desired. All participants were told not to drink functional drinks, such as cola or coffee, or take brain-stimulating drugs within 48 hours before participating in the experiment. The experiment began in June 2020 and lasted 3 weeks. A total of 90 people participated in the experiment. Each experiment was conducted from 4 pm to 6 pm and the average age of the participants was 21.17 years (± 0.83 years). There were 18 participants in each of the five groups. After participating in the experiment, each participant received a small gift. The room was quiet throughout the experiment. The experiment passed the professional evaluation and ethical requirements of the Mental Health and Development Center of Northwest Agriculture and Forestry University.

Measurements and data recording

The purpose of this study was to explore whether plants' physical characteristics are related to the work attention of college students and the recovery effect of fatigue. Therefore, we set up a desktop operation task to simulate the working state of the subjects; during the task, we measured the level of the subjects' attention to work (correct rate and reaction time) and recorded the brain waves of the subjects during the entire experiment as a physiological index to evaluate their nervous and relaxed states.

1. Desktop operation task. Our research used color digital search tasks. This task contains a total of 24 questions (8 questions in each group, repeated three times, and the order of 8 questions in each task was random). Each question consists of two pictures with colorful numbers. The subjects were asked to have 3 seconds to memorize the three colored numbers on the first picture, and then judge whether the nine colored numbers that appeared in the second picture included the colored numbers just asked to memorize. They need to respond within 5 seconds (if they considered the second picture contains all the colored numbers that appear in the first picture, then they needed to press the A key, otherwise press the L key). Subjects were required to complete the test quickly and correctly. We used the preinstalled E-Prime 2.0 software on the computer to record the correct rate and reaction time. The target stimuli in the experimental program appeared to reduce the practice effect randomly. The purpose of this task was to quantify the subjects' attention to work and their working memory by the correct rate and reaction time.



Figure 1. Five groups of stimuli.

E-Prime is a set of experimental generation systems for computerized behavior research jointly developed by Carnegie Mellon University, the Development Center of the University of Pittsburgh, and PST (Psychology Software Tools, Inc.). We used version 2.0 and wrote the program in advance using this software. When participants ran the program and completed the operational tasks as required, the computer automatically recorded whether their answers were correct and the reaction time. After collecting these data, we calculated the correct rate (number of correct questions/total number of questions × 100%). The unit of response was milliseconds.

2. EEG. Brain waves can accurately show the activity of the human brain, and they can be used to reflect the stress and anxiety of the individuals surveyed (Angelucci et al., 2014); therefore, brain waves are also a tool that can effectively reflect the effects of elements of nature on human beings (Hassan, 2019; Lee et al., 2015; Nakamura and Fujii, 1990b). EEG frequency is usually divided into five groups: delta (4 Hz), α waves (8–13 Hz), θ waves (4–8 Hz), β waves (above 13 Hz) and γ waves (31–42 Hz) (Hassan et al., 2017). In general, α waves are associated with physiological arousal (Ulrich, 1981), and they provide the basic rhythm of human brain waves. Some studies have shown that the wave value is the highest when people are awake, calm and relaxed, whereas when people encounter higher work pressure and larger tasks, the α wave value will decrease and the β wave value will increase (Angelucci et al., 2014).

In our study, the NeuroSky portable brainwave instrument with the NeuroSky TGAM brainwave chip made by the NeuroSky Company in the United States was used. The reference electrode was placed on the left side of the forehead, and the counter electrode was connected to the right earlobe. This device sent brainwave data of subjects to the computer in real time (Tian et al., 2019). During the experiment, subjects' α and β waves were recorded.

Procedure

After entering the experiment cubicle, the participants sat down, and a guide assisted them regarding how to wear the brainwave machine equipment. They were told to imagine that they had just finished a difficult task and were physically and mentally exhausted (2 min); their brainwave values were also recorded for the first time after completing the color digital search task (3 min). At this time, the white shielding cloth in front of the stimulus was removed, and the subjects were asked to look at the stimulus, adjust and relax themselves (5 min). Then, they were asked to complete the color digital search task (3 min) for the second time. After completing these steps, the participants took off the brainwave meter with the help of the guide, filled out the feedback questionnaire (1 min) and walked out of the experiment cubicle, as shown in Figure 2.

Statistical analyses

SPSS 20.0 software was used to analyze the data. We tested three types of indicators: accuracy rate, reaction time, and brain waves. When the subjects completed the first desktop operation task, the three indicators were used as their indicator baselines.

To make further multiple comparisons of the differences in the working ability indexes and physiological indexes of the subjects because of the different plant characteristics, we carried out a single-factor analysis of variance (ANOVA). Because the units of working ability indexes and physiological indexes were different, we adopted a unified judgment unit of recovery effect, which was defined as follows: recovery effect (%) = (first stage value-second stage value) / first stage value × 100%. On the basis of the original five groups, we made a second grouping comparison according to the different plant characteristics. The first comparative analysis aimed to evaluate the differences in plant leaf size; therefore, group 1 (control group), group 2 (large leaves), and group 3 (small leaves) were selected for the analysis. The second comparative analysis aimed to evaluate the differences in plant leaf color; therefore, group 1 (control group), group 2 (green leaves), group 4 (red-dominated mixed color), and group 5 (a mixture of colors with yellow and green as the main colors) were selected for the analysis.

In the data analysis, first, one-way ANOVA was performed to compare the indicator baselines among the groups. Second, a paired T-test was used to analyze the change in the indexes after observing plants in each group. Cohen's d was used to reflect the effect size of the T-test. Third, ANOVA was used to compare the recovery effects of different plant characteristics in different cubicles.



(a) The subject was performing her first desktop task.



(b) After the subject finished the desktop task, she was about to close the computer for plant observation.

Figure 2. Experimental setup.

Table 2. Paired T-test of the control group and the plant group to determine the working ability and EEG differences between before and after plant observation.

Detection indicator	Control group (n=18)					Plant group (n=108)				
	Pretest (M±SD)	Posttest (M±SD)	T	P	Effect size	Pretest (M±SD)	Posttest (M±SD)	T	P	Effect size
Correct rate	0.56±0.18	0.74±0.20	-3.64	0.002	0.94	0.65±0.17	0.74±0.18	-7.26	0.000**	0.51
Reaction time	2865.96±400.54	2961.09±353.21	-1.19	0.249	0.25	2932.61±491.01	2777.07±509.61	3.79	0.000**	0.31
α waves	21376.52±3878.27	22114.56±4571.40	-0.65	0.523	0.17	21976.11±4093.07	27690.48±6367.27	-11.1	0.000**	1.07
β waves	17054.32±4023.99	15435.59±3590.87	2.124	0.049	0.42	15984.78±4230.11	19199.94±5976.68	-5.49	0.000**	0.62

* $p<0.05$, significant difference; ** $p<0.01$, extremely significant difference.

Results

Effects of observing plants on college students' recovery of work attention and physiological indicators

1. Baseline detection of work attention and physiological indexes of college students before plant stimulation. Before plant stimulation, each subject completed three desktop operation tasks to simulate their working state and to induce a sense of fatigue. During the experiment, we recorded the correct rate and completion time for each subject's desktop operation tasks. The response time of each question and the α and β brain wave values are averaged as the participant's baseline level of work attention and brain waves, respectively. The results of the study showed that before the start of plant stimulation, the baseline values of different indicators of the five groups of subjects were as follows: accuracy of desktop operation tasks ($F=1.749$, $p=0.115$) and reaction time ($F=0.412$, $p=0.87$); also, for brain waves, there was no significant difference in the α wave value ($F=1.369$, $p=0.233$) or the β wave value ($F=1.632$, $p=0.144$). This shows that after the five groups of subjects were stimulated by the first instance of work pressure in this task, there was no significant difference in work ability or brain wave indicators. Therefore, this study can attribute the difference in work ability and brain wave indicators produced by different plants to the influence of the differences among the plants.

2. Effects of plant stimulation on work attention and physiological indexes of college students. In order to verify whether plant stimulation has an effect on the work attention and physiological indicators of college students, we performed a paired T-test before and after plant stimulation on the work attention and physiological indicators of the subjects, and compared the results of the experimental groups with those of the control group. The results of the study showed that after plant observation, the subjects' work ability indexes and EEG indexes were extremely different ($p=0.000$), whereas the subjects in the control group had no significant difference in work response time or EEG β waves. Although there was a significant difference in the work accuracy and EEG α waves in the control group, the difference in the recovery effect before and after was smaller than that in the plant group. For the specific values, see Table 2.

Effects of different plant characteristics on the recovery of work attention and the physiological indexes of college students

In order to explore the differences in the effects of plants with different characteristics on the work attention and physiological indicators of college students, we performed a paired T-test before and after plant observation in the 5 test groups; see Figure 3 for details. The results show that, in general, 5 min of self-relaxation could improve work fatigue and work efficiency. However, due to differences in plant characteristics, there were differences in recovery effects in each group; see Table 3 for details. The most obvious response is the wave value of EEG α waves. Compared with the control group, after plant stimulation, each plant group had significant differences in performance regardless of the plant characteristics; also, the α wave value of each plant group was significantly increased compared to that of the control group. In the reaction time for work tasks, except for group 2, there was no significant difference among the other groups.

In the comparison of leaf size, there was a significant difference in the correct rate between the control group and the

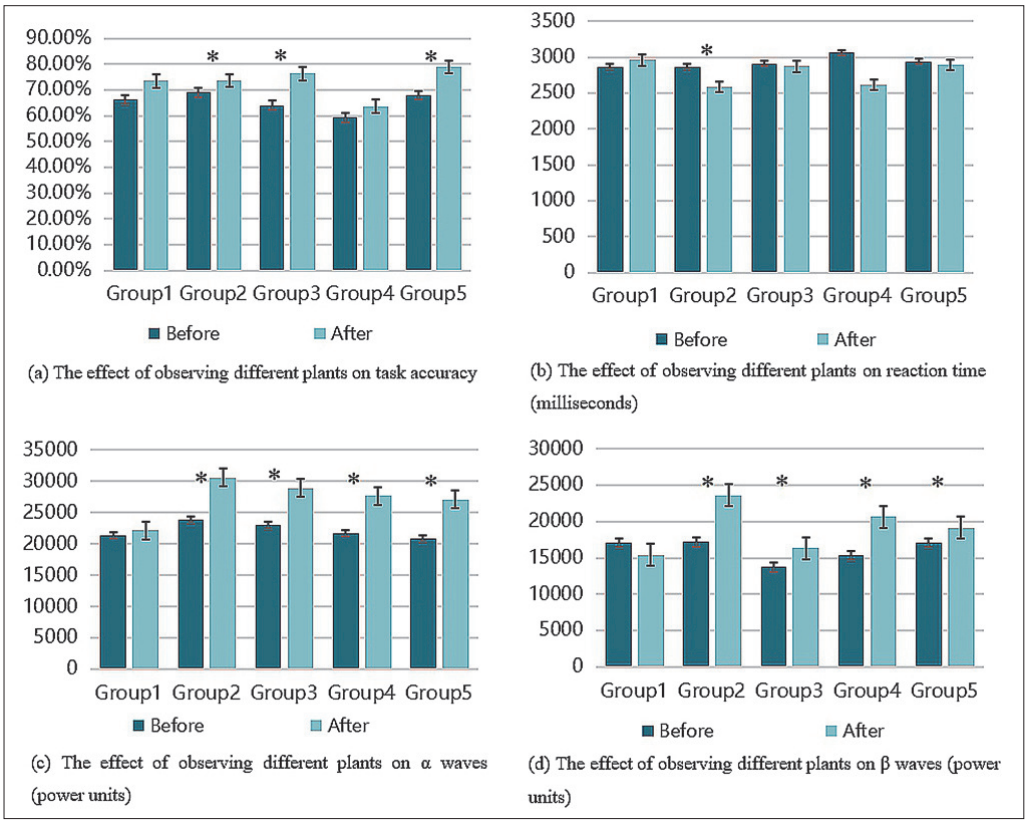


Figure 3. The effect of plant observation on the test index in the five experimental groups (* $p < 0.05$, significant difference).

large-leaf group ($p = 0.029$); also, in the EEG response, there was a significant difference in the α wave value among the three groups. Similarly, there was a significant difference in the β wave value between the control group and the large-leaf group ($p = 0.001$), but there was no significant difference in other groups. Therefore, it can be seen that, compared with the control, watching large-leaf plants (such as a green money plant, and others) is beneficial to the rapid recovery of working ability and physiological recovery in the case of overall plant stimulation and relaxation.

In the comparison of leaf color, there was a significant difference in the correct rate between the control group and the green-leaf group ($p = 0.045$), and the difference in the red-dominated, mixed-color leaf group was more significant than that in the other groups. In the recovery of the reaction time, there was a significant difference between the control group and the red-dominated, mixed-color leaf group ($p = 0.004$). Regarding EEG responses, there was a significant difference in the α wave value between the control group and the red-dominated, mixed-color leaf group ($p = 0.043$); a difference was also noted in the β wave value. There was a significant difference between the control group and the green-leaf group ($p = 0.001$), and a significant difference between the control group and the red-dominated, mixed-color leaf group ($p = 0.007$), but there was no significant difference among other groups. Therefore, compared with the control, in the case of overall plant stimulation and relaxation, watching green plants and red-dominated, mixed-color plants compared with overly complex flowers and colorful plants is conducive to the rapid recovery of working ability, physiological recovery, and relaxation.

Discussion

In this study, five experimental groups were evaluated to explore the effects of different plant characteristics on college students' work attention and physiological relaxation. The results show that under the stimulation of external work tasks, college students who have a sense of work fatigue can significantly improve their working ability and physiological relaxation after taking a five-minute break. This result confirms the self-recovery ability of human beings; that is, self-relaxation in a calm state is conducive to the self-recovery of one's physiological and working ability. However, compared with the control group, under the same time condi-

Table 3. Comparison of differences in task operation and physiological indexes between before and after relaxation in the five experimental groups.

Group no.	Correct rate		Reaction time		α waves		β waves	
	T	Sig.	T	Sig.	T	Sig.	T	Sig.
Group 1	-3.642	0.002*	-1.194	0.249	-0.651	0.523	2.124	0.049*
Group 2	-2.088	0.051	2.632	0.017*	-12.3	0.000*	-3.519	0.002*
Group 3	-3.727	0.002*	0.37	0.716	-4.339	0.000*	-2.411	0.028*
Group 4	-1.003	0.331	4.556	0.52	-3.887	0.001*	-3.393	0.004*
Group 5	-3.48	0.003*	0.475	0.641	-3.861	0.001*	-1.428	0.171

* $p < 0.05$, significant difference, ** $p < 0.01$, extremely significant difference.

tions, if the subjects looked at the plants during relaxation, the effect of physiological relaxation on the improvement in working ability showed higher levels of recovery. This result is consistent with a large number of existing views demonstrating that eye contact with natural plants is beneficial for human beings to maintain their physical and mental health (Berman et al., 2008; Hartig et al., 2003; Kaplan and Kaplan, 1989; Ulrich, 1981). Kaplan proposed that natural elements in natural scenes can provide human beings with a stimulus that does not require direct attention but triggers indirected attention, thus restoring the directed attention system (Kaplan and Kaplan, 1989). Furthermore, Kaplan proposed a "micro-repair" phenomenon, suggesting that people can activate unconscious attention by watching natural scenery for a very short period (Kaplan, 1993; Kaplan, 1995). This hypothesis has been verified by many studies (Berto, 2005; Felsten, 2009; Hartig et al., 2003; Laumann et al., 2003; Raanaas et al., 2011). This point of view is also particularly important for college students' recovery from attention fatigue (Li and Sullivan, 2016) because college students can restore the executive function of the brain and their self-regulating cognitive resources if they are visually stimulated by natural elements (Kaplan and Berman, 2010).

In terms of the recovery effect of the work attention index, the characteristics of plants influence the recovery effect of people within the same time frame in the same state of fatigue. This difference is significantly reflected by the improvement in people's work accuracy. On one hand, the improvement in task accuracy may be due to a more substantial recovery from work fatigue after relaxation, allowing people to concentrate more on completing the task (Cong et al., 2011). On the other hand, there may also be some practice effects (Kumar et al., 2009; Soto et al., 2012), although we took many precautions to avoid the practice effect as much as possible. In the recovery of participants' physiological state, although the EEG α wave values of in the control group increased significantly, this recovery was more obvious in the plant groups. This result is consistent with those of previous studies (Hassan et al., 2017, 2020; Tyrväinen et al., 2014).

Regarding the differences in the characteristics of different plants, we found that the size and color of plant leaves had a certain impact on the attention recovery effect of work. Compared with the ornamental, smaller leaves (leaf area of about 1–2 cm^2), the larger, green plant leaves (leaf area of about 15–20 cm^2) were more beneficial to the recovery of people's attention to work. The green plant with larger leaves selected in this experiment was the money plant, which is loved by most people and is often used to decorate homes, office spaces and public places. It has the characteristics of shade tolerance, easy maintenance, and easy reproduction, among others (Hassan, 2019). The results of this study can prove that, in addition to the above advantages, this plant also has the characteristics of greater relaxation and facilitating the rapid recovery of work attention, which is similar to the conclusion of the Hassan team's study of elderly individuals conducted in 2019 (Hassan, 2019). Interestingly, through the results of the study, we can see that the recovery effect of small leaves was much lower in plants even if they were also green. Therefore, we encourage placing green plants with larger leaves in the study and workplace to help restore work attention.

In addition, we found that the restorative effect of simple plants with red-dominated, mixed-color leaves is similar to that of simple green plants; however, when the plants are too colorful or the pattern is too complex, the restorative effect is weak. In the early study of landscape preference, Kaplan and Kaplan (1989) found that people prefer moderate stimuli to high stimuli to maintain physical and mental balance. In addition, from the perspective of plant evolution, plant colors and patterns are also the result of long-term natural selection to adapt to the environment. Studies have shown that complex colors and patterns of plants can frighten other insects and animals, thus providing self-protection (Li, 2012). Therefore, we consider that when placing foliage plants indoors, one should not choose too many single plants with patterns that are too complex and that have too many colors so that the plants can help maintain people's physical and mental balance.

This study also has some limitations. Because the whole process of this study was completed in 13–15 min, in which the plant relaxation stage was 5 min, the data only provide a measure of the recovery of physical and mental health in a short time. Some studies have proved that although some sense of relaxation caused by contact with plants can enable people to achieve physical and mental balance in a short time, with the extension of relaxation time, there is no significant difference in the sense of relaxation caused by plant stimulation compared with that in the control group (Zimengqiu et al., 2018). On the other hand, there is also a lack of research on the effects of natural factors on the recovery of people's physical and mental health after long-term contact with foliage plants. This line of research may need to incorporate a longer time span in the future to further explore the effectiveness of a person's recovery. In addition, we chose foliage plants with differences in leaf size/color as stimulants, but the pot sizes of these plants were different. In particular, the plant in group 5 was in a large pot, and that plant sat higher on the table than the other plants; these factors may have affected the results.

Conclusion

This study evaluated college students to explore the effects of foliage plants with different characteristics on the recovery of college students' work attention. Under the same time conditions, compared with the control, the subjects could quickly recover their work attention, improve their work efficiency and effectively relieve their physical fatigue by observing plants to relax. The recovery of work attention and physiological fatigue facilitated by a single green plant with larger leaf area (15–20 cm^2) was more effective than that facilitated by a single green plant with a smaller leaf area (1–2 cm^2). Plants with mixed colors, predominantly red and green leaves, had the same effect on work attention recovery. However, the recovery effect of work attention was weaker when observing plants with one more dominant color than observing plants with complex colors and patterns.

Based on the above research conclusions, we provide designers that, place as many plants with larger leaves with a green- or red-dominated mixed color as possible in the line of sight of the learning space to promote the productivity of those in the learning space and improve their work efficiency. Try to avoid putting too many foliage plants with too many colors and patterns in the learning space to avoid distracting learners' work attention or causing work fatigue due to overstimulation.

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Authors' contributions

Conceptualization, Kankan Li and Jianjun Liu; methodology, Kankan Li and Yuan Zhang; software, Yang Zhai; formal analysis, Qi Song; investigation, Kankan Li, Qi Song; resources, Yuan Zhang; data curation, Yang Zhai; writing – original draft preparation, Kankan Li and Yang Zhai; writing – review and editing, Kankan Li; project administration, Kankan Li; funding acquisition, Kankan Li and Jianjun Liu.

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Conflicts of interest

The authors declare no conflicts of interest.

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