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RESEARCH ARTICLE

THE VISUAL EFFECTS OF PLANT VARIEGATION ON HUMAN PSYCHO-PHYSIOLOGICAL RESPONSES

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ABSTRACT

Colors are one of the things that play a part in our daily lives. Studies have documented that exposure to plants had positive effects on human health. This study investigated how foliage color stimuli that included green and green-red and green-white influenced selected psychological and physiological responses in 28 college students in their twenties. Each plant was presented for 1 min, during the exposure time, eye movements were recorded by eye mark recorder. While, near-infrared spectroscopy was used in order to monitor the brain activity in the frontal, temporal, parietal and occipital lobes. The results revealed that different plantscape colors stimulated different psycho-physiological reactions. People prefer green to green-red and green-white plants. Furthermore, green plants were more effective in relaxing the body compared with the other colors evidenced by sedation of cerebral blood flow in the feeling area.

INTRODUCTION

It has been known for a long time that negative emotions are related to a higher prevalence and severity of disease. Certain types of plants have been considered physically, mentally, and socially good for people, yet, recently, there have been no studies to verify such claims. In the past thirty years, a number of scientific studies started documenting the relationships between people and plants, showing positive emotional, physiological and aesthetic responses when people react with plants and nature (Relf and Lohr, 2003). Fjeld *et al.* (2002) reported that there was a positive relationship between plants in the workplace and the health of the worker. Furthermore, they found a decline in the frequency of several health problems such as: fatigue, headaches and symptoms of dry throat and dry hands, when plants were placed in the office. Plant presence also seems to have a positive effect on cognitive functioning in terms of recovering concentration. There is evidence that people become calm and more relax when there are plants nearby (Butterfield and Relf, 1992). Plants of various colors have been shown to have physio-psychological benefits for human health. For example, green and purple plantscape were found to have more positive psychological response, as evidenced by lower ratings of irritability, reductions in anxiety, and improvements in mood, compared with red, yellow and white plantscapes (Li *et al*., 2012). Whereas previous studies in this domain almost exclusively focused on self-report variables, the research presented herein emphasizes physiological and psychological indicators. Although, people receive information from the environment through five senses, it is estimated that for the sighted, more than 70% occurs through visual perception (Song, 2004).

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Meanwhile, eye movement should be an indicator of humans' psychological status (Arai and Hasegawa, 2013). As the visual information perceived by the eyes is transferred to the brain. So, study the impacts of colors on eye movements and brain activity is being actively pursued in order to determine color effects on human psycho-physiological responses. Although plant colors have been largely unexamined, as have colors to stimulate positive feelings, variegated plants might well be able to stimulate desire responses of promoting calm and relaxation. The manuscript describes an experimental study in which primary plant-colors (green, green-red, green-white) are varied within subjects. Effects of this manipulation on eye movements and gaze duration and on brain activity were tested. The results will be used to generate practical applications for incorporating plants of particular color into built and natural environments.

MATERIALS AND METHODS

Interior plants

In order to present different plant color stimuli, three species with different foliage colors which include *Spathiphyllum wallisii* (green), *Cordyline terminalis* (green-red) and *Aglaonema pictum* (green-white) were selected as visual stimuli (Fig 1).

Experimental setting

The experiment was designed in a screened room at Chiba University, where subjects would be exposed to the fewest external influences and go through the test under the same conditions. In the middle of a shielded room (59.4 m^2) with a white walls and the indoor lighting

Fig. 1. ***S. wallisii*** **(left),** ***C. terminalis*** **(center) and** ***A. pictum*** **(right)**

consisted of fluorescent light bulbs (700±4 lux), a chair was set for the subject 150 cm away from the tested plants. The psycho-physiological recording devices were placed behind the participant to decrease the disturbance of the machines to him. A 73 °F temperature and 55 % relative humidity were maintained throughout the experiment (Fig. 2).

Fig. 2. Experimental setting and physiological measures, eye mark recorder and multi channel near infrared spectroscopy

Participants

The participants were 28 right-handed Japanese students (14 males and 14 females) in their twenties (mean± SD 21.42 ± 1.72 years) with normal or corrected-to-normal visual acuity and with no history of neurological illness were recruited from school of Horticulture, Chiba University in Japan. This study was conducted in accordance with ethics rules of Chiba University.

Psycho-physiological measurements

Eye movement, reflecting conscious and unconscious reactions to visual stimuli, was tracked to investigate cognitive characteristics of the plant color. Eye tracking and eye fixation were recorded using an eye mark recorder with the cornea and pupillary reflex method (EMR-9, NAC Image Technology Co., Ltd. Japan). A portable device of a type of goggles type was employed to simultaneously measure both eye movement and cerebral activity (Fig. 2).

As the visual information perceived by the eyes was transferred to the brain, the cerebral blood flow (CBF) was recorded while the participant was viewing the plant. The CBF was measured using multi channel infrared spectroscopy (NIRS, OMM-2001, Shimadzu, Co., Ltd. Japan). Measurement was limited to the right hemisphere of the brain only, because of its control over emotion and image creation (Silberman and Weingartner, 1986; Tucker, 1981). According to the theory of localization of brain function, 47 channels (ch) were positioned to correspond 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 (Caplan, 1993; Shepherd, 1901) (Fig. 3).

Procedures

During each trial, the NIRS electrodes and eye movement's detector were installed to the participant. The measuring conditions of cerebral

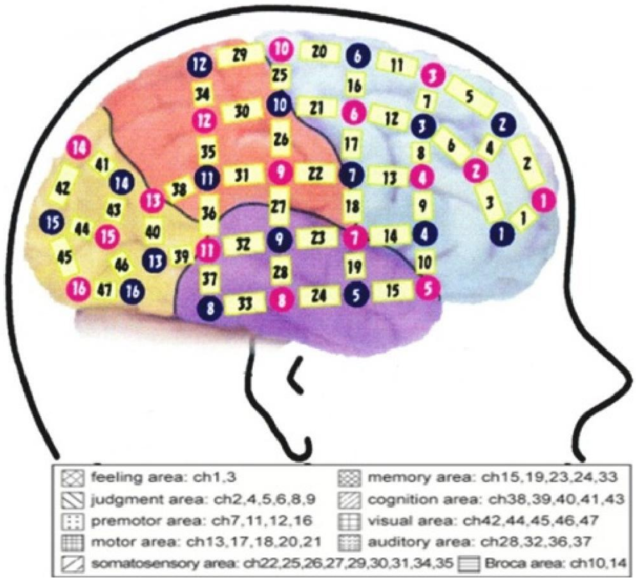


Fig. 3. Localization of functions in the brain Measurement locations in cerebral activity of right hemisphere

activities were checked, and calibration for eye movement was carried out. The participant was then instructed to relax fully with eyes closed to adjust his mood to the experimental environment, while the participant rested with his eyes closed, the first plant category was placed on a table covered with a black cloth at the participant's eye level to ensure a straight line of the sight of the object without having to move his head. After the NIRS monitor confirmed that cerebral activity was stable, the participant was asked

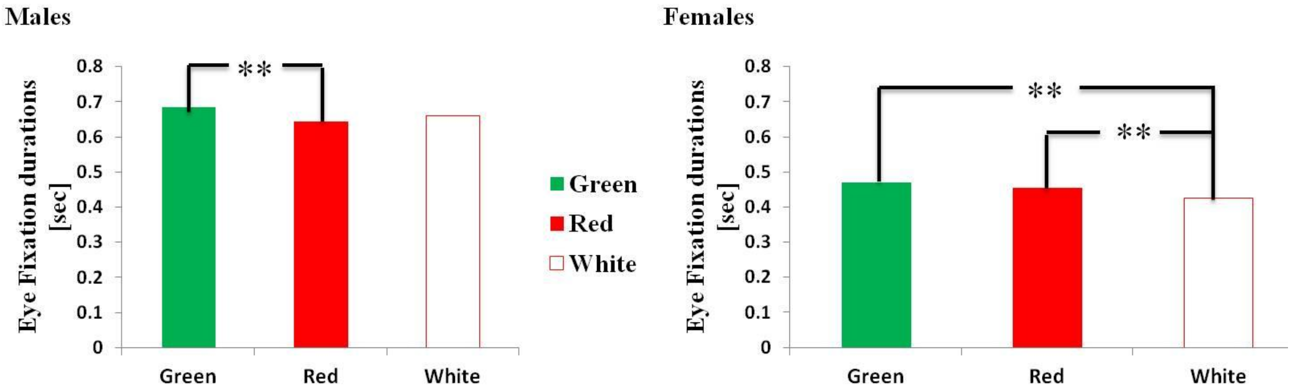


Fig. 4. Comparison of eye fixation durations among ***S. wallisii*** **(left),** ***C. terminalis*** **(center) and** ***A. pictum*** **(right).**

to open his eyes. The brain activities and eye movements were recorded for 1 min, then, the subject was asked to close eyes again afterwards, the second plant category takes place and the sequence was repeated with each color. Order of the plants presentation was randomized across the participants. After taking the psycho-physiological measurements for each subject, the subject was asked to indicate which plant he liked, and disliked, and the reasons for choosing one over another.

Statistical analysis

The number eye fixations(the visual points fixed for 0.2 sec or longer on the visual stimulus, is based on the fact that more than 0.2 sec is required to consciously recognize the stimuli) (Yarbus, 1962) and eye fixation durations for 1 min after exposure to the visual stimuli were analyzed by EMR-dFactory ver. 2.0. Steel-Dwass multiple comparison tests were used to statistically compare among the tested plants. Regarding CBF, the data were analyzed separately for each channel (ch). The cerebral changes during exposure to each plant category were examined by comparing the means of each 30-sec interval starting with the last 30 sec of the rest period before plants presentation. This was assumed to represent the most stable states of the brain and physiological activity during the rest period. A paired t-test (two-sided) was used to compare the physiological changes between rest and exposure periods. The cerebral activity analysis used fluctuations in oxygenated hemoglobin (oxy-Hb) as the index of cerebral changes, where increased oxy-Hb is associated with increased cerebral activity. The changes were separately computed in 47 measurement locations of the brain (Fig 3).

is a were significant difference between green and green-red plants (P=0.028), there appeared to be a trend that green plant resulted in a longer fixation duration of eye movement, compared with the green-red plant. On the other hand, regarding eye fixation numbers, it was found that there are significant differences between green-red and green (P=0.049), as well as between green-red and green-white (P=0.091). The results indicate that males carefully observed the details of green plant, because of long fixation duration. Moreover the males appeared to be calmer with the green plant, as evidenced by the lower numbers of fixation. However the green-red plant was evidently more exciting and stimulating evidently by higher fixation numbers. Regarding females, the green and green-red plants showed significant differences with respect to longer eye fixation durations and higher eye fixation numbers, compared with the green-white plant. These results indicate that female participants carefully observed and saw the details of the green and the red species to a greater extent than with the white species.

Impression evaluation

As expected, people expressed a range of preferences among the presented plantscape colors as shown in Figure 6. A variety of different comments were made by participants, and in some cases the reason given as to why someone liked a plant is the same reason another person gave for disliking it, and vice versa. For male subjects, in the case of the green plant it was concluded, that the six subjects liked it because of the sense of unity, normal, beautiful color, in contrast two subjects disliked it because it had a dark leaves color. Regarding to the red plant, two subjects liked it because of harmony of colors and

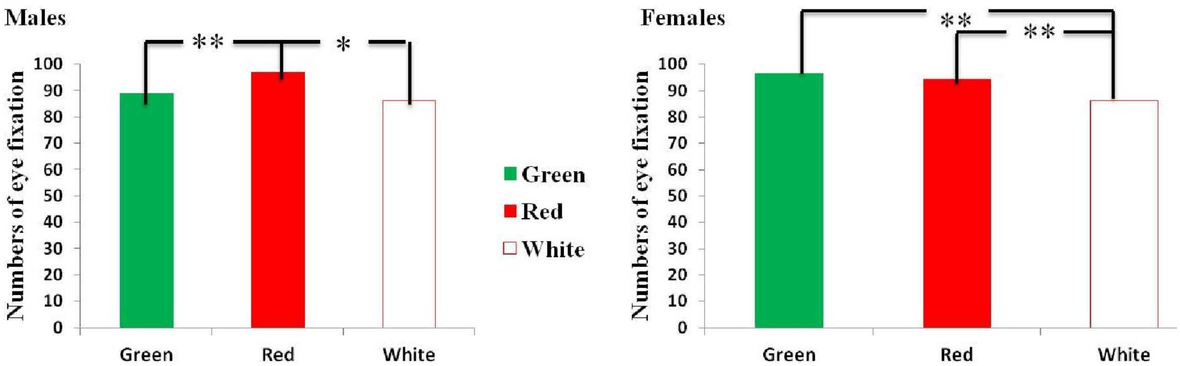


Fig. 5. Comparison of eye fixation numbers among *S. wallisii* (left), *C. terminalis* (center) and *A. pictum* (right)

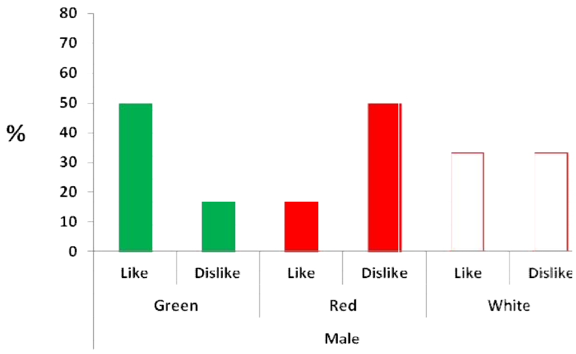


Fig. 6. Impression evaluation by vision between male and female participants

RESULTS

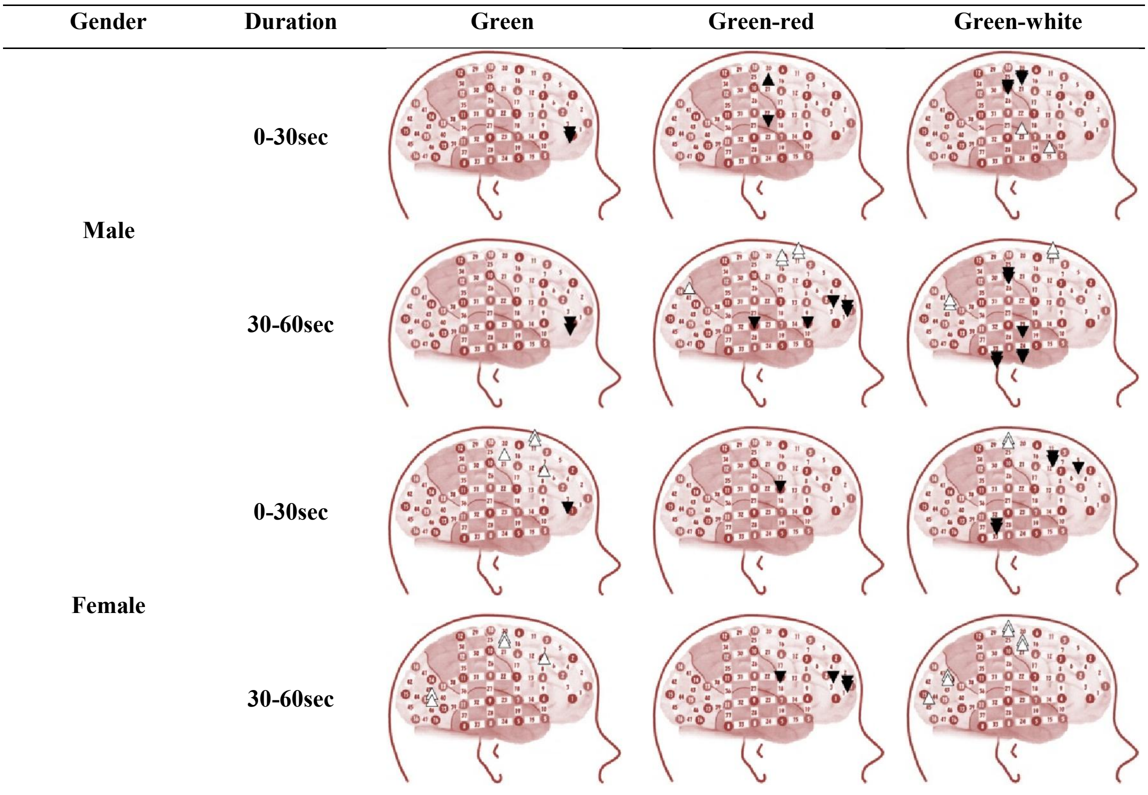
Eye movement

Eye movement showed significant differences among the tested plants with regard both of eye fixation numbers and eye fixation durations analysis (Figs. 4 and 5). Concerning male participants, there

leaves emerging from the roots. However six subjects disliked it because of a red combination with green considering is a bad color, red color like dark, red like death and they didn't like red color at all. White plants received both positive and negative ratings. Four subjects liked it because of brightness, beautiful color and way out leaves emerge from the plant, while four subjects disliked it because of white color at the leaves didn't look good, for them and leaves looked complicated. Female subjects have other comments for like and dislike, for the green plant seven subjects liked it because of the strong color leaves high density, stable condition, fresh and healthy. While one subject disliked it because seemed to have many leaves. In the case of the red plant, two subjects liked it because of the color, while other nine subjects disliked it because of the red color, seemed that mixed with green is bad color, it is red, red like poison and look like dark. Comments about the three subjects who liked white plants were related to soft and bright color and very good looking. In contrast the other two subjects disliked it because the plant has one stem and few leaves. Overall, Figure 6 clearly indicates that, so far as conscious impressions of participants were concerned, the green plant was the clear favorite for both genders. In contrast, the green-red caused strong disliked between males and females, while the green-ch16, P<0.05) and cognition area (ch41, P<0.10) which controls object recognition. In contrast, the stimulation with the green-white plants showed sedation in brain areas including the motor (ch20, P<0.05), somatosensory (ch25, P<0. 05) and memory areas (ch24 and 33 P<0.05) while the CBF was activated in the visual area (ch43, P<0.05) which involves specifically perception of color and vision motion.

Female participants

Female participants showed some different patterns of cerebral response while viewing the three plant types. When female subjects were viewing the green plant, the CBF was activated in the judgment (ch8 and 9 P <0.10), premotor (ch11, P <0.05), motor (ch21, P <0.05) and visual areas (ch46 P <0.05), on the other hand, the cerebral



, Significant increases in oxyhemoglobin concentration at P<0.05; , significant decrease in oxyhemoglobin concentration at P<0.05; , significant increase in oxyhemoglobin at p<0.10; , significant decrease in oxyhemoglobin at P<0.10

Fig. 7. Changes to cerebral activities by vision of each plant between male and female subjects

Changes to cerebral activities by vision

Figure 7 demonstrates fluctuation in brain activity, and shows the channels where significant fluctuations in oxy-Hb were observed when viewing the different plant colors, for both male and female participants.

Male participants

While male participants were shown the green plants, the CBF was significantly sedated in the feeling area (ch3, P<0.05) which is especially important in stimulating the feeling of relaxation. On the other hand, during the stimulation with the green-red plants, the CBF was significantly sedated in the judgment (ch2 and ch4, P<0.05) which controls concentration and attention, and in the somatosensory area (ch27, P<0.10) which is strongly associated with body senses, being responsible for processing sensory information such as smell, taste, touch, vision, and sound. In contrast, the CBF was notably increased in the motor area (ch21 P<0.10), premotor area (ch11 and

activity was sedated in the feeling area (ch3 P <0.05). However, in the presence of the green-red plants, the CBF was sedated in the judgment (ch2 and 4 P <0.05 and 0.1 respectively) and motor areas (ch17 P <0.10). When participants were shown the green-white plants, CBF was activated in the motor (ch20 and 214, P<0.10 and 0.05 respectively), somatosensory (ch25 P <0. 05), visual (ch42 P <0.10) and cognition areas (ch43 P <0. 05). While it was sedated in the judgment area (ch5 and 6 P <0.10).

DISCUSSIONS

The particular outcomes in this study support the findings of previous studies and confirm that different variegation colors can stimulate different responses and plants might well be able to stimulate desire responses of promoting calm and relaxation. Different results in eye movement characteristics indicate that different colors or variation in color makes some view more interesting, attractive and fascinating as the green plant which attains longer durations of eye movement, or irritating and less rest as the red plant which attains higher numbers of eye fixation. The results of this study are in harmony with those of a previous study by Mackworth *et al*. (1967) which compared between visual fixation and verbal estimates of the relative importance of regions within photographs. The study proved that the regions that classified as out a lot of information were produced the highest fixation frequency. Also, Baker *et al*. (1973) noted considerable correlations between ratings of the importance of sections of geometric forms and durations of fixations on those sections. Overall, resulting from longer fixation duration and higher fixation number of eye movement reveal that the participants spend more time interpreting or relating the visual representation to internalized representation. Based on the results of eye movement, CBF activity and impression derived from the experience of viewing the tested plants, it is concluded that when participants observed a green vista, they experienced a sense that promotes relaxation and also their brains were more calmly in the presence of the green than in the presence of the green-red or green-white plants. The results of this study are in harmony with those of a previous study that showed that the green plants are useful for improving cerebral blood activities, creating a comfortable environment and effective than other colors in promoting relaxation (Li *et al*. 2012; Chang and Chen, 2005; Kim, 1997). Even more relevant was the observation that when the participants were viewing the green plant there was a strong association that this color received longer eye fixation durations and their brains were calmer. It has concluded that the CBF increment was correlated with the degree of attention settled by the participants to the visual (Bondy, 1974). For both gender of participants, nevertheless, the green-red plants were effective in promoting a sense of strength, as evidenced by the cerebral activation in the motor area which controls muscles. These results are in accord with those of Kuller *et al*. (2009), who found that the red color put the brain into a more excited state. In contrast, it was clear that CBF was significantly decreased in the judgment area when the stimulus was viewed. These results suggest that a decrease in the concentration and the creativity were associated with the lower activity in this part of the brain, which controls attention and interest. In addition, it was clearly observed that the brain activities were sedated in the somatosensory area, the results indicating that the green-red plant could result in diminishing the sensation of the body or skin; it means that participants did not care of the vision of this plant color (FitzGerald, 1996). While in the case of female participants, it was observed that viewing the green-white plant decreased the concentration and attention, increased the sensation of the skin and visual function and promoted a sense of strength. This result was contrary to what happened in the case of male participants when they were viewed the same plant. In words, results showed that people prefer the green to green-red and green-white plants. Furthermore, people exhibit different responses to a range of plantscape colors. The outcome is of practical applicability for selecting subjective favorite colors in conjunction with the interior and living environments. Plant colors can be used to help people release stress and improve emotional status. Green plants could be incorporated into parks or hospitals in order to create relaxing environment. While, green- red plants, which stimulated the motor area in the brain which controls muscles, can be used in office environment to improve employees' productivity.

Conclusion

The results revealed that people response differently to plant with different colors, we suggest that each color is recommended for a specific situation. As a result, carful choices of plant colors should be made during decorating the indoor environment. Green plant could be incorporated into parks or hospitals in order to provide relaxing. Different vegetation can be used according to different environmental demands to create healthy and livable indoor environments.

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