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Research article

Foliage colors improve relaxation and emotional status of university students from different countries

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ABSTRACT

The therapeutic advantages of seeing plants have gained increasing consideration in stressful modern societies, however, evidence-based studies on how physiological and emotional states of individuals from different nationalities change when seeing different foliage colors are limited. The study was conducted to explore the physiological and psychological advantages of foliage colors as visual stimuli. The experiment included 40 men from two nations (age: 21.34 ± 3.50 years) and was carried out using five foliage colors including green, light green, green-yellow, green-red and green-white. Participants were exposed to each color for 2 min, when seeing the foliage colors, eye movements and oxy-Hb concentrations were continuously measured. Subjective evaluations of emotions were performed utilizing a semantic differential questionnaire. A significant decrease in oxy-Hb concentration in the frontal lobe was associated with the viewing of green and green-white plants by the Japanese participants and with viewing light green and green-yellow by the Egyptian participants. Participants spent higher fixation numbers and longer durations on these colors. The findings indicate that viewing of these plant colors was positively associated with physiological relaxation. Furthermore, these colors were associated with more positive feelings, such as calmness, comfort and naturalness. Therefore, the presence of these colors in spaces may have positive impacts on relaxation and emotional status.

1. Introduction

In recent decades, there has been an ever-growing number of pressing challenges confronting urban dwellers. One of the major global health problems of the 21st century is the rapid increment in urban populations [1]. It is estimated that by about 30 years from now, more than 66% of the world's residents will live in cities, up from about 54% today. Despite the advantages of urbanization, there are some disadvantages that cannot be overlooked. Through the impact of stressors and developing factors, for example, a crowded and polluted environment, elevated levels of viciousness, diminished social help and urbanization can negatively affect human psychological well-being. The spectrum of urbanization-related health disorders is huge. Some of them are extreme psychiatric illnesses, including anxiety and depression. Moreover, there are commonly higher risks in cities for certain fundamental states of mind, for example, tension, psychotics, temperament or addiction [2].

A *meta*-analysis by Reddy and his colleague [3] reported a higher predominance of mental illness in cities i.e., 80%, compared to 48% in the countryside, consisting mainly of depression, stress and neurotic disorders. The negative effects of depression are so high that it was declared a global epidemic by the World Health Organization [4, 5]. Furthermore, it is expected to be the key driver of disease burden around the world by 2030 [6].

Urban green spaces are seen as important contributors to the health and well-being of individuals and can be an important part of sustainable development. As beneficial outcomes of contact with nature are known, several studies has given to showing the significance of the natural spaces for human prosperity [7, 8, 9]. Studies have come to promising conclusions on the psycho-physiological impacts of green spaces [10, 11, 12, 13, 14, 15]. Conservation of green spaces, in terms of quantity and quality, is an urgent global challenge in the face of growing urbanization [16, 17]. A recent research indicates that viewing the green facade appears to

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enhance individuals' mental and physiological health compared to viewing the building-wall [18]. Access to green spaces is declining rapidly as urban areas develop decreasing opportunities for individuals to experience contact with nature [19].

Studies have assessed the impact of having indoor plants in work places [11, 20] showed that plant arrangement enhanced office's aesthetic quality and causes participants to feel calmer. In a clinical study, patients who were allocated to stay with a green space view recuperated quicker than those assigned to a room with windows confronting structures [21]. Furthermore, it was reported that indoor plants positively affected emotions, well-being, mood and concentration [22]. To deal with increasing urban density, population growth and natural space decline in cities, it is necessary to know the impact of foliage plants on human' mental health. It will facilitate the use of colored plants in the form of indoor plants, trees, shrubs or vertical greening as a method that can effectively relieve stress and induce mental relaxation in densely populated cities.

As aforementioned, the useful effects of nature and plants on human physiological and psychological states have been well reported. Nonetheless, limited research has been conducted to examine the physiological and psychological effects of foliage plants with different colors. Color is an inseparable part of life and its existence is apparent in all that we see; it is known to affect people's feelings [23, 24, 25]. Several factors are liable for color perception and preference, for example, sex [26], personality, topographical location of home and culture [27]. Although many investigations have looked at personality and sex differences in color inclination and perception, few have focused on geographical locations, particularly the cross-cultural perspective. Recently, considerable attention has been paid to comparative investigations between racial and cultural groups. Such studies showed that cultural factors played a vital role in the differences in color preference. Individuals from a similar region would have a similar color inclination, regardless of race. In addition, one district may have different inclinations than another district, regardless of race [26, 28]. Perceptions of color vary from region to region, and a single color can have different, even contrasting effects around the world [29, 30]. Considering the developing enthusiasm for investigating the psychological and physiological effects of plant colors on people, more evidence-based research is needed to understand the impact of plant colors on eye movement, brain activity and emotional status of individuals of various races. There are very few studies that have focused on the impacts of plants and green spaces on eye movement [31] and brain activity [32]. Nonetheless, these studies have limitations, including small sample sizes and evaluations assessments performed with one color on one ethnicity.

Regardless of the tremendous endeavors of urban greening initiatives, the maximum advantages of natural environments may not be realized if the selection of plants centers carefully around those that produce green foliage, as is the case with certain plants, they may contain leaves that are not green. Since most of the restoration studies focus on "green" environments as a therapeutic binary inverse to urban environments, we may need to re-evaluate this relationship, as it appears that maybe ''white or yellow'' is at least as restorative as "green" when it comes to foliage [33]. Therefore, this study aims to examine the effects of visual stimulation with five plant colors of *Hedera helix*, i.e., green, light-green, white-green, green-yellow and, green-red on eye movement, cerebral blood flow and emotional status. The outcomes could assist to better clarify how plant colors, in various societies, can influence people's wellbeing and provide scientific proof for healthy indoor and outdoor environments that could help landscape designers to recognize the suitable plant colors for different landscape decorations. We believe that foliage colors can minimize stress levels in everyday life.

2. Materials and methods

2.1. Subjects

Forty students, half of them Japanese and the other half Egyptians, aged 21.34 ± 3.50 years were enrolled in this study (Table 1).

Table 1. Descriptive information of participants who enrolled in the study (n = 40).

Variable	Mean	Std. Err.
Age (Year)	21.34	3.50
Height (cm)	175.50	5.62
Weight (kg)	70.82	6.22

Participation was entirely voluntary. Students who are currently undergoing treatment for any neurological or psychiatric disorders were exempt. During the experiment, participants were asked not to drink alcohol the day before the experiment to guarantee their physical and mental health. All subjects participating in the present study gave their informed consent prior to participation. The study was approved by the Human Research Ethics Committee of Graduate School of Horticulture, University of Chiba, Japan (Approval Number #12-03), and it was conducted in accordance with the Declaration of Helsinki.

2.2. Stimuli

We decided to use a plant that is well known worldwide and has various foliage colors. In any case, it ought to remain appropriate for outdoor spaces and indoor uses. Moreover, presenting various colors with a similar leaf shape to the subjects (to recognize color impacts). English ivy plants have been utilized as important plant material in green outdoor applications and indoor cultivation [34]. Five varieties of English ivy, including green, light green, green-yellow, green-red and green-white, were used in the current study, as shown in Figure 1. Twenty samples of each plant color were placed into one plate to form a group and to display it as one cluster for each color.

2.3. Experimental protocol

The study was conducted during the semester examination days to ensure that the participants needed relaxation in order to enhance the restorative effects. The time of the experiment was chosen by the subjects to suit their schedule. They also have the right to cancel and/or change the date of participation in the experiment. The participants were first informed about the study targets and procedures in the waiting room. They were also asked to turn off their phones. Each participant was asked to move to the test room (60 m^2) painted white and lighting comprising of fluorescent light (750 Lux) for physiological and psychological measures at 22 ± 1.50 °C and 55 ± 3.22% relative humidity. Prior to the participants going into the room, the tested plants were hidden. The distance between the participant and the tested plants was determined to be 50 cm (Figure 2), while Eye movement detector and NIRS electrodes were fitted for the psychological and physiological measures. Estimation conditions for eye movement calibration and brain activity were performed. At that point, each participant was asked to relax with his eyes closed for 2 min to adjust his mood to the experimental condition, and while the participant was closed his eyes, the first plant color was put on the participant's eye level on the table to guarantee a straight vision without shifting his head. After confirming a stable brain activity on the NIRS monitor, the participant was informed to open his eyes and look at the visual stimulus for 2 min. Immediately after completing the task, the participant was asked to respond to semantic differential questionnaire (SD). Visual stimuli were randomly displayed to overcome the order impact. Figure 3 illustrates the experimental protocol and measurement processes. A within-subject design experiment was utilized, where all participants experienced all tested plants. The entire duration of each participant's experiment was about 1 h. Since all the participants were students, and utilized the English language in their daily lives, the English language was utilized in the experiment.

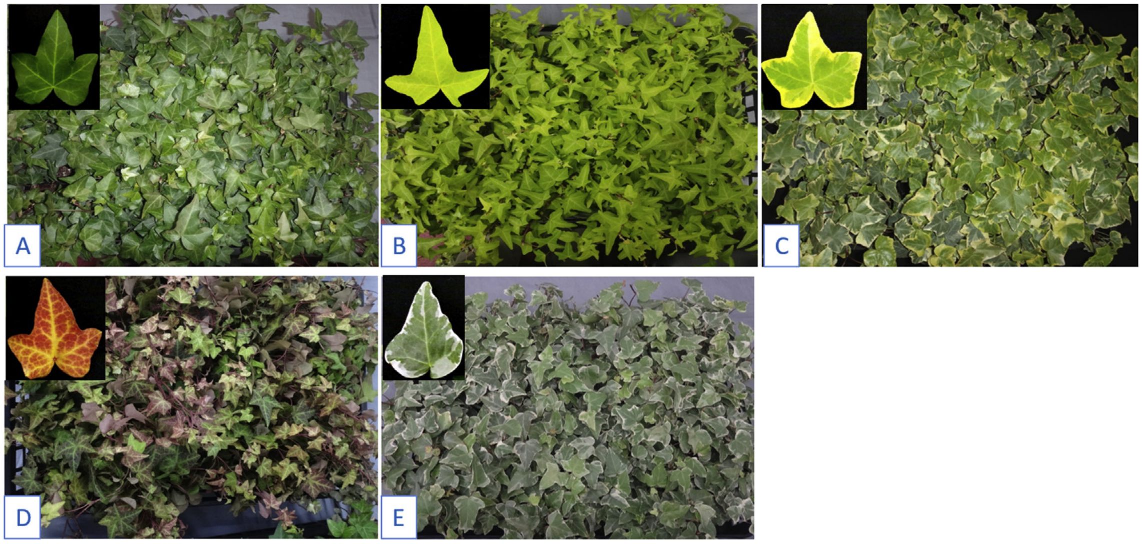


Figure 1. English ivy varieties A: green; B: light green; C: green-yellow; D: green-red; E: green-white.

2.4. Measurements

2.4.1. Physiological measurements

2.4.1.1. Eye tracking. The eye movement system is directly linked to cognitive processes including recognition, and consideration [35]. Since we utilize our eyes in nearly all that we do, it is conceivable that eye movements could give a supportive information source for activity recognition [25]. It is broadly utilized to examine information processing tasks, for example, reading [36], impression of scenes [37] and visual examination [38]. It is not surprising that eye movement provides the simplest and the most precise method of extracting information from our environment and it is generally figured out which information is chosen for additional processing [39, 40]. For recording eye movement, EMR-9 Glasses-Type Head Unit, Dual Eye Detection (NAC Image Technology Co., Ltd. Japan) was used. This device uses two cameras to monitor the participant's pupil position. The eye tracking variables used in the present study were fixation numbers and durations [35]. The fixation numbers are identified with the measure of data that can be prepared on every fixation and how the following saccade target is picked, while the fixation duration shows how long it takes to process information around the fixation and how long it takes to plan the next saccade [41].

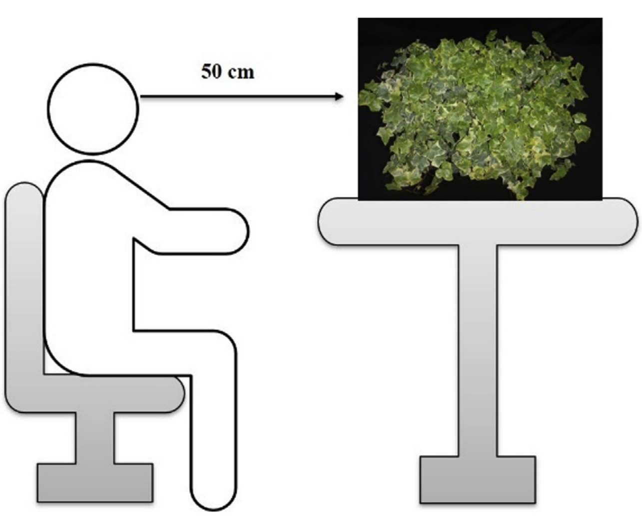


Figure 2. Experimental setting.

2.4.1.2. Cerebral blood flow (CBF). In the present study, we recorded brain activity during the visual stimulation using a multichannel near-infrared spectroscopy (NIRS; OMM-2001; Shimadzu Co., Ltd., Japan). NIRS is a non-invasive technique that can be used to recognize changes in oxygenated (Oxy-Hb) and deoxygenated hemoglobin concentrations in the brain, which are inferred to reflect changes in cerebral metabolism and perfusion [42]. Here, we focused on the oxy-Hb concentrations which proved to be a sensitive indicator of cerebral blood flow fluctuations [43]. The measurements were confined to the right brain hemisphere since it is the seat for emotional and image-related activities [44]. Forty-seven measuring locations, called channels (e.g., ch1, ch17, ch47), were set in the frontal, parietal, temporal and occipital lobes (Figure 4).

2.4.2. Subjective emotion assessment

The emotional status prompted by foliage colors was evaluated using a semantic differential method (SD), which was found to be a reliable and valid method of quantifying the participants feelings towards external stimuli [45]. Fourteen sets of contrasting adjectives (for example, comfortable-uncomfortable, beautiful-ugly, calm-unquiet) were utilized, which were intended to rate the subjects' feelings on a 5-point scale from 1 (extremely positive) to 5 (extremely negative).

2.5. Statistical analysis

Statistical analysis was done using SPSS ver. 25 (IBM Crop., USA). All data were expressed as means ± standard error. To determine whether nationality could influence eye movement phenomena and brain activity, a two-way ANOVA followed by Bonferroni post hoc test between-groups factors was performed. Steel–Dwass multiple tests were utilized to compare SD questionnaire scores between the two groups. A p-value less than 0.05 was considered significant.

3. Results

3.1. Physiological responses

3.1.1. Eye tracking

3.1.1.1. Fixation numbers. As presented in Figure 5, the average fixation numbers of eye movement are influenced by foliage colors. A significant main effect of nationality (F (1, 14.54) = 3.94, p < .001) was found, because the Egyptian participants had a higher number of fixations than Japanese participants. There was a significant interaction between

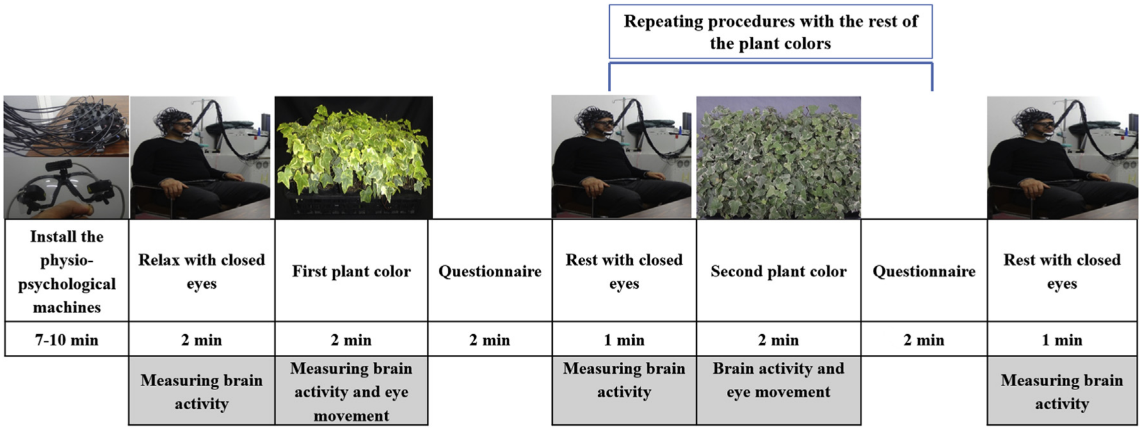


Figure 3. Experimental protocol.

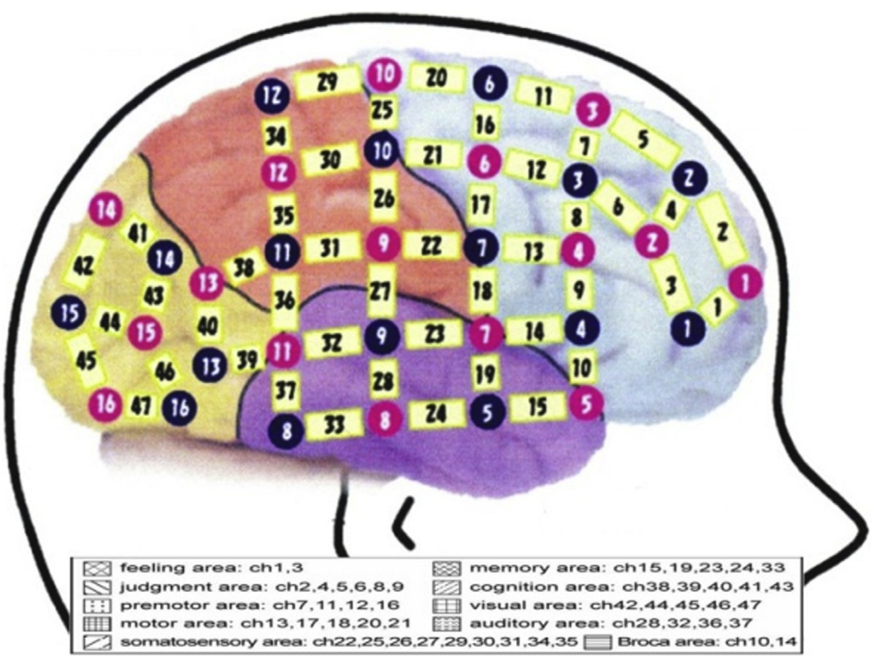


Figure 4. Localization of the brain function, forty-seven channels matching with ''feeling (ch1, 3), judgment (ch2, 4, 5, 6, 8, 9), premotor (ch7, 11, 12, 16), motor (ch13, 17, 18, 20, 21), somatosensory (ch22, 25, 26, 27, 29, 30, 31, 34, 35), memory (ch15, 19, 23, 24, 33), cognition (ch38, 39, 40, 41, 43), visual (ch42, 44, 45, 46, 47), auditory (ch28, 32, 36, 37), and speech (Broca, ch10, 14)'' functions.

nationality and foliage color (F (4, 3.87) = 2.47, $p < .01$). Regarding the nationality impact, there was a considerable difference between Japanese and Egyptian participants when they saw the light green (84.00 $\pm$ 5.74 vs. 120.57 $\pm$ 13.11, $p < 0.01$), green-yellow (88.20 $\pm$ 5.63 vs. 110.40 $\pm$ 4.49, $p < 0.01$) and green-red plants (86.31 $\pm$ 5.27 vs. 99.43 $\pm$ 5.99, $p < 0.001$). On the other hand, there were no significant differences between Japanese and Egyptian when they looked at green and green-white plants. The results showed that Egyptian participants carefully watched the details of the light-green, green-yellow and green-red plant as proven by higher fixing numbers compared with Japanese participants.

3.1.1.2. Fixation durations. Figure 6 illustrates that the Egyptian subjects' fixations were of longer duration than those of their Japanese partners while seeing the tested plants. There was a significant main impact of nationality (F (1, 9.83) = 3.93, $p < .01$) because the Egyptian subjects had longer fixations duration than the Japanese subjects. There was a significant interaction between nationality and plant color (F (4, 5.08) = 2.45, $p < .01$). Regarding the nationality impact, there was a considerable difference between Japanese and Egyptian subjects when they looked at the light green (40.78 $\pm$ 2.04 vs. 50.42 $\pm$ 2.02, $p < 0.01$), and green-yellow plants (40.13 $\pm$ 1.47 vs. 49.23 $\pm$ 2.02, $p < 0.01$). On the other hand, there were no noteworthy differences between Japanese and Egyptian when they saw green, green-red and green-white plants.

3.1.2. Cerebral blood flow

Figure 7 shows brain activities and channels that display substantial fluctuations in oxy-Hb concentration during visual stimulation using different plant colors for Japanese and Egyptian participants. When Japanese subjects viewed the green plants, oxy-Hb was substantially diminished in the feeling area ($p < 0.01$), that manages relaxation, focus, and awareness. While green plants were substantially improved in the visual area ($p < 0.01$) which integrates visual information, gives meaning to the current stimulus in relation to experiences and knowledge. On the other hand, concerning the Egyptian participants, the same color succeeded in increasing oxy-Hb in the motor area ($p < 0.01$) which controls

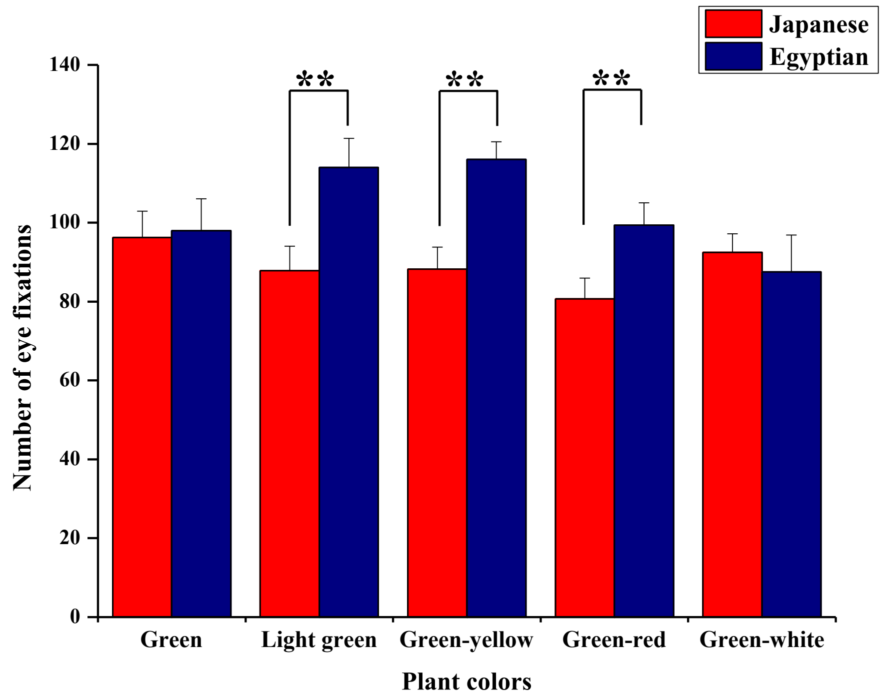


Figure 5. Comparisons of the participants' averages of eye fixation numbers of the (Japanese and Egyptian) among English ivy colors, mean ± standard error, $^{**}p < 0.01$.

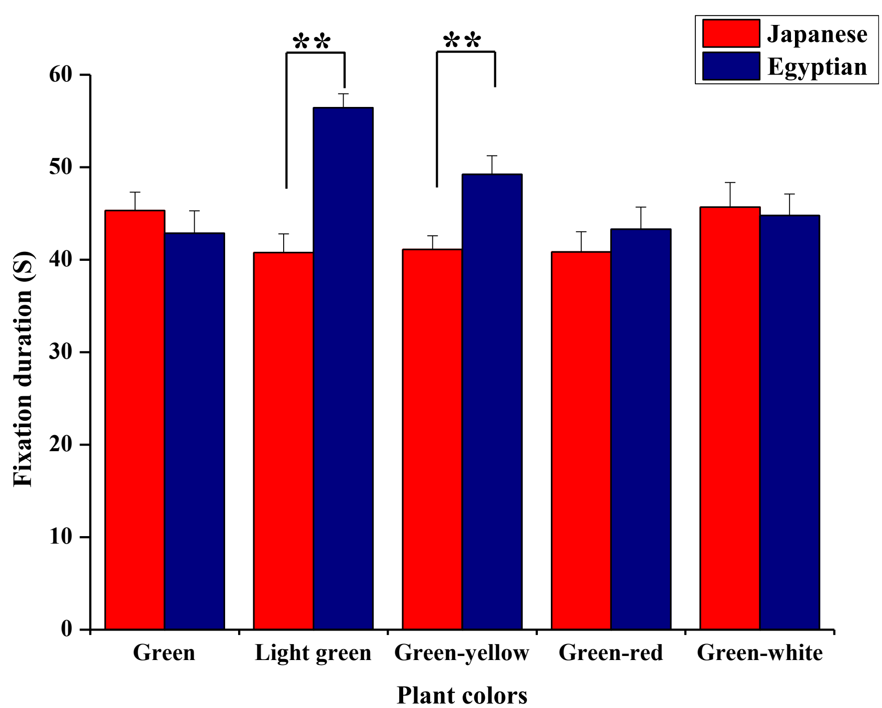
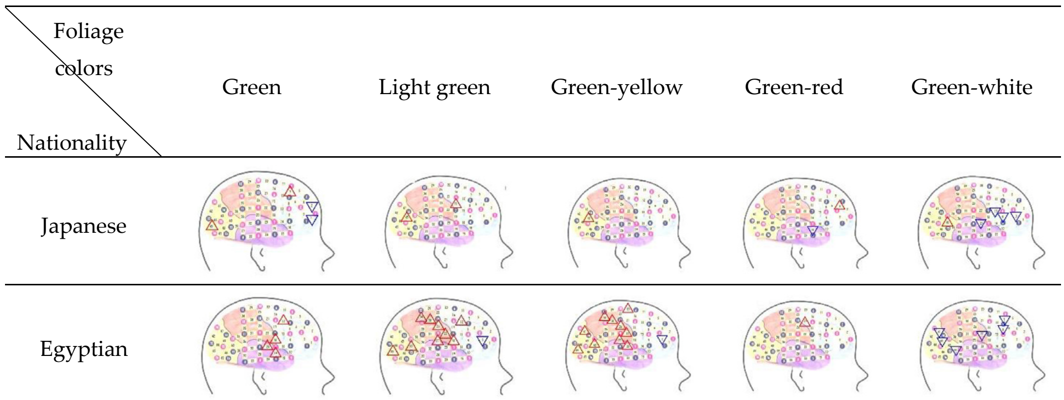


Figure 6. Comparisons of the average of eye movement fixation duration of Japanese and Egyptian participants while looking at English ivy colors. Mean ± standard error, $^{**}p < 0.01$.

motor function and in the memory area ($p < 0.01$) which is important for the arrangement of conscious memories. The light green color had a different influence on the Japanese participants represented by oxy-Hb increment in the motor and cognition areas ($p < 0.01$). While for the Egyptian participants, oxy-Hb was significantly sedated in the feeling area and activated in the premotor, motor, somatosensory, and the cognition areas ($p < 0.01$).

As far as green-yellow color is concerned, this color significantly increased the concentration of oxy-Hb in the cognition area ($p < 0.01$) for the Japanese participants. Although it significantly decreased it in the feeling area ($p < 0.01$) for the Egyptian participants. Furthermore, this color contributed to significant increases of oxy-Hb in the motor, memory, somatosensory, cognition and the visual areas ($p < 0.01$). Regarding the green-red color, it was significantly increasing the oxy-Hb in the



△, significant increase in oxyhemoglobin; ▽, significant decrease in oxy-Hb at $p<0.01$.

Figure 7. Changes in oxy-Hb concentrations in the brain during visual stimulation with English ivy colors by Japanese and Egyptian participants.

judgment area ($p < 0.01$), and a significant reducing in the memory area ($p < 0.01$) for the Japanese participants. Though it has contributed to a significant increment in the oxy-Hb concentration in the motor area ($p < 0.01$) for the Egyptian participants. The white plant color significantly diminished the oxy-Hb in the feeling area and increased in the cognition area ($p < 0.01$) for the Japanese participants. While for the Egyptian participants, it significantly decreased in the premotor, judgment, and cognition areas ($p < 0.01$). These findings reveal that seeing the green and green-white plants by the Japanese participants as well as the light green and green-yellow plants by the Egyptian participants has positive relations with improving brain activity and calming.

3.2. Subjective emotion assessment

Participants' self-reported feeling scores estimated by the SD survey are shown in Figure 8. Interestingly, green and green-white plants stimulated a sense of relaxation and calmness based on the results of the Japanese participants. While it was mostly described by the Egyptian participants as giving rise to a feeling of strength. The light green and green-yellow plants were bright and showy for Japanese participants. Although they were generally observed to be bright, characteristic, beautiful, stable and natural, and evoked mostly positive responses, for example, cheerfulness, calmness, comfort and a sentiment of roominess for Egyptian participants.

4. Discussion

Contact with nature has relaxing effects and increasing attention has been paid to its healing effects [46]. Natural elements have mainly been identified as a key tool for enhancing the restoration impact in this context [47]. Fewer studies on the advantages of foliage colors for human wellbeing have been done. The current study therefore attempts to explore the psychological and physiological impacts of different foliage colors on human health, as well as to explore the potential impact of culture on color perception. The outcomes support the results of previous studies confirming the positive influences of seeing plants on people's wellbeing, as well as providing a novel comparison of the effects on different nationalities. The relaxation effect is not limited to green color, but other colors may cause it. The physio-psychological findings were generally well supported by the argument that different colors induce different beneficial outcomes for individuals [11, 12, 48].

Eye movement, indicating where and how individuals look inside a scene and is increasingly being used in various fields such as cognitive and attentional [49]. The fixation duration is typically intended to represent the time required to process the information across fixation and the time required to schedule the following saccade (eye movement that shifts the center of gaze from one part of the visual field to another), and number of saccade is identified with how much information could be prepared on fixation and how to pick the following saccade target [36]. The extra duration of fixation on color might be correlated with detailed color analysis. Our findings showed that eye movement characteristics are influenced by the color of the plant and nationality. While the participants looked at the plants with different colors, different numbers and durations of fixation were noted, which revealed that some colors have a restorative impact when seeing it. It may rely upon the participants' nationality. Results showed that Egyptian participants had more fixation numbers and durations than Japanese participants when viewing light green or green-yellow plants. The increase in duration and fixation numbers led to the conclusion that when Egyptian participants were seeing light green and green-yellow they were more engaged with interpreting visual representations on the scene, attempting to link them with recently internalized representations [31]. These results are consistent with Ruggieri [50] findings and conclude that when people effectively consider an object, eye movements are substantially more active than when people think passively of an object. The present study results revealed that fixation numbers and duration are associated with color preference. Furthermore, eye movement can be used to identify which element has a therapeutic potential by identifying the elements that show a higher fixations numbers and longer durations on specific areas than other components [46]. A recent study, which combined eye movements with physiological measures while seeing a Japanese garden, concluded positive associations between eye movement and heart rate variability, recommending a link between engagement/focus and relaxation [51]. Although plant colors play a key role, the outcomes also indicated that nationality could affect individual's eye patterns. This implies that foliage colors can cause more visual activity.

On the other hand, the results of the brain activity of the participants showed that different plant colors and different nationalities had different brain activity reactions. Prior research stated that a change in feelings, whether good or negative, could result in a considerable reduction in oxy-Hb [52]. In this study, a reduction in Oxy-Hub was observed in the feeling area when viewing green and green-white, as well as light green and green yellow plants. Indicating that relaxation occurred while viewing these colors. The outcomes are in line with Hoshi's findings [43] which stated that pleasant and positive feelings are followed by decreased concentration of oxy-Hb in the prefrontal cortex. Concerning the positive responses of the Japanese participants for the green plants, the results are generally in agreement with those of Saito [27] and Hemphill's [23] studies which reported green color as a calm, relaxing color. The positive responses could be attributed to the association between green color and nature, grass, and trees and remind observers both outside and spring. The results of the study seem to support that seeing green plants can have relaxing effects for the Japanese as appeared by decreasing Oxy-Hb in the feeling area and might affect the

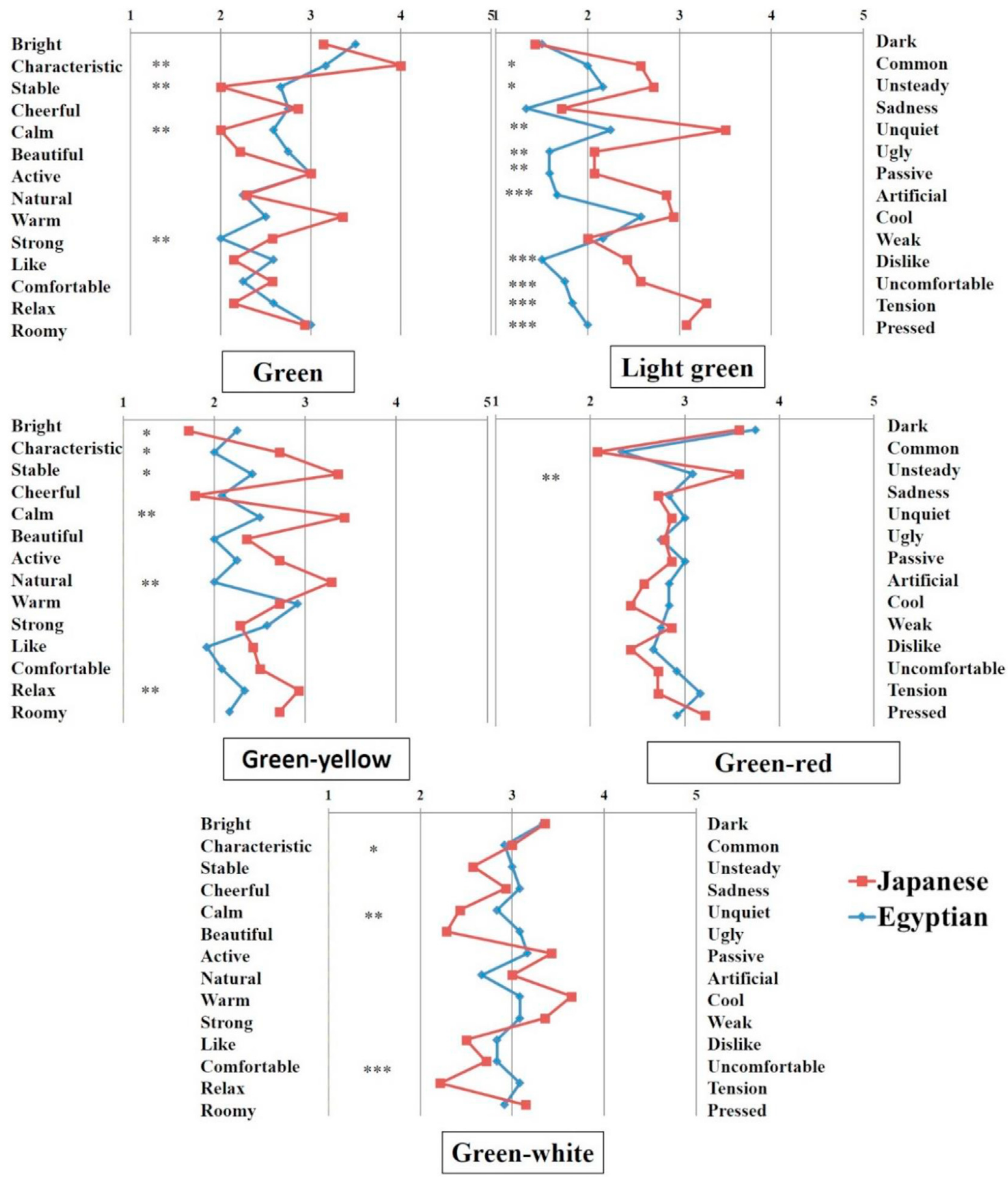


Figure 8. Self-reported emotions according to the semantic differential questionnaire after viewing the five visual stimuli. *, ** Significance at $p < 0.05$ and <0.01, respectively.

motor skill for Egyptians as demonstrated by increased Oxy-Hb in the motor area [53, 54]. Previous studies showed that green color was the most efficient color for mental comfort [55, 56]. On the other hand, viewing green plants significantly decreased Oxy-Hb concentration in the feeling area for the Japanese participants because this color could provide a comfortable environment [12, 24]. These findings showed distinct conclusions about what each color represents and its impacts on brain activity.

Light green and green-yellow plants evoked brain activation in different areas of the Egyptians' brain. Decreased oxy-Hb in the feeling area indicated an increase in relaxation. Song and his colleagues [57] studied the impact of forest imagery on cerebral blood flow and demonstrated a decreased concentration of oxy-Hb in the prefrontal cortex and an increased feeling of comfort. On the other hand, there were increases in the oxy-Hb in somatosensory, cognition and visual areas. Interestingly, we found that oxy-Hb increased in most areas of the participant's brain in the presence of these plant colors. These results are consistent with those observed in an earlier study by Suzuki and his colleagues [58], which found a correlation between the increase in oxy-Hb and the state of happiness, activity, relaxation or comfort. Cerebral blood flow increases are associated with the level of awareness provided to the visual stimulus and emotional status of the participants [59].

Previous studies have reported that colors directly influence viewers' emotions. Based on the results of the SD questionnaire, the presence of green and green-white plants for Japanese participants and light green and green-yellow plants for Egyptian participants caused feelings of 'comfort', 'relaxation', 'natural', 'beautiful' and 'cheerful' compared to other colors. The results are in line with the outcomes of Li and colleagues' study [60], which showed that the view containing light green plants is emphatically connected with comfort. Also, viewing yellow and green colors has given rise to feelings of stability, happiness, and calmness. Hemphill [23] reported that bright colors were generally responsible for eliciting positive feelings, whereas dark colors evoked negative feelings, which confirmed the outcomes. Considering the scores obtained from the participants' self-reported emotions, Japanese participants felt stable and calm when they were seeing both the green and the white plants. Light green and green yellow plants, on the other hand, have more beneficial outcomes and have enhanced positive feelings such as calmness, characteristic, and naturalness for Egyptians. While the negative impact of green-white plants on Egyptian participants could be attributed to the meaning of white color in plants that indicate infected or dead plants or to a relationship with the picture of death [25]. Hurlbert [26] revealed that nationality played a role in differences in the color preference. Based on the preference for color, Al-Rasheed [28] concluded that the preference for color varies with gender, in a way that depends on nationality. Saito [27] reported exceptional color inclination trends among Japanese and Korean, and within the individual nation with respect to age, sex and geographical area.

While perception and recognition of landscape are ultimately human mental phenomena, culture has a considerable impact on the individual mind, and therefore, could explain certain experiential attitudes towards landscapes [61]. A previous survey focused on psychological processes and culture influences reported that "a great deal of recent research has shown the power of culture to affect its members' perceptions, attentions, feelings, and behaviors" [62]. Our study found that viewing green and green-white plants by Japanese participants provided more visual awareness, and they were personally more relaxed compared with other plant colors. While the Egyptian participants gave more visual consideration and were emotionally more relaxed when viewing light green and green-yellow plants compared to other plant colors. Foliage colors should be considered as one of the resources that promote individuals' psychological health. The findings indicate that for Japanese participants, green and green-white plants can be introduced into the environment in order to create comfortable and relaxing environment. While the light green and green-yellow may have the same positive impact on the Egyptian participants. This study can help to understand more about foliage colors and how they affect us, making better choices when choosing plants for the desired purpose.

Despite these findings, the present study has some limitations that could be addressed in future research. First, the study focused on healthy young males and it is unknown whether the outcomes could be generalized when applied to different groups, such as females and different ages, such as the elderly and children. Secondly, each participant saw each plant color only once for a short time, so that the influence of repeated viewing and the long-term effects remain unclear. More scientific evidence and cooperation between scientists in the relevant research area are needed to encourage the use of foliage plants as a resource to promote the well-being of individuals in urban areas.

5. Conclusions

This study attempted to provide scientific support for the physiological and psychological impacts of viewing foliage colors and offer evidence of nationality influences on color perception. Results showed that each color is related to certain emotional responses, and therefore color would be recommended for the intended purpose. Notably, we found that green and green-white plants had the greatest ability to enhance Japanese participants' feelings of relaxation and calmness compared to other colors. While light green and green-yellow had the greatest ability to stimulate calmness, cheerful, exciting feelings for Egyptian participants compared to other colors. The outcomes provided a deeper insight into the health-related values of foliage colors, promoting the therapeutic function of foliage colors for individuals' well-being.

Declarations

Author contribution statement

Liu Kexiu: Conceived and designed the experiments; Analyzed and interpreted the data; Wrote the paper.

Mohamed Elsadek: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Binyi Liu: Conceived and designed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Eijiro Fujii: Conceived and designed the experiments; Analyzed and interpreted the data.

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Data availability statement

Data will be made available on request.

Declaration of interests statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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References

[1] K. Srivastava, Urbanization and mental health, Ind. Psychiatr. J. 18 (2009) 75–76.
[2] O. Gruebner, M.A. Rapp, M. Adli, U. Kluge, S. Galea, A. Heinz, Cities and mental health, Dtsch. Arztebl. Int. 114 (2017) 121–127.
[3] V.M. Reddy, C.R. Chandrashekar, Prevalence of mental and behavioural disorders in India: a meta-analysis, Indian J. Psychiatr. 40 (1998) 149–157. http://www.ncbi.nlm.nih.gov/pubmed/21494462. (Accessed 20 August 2020).
[4] F.-D.M. Nieuwenhuijsen K, D. Bruinvels, Psychosocial work environment and stress-related disorders, a systematic review, Occup. Med. 60 (2010).
[5] WHO, Occupational health, Stress at the Workplace, World Health Organization, 2010. https://www.who.int/occupational_health/topics/stressatwp/en/. (Accessed 23 November 2020).
[6] WHO, Global burden of mental disorders and the need for a comprehensive , coordinated response from health and social sectors at the country level, Sixty-Fifth World Heal. Assem. (2012) 1–6. https://apps.who.int/gb/ebwha/pdf_files/EB130/B130_9-en.pdf. (Accessed 24 November 2020).
[7] H. Frumkin, Beyond toxicity: human health and the natural environment, Am. J. Prev. Med. 20 (2001) 234–240.
[8] E. Janeczko, E. Bielinis, R. Wã³jcik, M. WoÅºnicka, W. Kä™dziora, A. Åukowski, M. Elsadek, K. Szyc, K. Janeczko, When urban environment is restorative: the effect of walking in suburbs and forests on psychological and physiological relaxation of young polish adults, Forests 11 (2020) 591.
[9] M. Elsadek, B. Liu, Z. Lian, X. Junfang, The influence of urban roadside trees and their physical environment on stress relief measures: a field experiment in Shanghai, Urban For. Urban Green. 42 (2019) 51–60.
[10] K.-T. Han, L.-W. Ruan, Effects of indoor plants on self-reported perceptions: a systemic review, Sustainability 11 (2019) 4506.
[11] M. Elsadek, B. Liu, Effects of viewing flowering plants on employeesâ€™ wellbeing in an office-like environment, Indoor Built Environ. (2020) 1–12. In press.
[12] H.S. Jang, J. Kim, K.S. Kim, C.H. Pak, Human brain activity and emotional responses to plant color, Stimuli 39 (2014) 307–316.
[13] M. Elsadek, M. Sun, R. Sugiyama, E. Fujii, Cross-cultural comparison of physiological and psychological responses to different garden styles, Urban for, Urban Green 38 (2019) 74–83.
[14] J.J. Roe, C.W. Thompson, P.A. Aspinall, M.J. Brewer, Green Space and Stress: Evidence from Cortisol Measures in Deprived Urban Communities, 2013, pp. 4086–4103.
[15] Y. Shao, M. Elsadek, B. Liu, Horticultural activity: its contribution to stress recovery and wellbeing for children, Int. J. Environ. Res. Publ. Health 17 (2020) 1229.
[16] J. Colding, Å…. Gren, S. Barthel, The incremental demise of urban green spaces, Land 9 (2020) 162.

[17] M. Elsadek, B. Liu, J. Xie, Window view and relaxation: viewing green space from a high-rise estate improves urban dwellers™ wellbeing, Urban For. Urban Green. 55 (2020) 126846.
[18] M. Elsadek, B. Liu, Z. Lian, Green faÃ§adesâ€: their contribution to stress recovery and well-being in high- density cities, Urban For. Urban Green. 46 (2019).
[19] R.A. Fuller, K.J. Gaston, The scaling of green space coverage in European cities, Biol. Lett. 5 (2009) 352–355.
[20] C.Y. Chang, P.K. Chen, Human response to window views and indoor plants in the workplace, Hortscience 40 (2005) 1354–1359.
[21] R.S. Ulrich, View through a window may influence recovery from surgery, Science (80-.) 224 (1984) 420.
[22] J.D. Thomsen, H.K.H. Sã¸nderstrup-Andersen, R. Mã¼ller, People-plant relationships in an office workplace: perceived benefits for the workplace and employees, Hortscience (2011).
[23] M. Hemphill, A note on adultsâ€™ colorâ€"emotion associations, J. Genet. Psychol. 157 (1996) 275–280.
[24] M. Elsadek, S. Sayaka, E. Fujii, E. Koriesh, E. Moghazy, Y.A. El Fatah, Human emotional and psycho-physiological responses to plant color stimuli, J. Food Agric. Environ. 11 (2013) 1584–1591.
[25] M. Elsadek, M. Sun, E. Fujii, Psycho-physiological responses to plant variegation as measured through eye movement, self-reported emotion and cerebral activity, Indoor Built Environ. 26 (2017) 758–770.
[26] A.C. Hurlbert, Y. Ling, Biological components of sex differences in color preference, Curr. Biol. 17 (2007).
[27] M. Saito, Comparative studies on color preference in Japan and other asian regions, with special emphasis on the preference for white, Color Res. Appl. 21 (1996) 35–49.
[28] A.S. Al-Rasheed, An experimental study of gender and cultural differences in hue preference, Front. Psychol. (2015).
[29] T.J. Madden, K. Hewett, M.S. Roth, Managing images in different cultures: a cross-national study of color meanings and preferences, J. Int. Mark. (2000).
[30] Reena Mukamal, How humans see in color, Am. Acad. Opthamol. (2020). https://www.aao.org/eye-health/tips-prevention/how-humans-see-in-color. (Accessed 25 November 2020).
[31] S. Goto, Y. Morota, C. Liu, M. Sun, B.E. Shi, K. Herrup, The mechanism of relaxation by viewing a Japanese garden: a pilot study, Heal. Environ. Res. Des. J. 13 (2020) 1.
[32] S. Park, C. Song, K. Son, Comparison of Physiological and Psychological Relaxation Using Measurements of Heart Rate Variability , Prefrontal Cortex Activity , and Subjective Indexes after Completing Tasks with and without Foliage Plants, 2020, pp. 1–12.
[33] E. Paddle, J. Gilliland, Orange is the new green: exploring the restorative capacity of seasonal foliage in schoolyard trees, Int. J. Environ. Res. Publ. Health 13 (2016).
[34] Y. Hua, T. Shuai, L. Rui, A study on the growth of Hedera helix in radiation (PAR) scope were conducted indoors, Zhiwu Yanjiu 24 (2004) 179–183. https://europepmc.org/article/cba/401186. (Accessed 24 August 2020).
[35] R. Berto, S. Massaccesi, M. Pasini, Do eye movements measured across high and low fascination photographs differ? Addressing Kaplan™s fascination hypothesis, J. Environ. Psychol. 28 (2008) 185–191.
[36] K. Rayner, X. Li, C.C. Williams, K.R. Cave, A.D. Well, Eye movements during information processing tasks: individual differences and cultural effects, Vision Res. 47 (2007) 2714–2726.
[37] A. Torralba, A. Oliva, M.S. Castelhano, J.M. Henderson, Contextual Guidance of Eye Movements and Attention in Real-World Scenes: the Role of Global Features in Object Search, 2006.
[38] J. Najemnik, W.S. Geisler, Optimal eye movement strategies in visual search, Nature 434 (2005) 387–391.
[39] S. PeiÃŸl, C.D. Wickens, R. Baruah, Eye-tracking measures in aviation: a selective literature review, Int. J. Aerosp. Psychol. 28 (2018) 98–112.
[40] D.E. Hannula, R.R. Althoff, D.E. Warren, L. Riggs, N.J. Cohen, J.D. Ryan, Worth a glance: using eye movements to investigate the cognitive neuroscience of memory, Front. Hum. Neurosci. (2010).
[41] S.N. Yang, G.W. McConkie, Eye movements during reading: a theory of saccade initiation times, Vision Res. (2001).
[42] B.M. Ances, Coupling of changes in cerebral blood flow with neural activity: what must initially dip must come back up, J. Cereb. Blood Flow Metab. 24 (2004) 1–6.
[43] Y. Hoshi, J. Huang, S. Kohri, Y. Iguchi, M. Naya, T. Okamoto, S. Ono, Recognition of human emotions from cerebral blood flow changes in the frontal region: a study with event-related near-infrared spectroscopy, J. Neuroimaging 21 (2011).
[44] K.M. Alfano, C.R. Cimino, Alteration of expected hemispheric asymmetries: valence and arousal effects in neuropsychological models of emotion, Brain Cognit. 66 (2008) 213–220.
[45] J. Kang, M. Zhang, Semantic differential analysis of the soundscape in urban open public spaces, Build. Environ. 45 (2010) 150–157.
[46] Y. Kang, E.J. Kim, Differences of restorative effects while viewing urban landscapes and green landscapes, Sustainability 11 (2019) 2129.
[47] H. Nordh, K.H. Evensen, M. SkÃ¥r, A peaceful place in the cityâ€"A qualitative study of restorative components of the cemetery, Landsc. Urban Plann. (2017).
[48] M. Håla, J. Flegr, What flowers do we like? The influence of shape and color on the rating of flower beauty, PeerJ 2016 (2016).
[49] M.L. Mele, S. Federici, J.L. Dennis, Believing is seeing: fixation duration predicts implicit negative attitudes, PloS One 9 (2014), e105106.
[50] V. Ruggieri, The running horse stops: the hypothetical role of the eyes in imagery of movement, Percept, Mot. Skills 89 (1999) 1088–1092.
[51] C. Liu, K. Herrup, S. Goto, B.E. Shi, Viewing garden scenes: interaction between gaze behavior and physiological responses, J. Eye Mov. Res. 13 (2020) 1–15.
[52] M.J. Herrmann, T. Huter, M.M. Plichta, A.C. Ehlis, G.W. Alpers, A. Mã¼hlberger, A.J. Fallgatter, Enhancement of activity of the primary visual cortex during processing of emotional stimuli as measured with event-related functional near-infrared spectroscopy and event-related potentials, Hum. Brain Mapp. 29 (2008) 28–35.
[53] W. Briki, L. Majed, Adaptive effects of seeing green environment on psychophysiological parameters when walking or running, Front. Psychol. 10 (2019).
[54] W. Briki, O. Hue, How red, blue, and green are affectively judged, Appl. Cogn. Psychol. 30 (2016) 301–304.
[55] S. Wells, Horticultural Therapy and the Older Adult Population, Hawthorne Press Inc., New York, 1997. https://www.amazon.com/Horticultural-Therapy-Population-Suzanne-Paperback/dp/B00ZT18WPU. (Accessed 5 October 2020).
[56] M. Elsadek, H. Jo, M. Sun, E. Fujii, Brain activity and emotional responses of the Japanese people toward trees pruned using sukashi technique, Int. J. Agric. Environ. Biotechnol. 6 (2013) 344–350.
[57] C. Song, H. Ikei, Y. Miyazaki, Physiological effects of visual stimulation with forest imagery, Int. J. Environ. Res. Publ. Health 15 (2018).
[58] M. Suzuki, J. Gyoba, Y. Sakuta, Multichannel NIRS analysis of brain activity during semantic differential rating of drawing stimuli containing different affective polarities, Neurosci. Lett. 375 (2005) 53–58.
[59] C.M. Tyng, H.U. Amin, M.N.M. Saad, A.S. Malik, The influences of emotion on learning and memory, Front. Psychol. (2017).
[60] P.H.-T. Li X, Z. Zhang, M. Gu, D.-Y. Jiang, J. Wang, Y.-M. Lv, Q.-X. Zhang, Effects of plantscape colors on psycho-physiological responses of university students, J. Food Agric. Environ. 10 (2012) 702–708. https://www.cabdirect.org/globalhealth/abstract/20123098886. (Accessed 5 October 2020).
[61] M. Jacobs, Psychology of the visual landscape, Res. Urban. Ser. 2 (2011) 41–54.
[62] D.R. Lehman, C.Y. Chiu, M. Schaller, Psychology and culture, Annu. Rev. Psychol. 55 (2004) 689–714.