THE PHYSIOLOGICAL AND EMOTIONAL RESTORATIVE EFFECTS OF ORIENTAL HYBRIDS ON STRESSED YOUTH: AN INTERACTIVE SMELL AND SIGHT STUDY

BU, W. N. – ZHANG, X. – CHEN, H. N. – WANG, Q. H. – SUN, M. – CAI, Y.*

College of Forestry and Grassland Science of Jilin Agricultural University, Jilin, China
(e-mail: Bu, W. 15144976446@163.com; Zhang, X. zx976392912@163.com; Chen, H. 15584273267@163.com; Wang, Q. w857736758@163.com; Sun, M. sunmiao000521@163.com)

**Corresponding author*
e-mail: yanc@jlau.edu.cn; phone: +86-158-4305-9169

(Received 19th Jul 2024; accepted 4th Nov 2024)

Abstract. Aromatherapy is gaining popularity as a method to regulate mood and relieve stress. This study aims to investigate how the smell of flowers and the interaction between sight and smell influence physiological indicators like blood pressure, pulse, heart rate variability, Galvanic skin signals, brain waves and Total Mood Disturbance (TMD) in stressed young individuals, and further explored the differences in the effects between the two groups, as well as on the main constituents of floral scent. Oriental Lily (Oriental hybrids) was used as the material for the olfactory, visual-olfactory interaction and no-olfactory-control groups of perceptual experiments. Aroma composition and emission rate of Oriental lilies were analyzed by headspace solid-phase microextraction (GC-MS SPME) technique. The following results were obtained: 1) Both the olfactory and visual-olfactory interaction groups experienced reductions in blood pressure, pulse, electrodermal activity, beta-wave power spectral density, emotional disturbance scores and showed improved heart rate variability and a significant increase in brain alpha wave activity. 2) The VOIG group was more effective than the OG group in restoring physical and emotional well-being. 3) Monoterpenes are identified as the primary aroma components of Oriental lilies, constituting 66.18% of the relative content of volatile components.
Keywords: *aromatherapy, biogenic volatile organic compounds, EEG, emotions, smellscape*

Introduction

With the increasing trend of globalisation, the rapid growth of urban areas has led to a range of environmental issues. Both air pollution and noise have a detrimental impact on the physical and mental well-being of individuals (Giles-Corti et al., 2016; Münzel et al., 2018; King, 2018; Manisalidis et al., 2020). Moreover, high-pressure environments can heighten the likelihood of mental health disorders (Stojanovich and Marisavljevich, 2008; Gong et al., 2012; Liu et al., 2017; Ohno, 2017). Young people, in particular, face additional stress from academic, professional, and social pressures, further increasing their risk of anxiety and depression (Mirón et al., 2019). Given these concerns, it is imperative to develop effective strategies for stress management and relaxation to safeguard the health of the youth population.

Aromatherapy utilizes aroma to alleviate stress (Laohakangvalvit et al., 2023). Inhaling the aroma can induce feelings of relaxation, romance, reduced stress, and calmness (Dobetsberger and Buchbauer, 2011). It is commonly used in the treatment of tension, anxiety, and depressive symptoms in individuals experiencing mental stress (Sunhee Jung et al., 2006; Yun-Ah et al., 2018). The field of aromatherapy has seen an increase in research focusing on the impact of aromatic plant scents on the human body. Studies have demonstrated that these scents not only enhance brain function (Jo et al., 2010, 2013; Kilonzi et al., 2019) and mood (Lei, 2011; Baik et al., 2018) but also have

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2302_18311852

the potential to lower blood pressure and promote feelings of comfort and relaxation (Yan-Ying et al., 2010; Igarashi et al., 2014; Kim et al., 2016; Song et al., 2016). Aromatherapy sources include fresh plants (Zhao et al., 2019), perfumes, and essential oils extracted from plants (Hongratanaworakit and Buchbauer, 2006; Hongratanaworakit, 2009; Kritsidima et al., 2010). While much of the existing research has concentrated on the use of aromatic plant extracts for emotional well-being (Kikuchi et al., 1993; Song et al., 2019; Chandharakool et al., 2020; Song and Wu, 2022), there is a scarcity of studies examining the physiological and emotional health effects of fresh aromatic plants in indoor environments. Qualitative studies have explored the aroma components of aromatic sources (Kong et al., 2012; Zouaoui et al., 2020; Wang et al., 2024), with few. Indoor application of aromatherapy has been found to be more than outdoor application (Lu et al., 2023). This particular study focuses on the use of Oriental lily (Oriental hybrids), a common fresh cut flower, as an olfactory-perceived aroma source.

Human recovery is rooted in nature, with sensory experiences serving as the foundation for human interaction with the environment. The theory of restorative environments is primarily built upon the attention restoration theory and stress reduction theory (Ulrich et al., 1991). The stress reduction theory (Kaplan, 1995). specifically highlights the stress-alleviating effects of exposure to nature. While most environmental information is acquired through visual and auditory senses, recent research has emphasized the role of olfaction in environmental perception. Olfactory stimuli not only enhance interactions (Min Ching et al., 2019; Nitidara et al., 2021) with the environment but also evoke memories that elicit emotional responses. Therefore, it is imperative to investigate the appropriate olfactory factors in aromatherapy. Studies on aromatic plants have varying focal points, and the mechanisms of visual and olfactory interactions are intricate (Zhao et al., 2018), with diverse research directions, measurement indices, and methodologies. For example, indicators such as blood pressure, pulse rate, EEG, and POMS scale were used in the indoor study of the effects of primula flowers scent on the human body (Jiang et al., 2021); and indicators such as skin conductivity were added in the study of the effects of osmanthus scent on the human body (Zhang et al., 2023). This experiment used a combination of these indicators to explore the physiological and emotional interactions between visual perception and olfactory perception, aiming to alleviate the negative emotions of the adolescent group (Fraigneau, 2019; Finnerty et al., 2022), further enrich the study of aromatherapy, and advance our understanding of aromatherapy. Such research is crucial for unraveling the intrinsic mechanisms of environmental perception and human health.

Human recovery is believed to be linked to contact with nature, as sensation plays a crucial role in how humans interact with their environment. Recent advancements in brain science and imaging technologies have sparked interest in exploring the connection between aromatherapy and its impact on brain activity. Studies have shown that emotional states such as happiness, sadness, and relaxation can be predicted using EEG devices (Vásquez et al., 2023). Research has also indicated that essential oils like stigmasterol oxide, eucalyptol, and linalool oxide can influence human mood and EEG readings (Chang et al., 2017). For example, exposure to lemongrass essential oil has been found to increase alpha-wave power and reduce beta-power in specific brain regions (Jahan et al., 2024), suggesting that aromas can modulate brain wave activity and promote relaxation. Investigating the physiological and emotional effects of plant fragrances on young individuals using EEG equipment holds practical significance.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2302_18311852

In summary, the expected results of this paper are as follows: (1) Oriental lily scent has a restorative effect on human physiological and emotional recovery; (2) Visual-olfactory interaction perception has a stronger restorative effect than olfactory Oriental lily alone; and (3) Oriental lily terpene constituents allow us to produce psychological and emotional recovery after olfactory.

Experimental materials and methods

Experimental materials and subjects

The potted Oriental lilies used in this experiment were purchased in December 2023 at the Changchun Qingyifang Flower Comprehensive Market, with an average plant height of about 40~50 cm. The flowers were positioned at a height equivalent to the subject's nose when seated and spaced 20 cm apart. A total of 60 undergraduate and postgraduate students from Jilin Agricultural University participated in the study, with a gender ratio of 1:1 to ensure subject diversity. Sample size calculations were conducted using GPower, with $\alpha = 0.05$ and a power of 0.8 to determine the number of participants needed. Inclusion criteria for the subjects involved good health, no history of serious illnesses, absence of pollen allergies, adequate sleep the night before, avoidance of alcohol, coffee, and stimulating foods to avoid over-excitement of the brain which may affect the EEG results; as the GSR device needs to be clipped on the finger for monitoring, no manicure is allowed on the day of the experiment to ensure the accuracy of the HRV monitoring, and avoidance of strong-smelling perfumes or cosmetics to prevent interference with the sense of smell sensitivity.

Experimental design

Study on the effect of perceiving Oriental lily on human physical and mental health

The 60 subjects in this experiment were first divided into two groups of men and women, and then these two groups were randomly divided into three groups of olfactory (OG), visual and olfactory interaction (VOIG) and control (CG), respectively, which ultimately ensured that there were 20 subjects in each of the three groups of olfactory (OG), visual and olfactory interaction (VOIG) and control (CG), with the ratio of men to women being 1:1, the average age of the subjects was 21.38±1.89 (*Table 1*).The experiment spanned 9 days, with the CG group on days 1-3, OG group on days 4-6, and VOIG group on days 7-9. All groups started the experiment at the same time each day. The study adhered to the ethical principles of the Declaration of Helsinki and was approved by the Ethics Committee of Jilin Agricultural University (approval number recorded in the Academic Committee documents).

Table 1. *Basic demographic information on subjects*

Time (day)	Experimental group	Number of subjects	Basic demographic information	
			Age	Sex ratio
1-3	control (CG)	20	18-25	1:1
4-6	olfactory (OG)	20	18-25	1:1
7-9	visual and olfactory interaction (VOIG)	20	18-25	1:1

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2302_18311852

The experiment consisted of three phases: before the experiment, experiment, and after the experiment, with a detailed flow shown in *Figure 1*. Each participant signed an informed consent form in Room 1, where the experimental assistant explained the procedure. Participants were then completing calculations for math problems within 3 minutes, followed by measuring their blood pressure and pulse and filling out the POMS scale as pre-test data. Moving into Room 2, participants began the experiment by adjusting and wearing the apparatus. The OG group closed their eyes and sniffed Oriental lilies for 10 minutes, the VOIG group viewed and sniffed the lilies, and the CG group observed a white wall with their eyes open. Prior to the start of the experiments in the OG and VOIG groups, it was ensured that 8-10 of the two pots of Oriental lilies were in the process of opening and were placed in Room 2 an hour in advance to allow the fragrance to fill the room. Throughout the experiment, real-time data on galvanic skin signals (GSR), heart rate variability index (HRV), and EEG (α-wave, β-wave PSD) were recorded. EEG data were closely monitored during specific time intervals for accurate recording. After the experiment, all equipment was removed, and participants remained seated in Room 2 to prevent any influence on measurement results while completing post-POMS forms and final measurements.

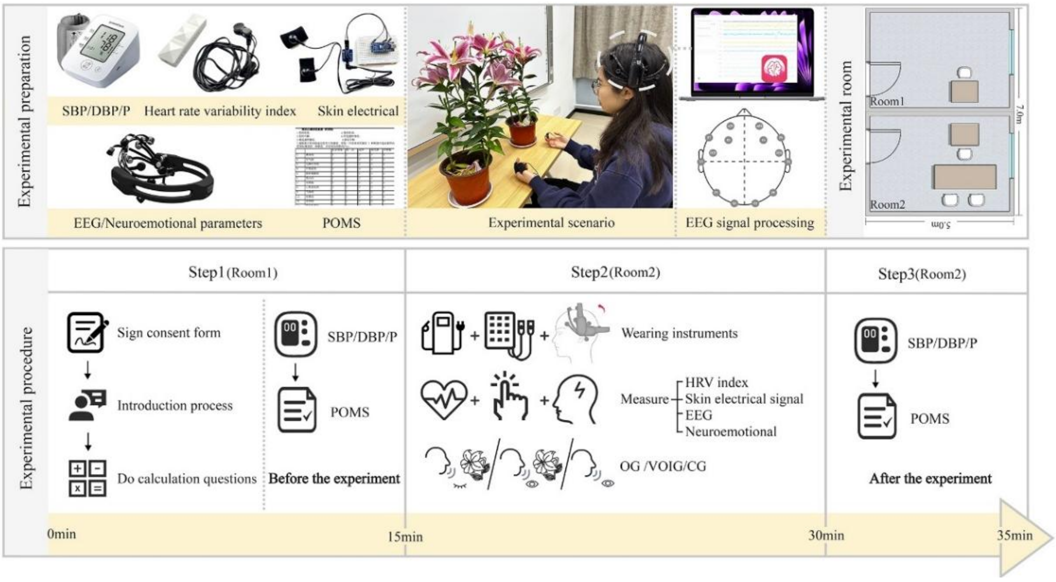


***Figure 1.** Experimental process diagram*

Aromatic composition and emission rate BVOCs of volatiles from Oriental lily flowers

The volatile components and Biogenic volatile organic compounds (BVOCs) of Oriental lily flowers were determined by headspace solid-phase microextraction (GC-MS SPME). A blooming lily of the valley flower was cut from the test material and weighed 11.37 g. It was placed into a 2-L Teflon FEP membrane gas sampling bag for in situ sampling of BVOC emissions, and a blank sample was collected as background value for a period of 30 min, after which all the sampling bags were recovered. Subsequently, the SPME fibre was inserted into the sampling bag and exposed to volatiles for 40 min to ensure adequate adsorption of volatiles. Subsequently, the extraction needle was moved to GC-MS for resolution (GC working conditions: chromatographic column: DB-624MS (60m×0.32 mm×1.8 um); programmed temperature increase: 40°C for 3 min, increase to

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2302_18311852

250°C at 6°C /min, hold for 3 min, and then increase to 270°C, hold for 5 min. MS working conditions: ionisation mode, EI; electron energy 70 eV (scanning range: 29~350 amu; interface temperature: 250°C; ion source temperature: 230°C; quadrupole temperature: 150°C). On the basis of the NIST08 spectral library search, the qualitative analysis was carried out by combining the literature and the nature of the volatile compounds themselves, and the relative content of each volatile was calculated by the peak area normalisation method. Meanwhile, quantitative analysis was carried out by internal standard method to determine BVOCs. 50 µl of decyl acetate and 20 ml of ether were selected for the standard to be dissolved, and then 10 µl of the drop was taken and dried by natural evaporation on a glass slice, which was put into a glass vial, and the extraction needle was inserted and adsorbed for one hour.

The emission rate BVOCs was calculated according to the following formula: $E = M / (m*t)$. Where E ($ng\text{-}g^{-1}\text{-}h^{-1}$) is the emission rate BVOCs, M (ng) is the measured BVOC concentration, m (g) is the dry weight of the flowers in the sampling bag and t (h) is the sampling time.

Measurement of data

Measurement of physiological indicators

Physiological indicators including blood pressure, pulse rate, heart rate variability index, skin conductance level signals, EEG α-wave and β-wave, and EEG emotional efficacy indexes (Engagement, Excitement, Stress, Relaxation, Interest, and Focus) were chosen for this study (Wu et al., 2023). Previous research has shown that emotions can impact blood pressure and pulse rate (Schwartz et al., 1981; Deng and Deng, 2018), with stress leading to an increase and relaxation leading to a decrease (Zanstra and Johnston, 2011; Hassan et al., 2018). A Fisheye upper arm sphygmomanometer was used to measure blood pressure and pulse rate. The heart rate variability index reflects changes in heart rate cycle (Robin et al., 1998; Tugade and Fredrickson, 2004), with lower indices indicating a more stable state. HRV heart rate ear clip monitoring was used for experimental manipulation. Skin electrical signal intensity is linked to tension levels, with GSR sensors placed on the index and middle fingers to capture this signal.

External stimuli like vision and smell (Cheng and Lin) can alter human EEG patterns (Ulrich, 1979; Krbot Skorić et al., 2015; Sowndhararajan et al., 2015; Zhu et al., 2021). Alpha waves (8-13 Hz) are associated with mental coordination, calmness, and alertness (Başar, 2012; Kim et al., 2013), while beta waves (13-30 Hz) are linked to alertness (Chang and Chen, 2005), problem-solving, decision-making, and focused mental activities (Neuper and Pfurtscheller, 2001). Beta wave activity increases during high alertness and decreases during relaxation (Lee et al., 2014; Alarcão and Fonseca, 2019). As a result, alpha and beta waves were chosen for this research study. EEG signals were recorded using the EMOTIV EPOC-X device created by Emotiv System, a US neurotechnology company. This device has 14 sensor electrodes and utilizes non-invasive EEG technology to reliably capture each EEG band and six emotional efficacy metrics (as depicted in *Figure 1*).

Measurement of psychological indicators

The short-form State of Mind Scale (Profile of Mood States) was selected for measuring emotional indicators. This questionnaire consists of 40 adjectives rated on a 0-4 scale, representing different emotional factors: tension (T), anger (A), fatigue (F),

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2302_18311852

depression (D), vigor (V), confusion (C), and self-esteem (S). Total Mood Disturbance (TMD) is calculated as T + A + F + D + C - V - S + 100, where higher TMD values indicate a more negative and irritable mood (Zhu Beili, 1995).

Statistical analyses

GSR and HRV were continuously monitored for 10 minutes in real time. The EEG data was extracted from the raw EDF format file using EMOTIV PRO, with the stress data selected from 0-60 seconds and the recovery values from the 540th to 600th second. Pre-processing was carried out using MATLAB (version 2021b). Firstly, electrode position localisation was conducted to eliminate irrelevant electrode data, then the sampling rate was lowered, the re-reference was set to average reference, the filtering was set to high-pass filtering (0.5Hz) and concave filtering (48-52Hz), filtering in addition to filtering out the low-frequency interferences and IF interferences, next the data was browsed, artefact rejection was performed, the default options were kept to run the ICA, and then the attributes of the individual independent components were observed, and the independent components were removed again in relation to the artefact-related independent components and correct for errors due to eye movements and EMG. Following the completion of preprocessing, changes in brainwave activity before and after the experiment were analyzed using power spectrum analysis. EEG mood data in CSV format was imported into Excel through EMOTIV PRO for statistical analysis. GSR, heart rate, and HRV index data were collected using the Arduino platform and exported to a txt format. All data were analysed using IBM SPSS 26.0, with hypothesis tests to determine whether the pre- and post-differences in the measures conformed to a normal distribution, and then analysed by paired t-tests, with $p < 0.05$ indicating significant differences. Cohen's d was calculated to determine the difference between the means of the two groups, with the formula d = (M1-M2)/ SD, where M1 and M2 represent the means of the two groups, and SD is the standard deviation. Absolute values were used for calculations, with Cohen's d values falling within the range of 0.2 to 0.5 considered small effects, 0.5 to 0.8 considered medium effects, and values above 0.8 considered large effects. A higher Cohen's d value indicates a greater difference between the two groups. All graphs were generated using Origin Pro 2021.

Analysis of experimental results

Analysis of the results of the effect of Oriental lilies on human physiological indicators

Blood pressure (BP) and pulse rate (P)

The changes in blood pressure (BP) and pulse (P) before and after a 10-minute perception in the OG, VOIG, and CG groups are illustrated in *Figure 2.* In the OG group, participants experienced highly significant decreases in diastolic blood pressure (DBP) ($p < 0.001$, d = 0.869), as well as significant decreases in systolic blood pressure (SBP) ($p < 0.01$, d = 0.869) and pulse (P) ($p = 0.01$, d = 0.519). Similarly, the VOIG group exhibited highly significant decreases in SBP ($p < 0.001$, d = 0.989), DBP ($p < 0.001$, d = 1.197), and P ($p < 0.001$, d = 1.456). On the other hand, the CG group displayed a decreasing trend in SBP ($p > 0.05$), DBP ($p > 0.05$), and P ($p > 0.05$) before and after the experiment, but no significant changes were observed. These findings suggest that both sniffing lilies and visual and olfactory interaction perception of lilies can effectively reduce BP and P. Additionally, sniffing may have a more pronounced effect on reducing SBP and P compared to visual and olfactory interaction perception.

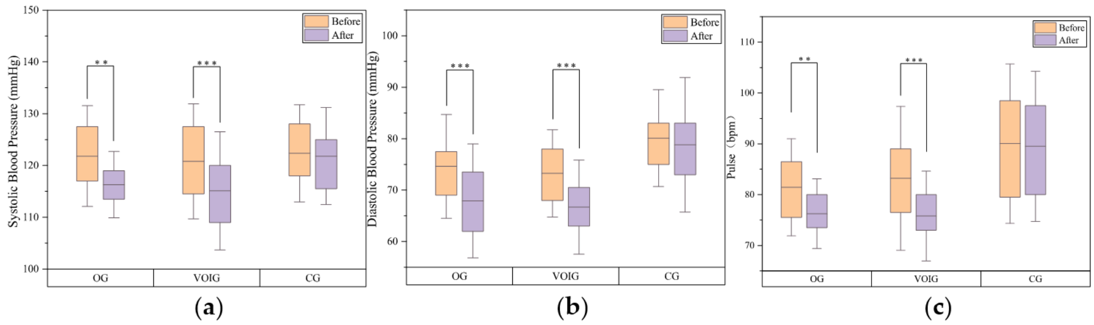


Figure 2. *Changes in blood pressure and pulse in the three groups before and after the experiment. (a) Change in systolic blood pressure; (b) Changes in diastolic blood pressure; (c) Changes in pulse rate (OG: Olfactory Group; VOIG: Visual-olfactory Interaction Group; CG: Control Group; *** p < 0.001. ** p < 0.01. * p < 0.05)*

Heart rate variability index (HRV)

The changes in HRV indices of the three groups before and after 10 minutes are presented in *Figure 3*. Participants in the OG group showed a significant decrease in HRV indices (p < 0.05, d = 0.621), while participants in the VOIG group displayed a highly significant decrease in HRV indices (p < 0.01, d = 0.820), indicating a trend towards increased calmness. There were no statistically significant differences observed (p > 0.05) among the groups.

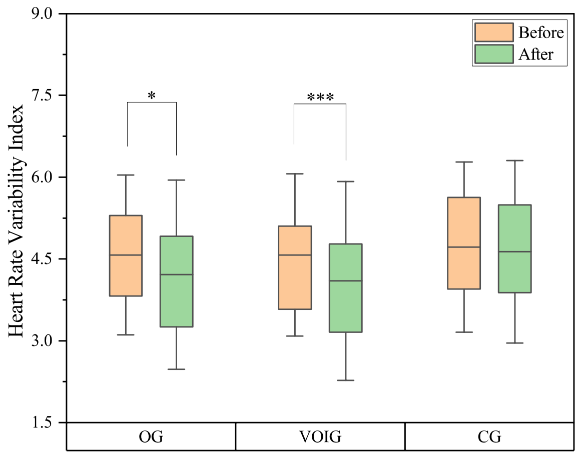


Figure 3. *Changes in heart rate variability index between the three groups before and after the experiment (OG: Olfactory Group; VOIG: Visual-olfactory Interaction Group; CG: Control Group; *** p < 0.001. ** p < 0.01, * p < 0.05)*

Galvanic skin signals (GSR)

The results depicted in *Figure 4* show varying intensities of galvanic skin signals in the sniffing groups under different conditions after 10 minutes of activity. In the CG group, there was no significant change observed (p > 0.05) between the before and after

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2302_18311852

measurements. However, in the OG group ($p < 0.001$, d = 1.436) and the VOIG group ($p < 0.001$, d = 1.581), a notable decrease in galvanic skin signal strength was noted. This decrease implies a gradual relaxation in participants' state in both the OG and VOIG groups, highlighting the restorative effects of sniffing lilies and engaging in visual and olfactory interactions to perceive lilies.

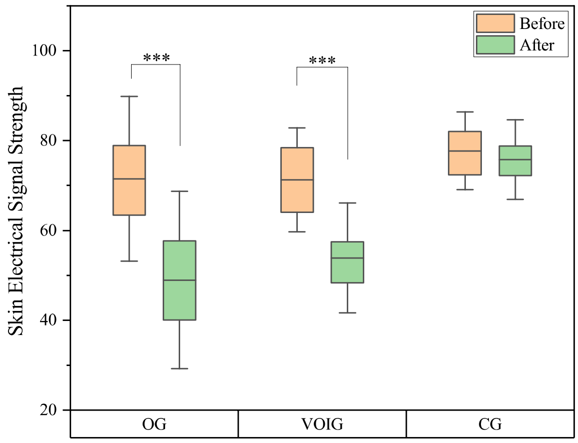
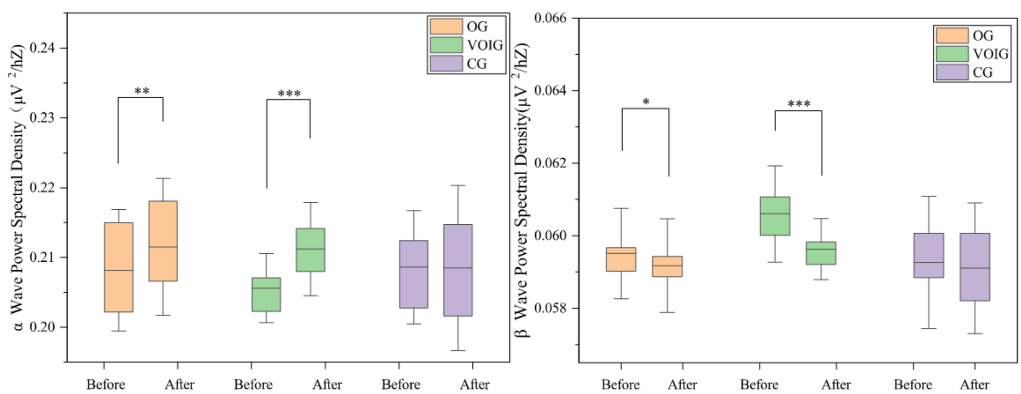


Figure 4. *Changes in galvanic skin signals in the three groups before and after the in the three groups before and after the experiment (OG: Olfactory Group; VOIG: Visual-olfactory Interaction Group; CG :Control Group ;*** p < 0.001. ** p < 0.01. * p < 0.05)*

EEG alpha and beta wave power spectral densities (PSD) and indicators of emotional efficacy

Subjects' alterations in α-wave and β-wave Power Spectral Density (PSD) pre and post 10 minutes under varying experimental conditions are illustrated in *Figure 5*. Comparative analysis with the Control Group (CG) reveals significant enhancements in α-wave PSD and reductions in β-wave PSD for the Olfactory Group (OG) and Visual Olfactory Interaction Group (VOIG). Notably, α-wave PSD elevation was highly pronounced in both the OG group ($p = 0.01$, d = 0.625) and the VOIG group ($p = 0.001$, d = 0.890).



(a) (b)

Figure 5. *Power spectral density of alpha and beta wave before and after exposure. (a) Change in alpha wave psd; (b) Changes in beta wave psd (OG: Olfactory Group; VOIG: Visual-olfactory Interaction Group; CG: Control Group; *** p < 0.001. ** p < 0.01. * p < 0.05)*

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2302_18311852

Conversely, significant decreases in β-wave PSD were observed in the OG group ($p < 0.05$, $d = 0.469$) and highly significant reductions were noted in the VOIG group ($p < 0.001$, $d = 1.254$). These findings suggest a gradual transition to calmer brain states among participants in the two groups, with visual and olfactory stimuli playing a more effective role in lily perception. (*Figure 6* depicts changes in brain topography pre and post experiment for select participants).

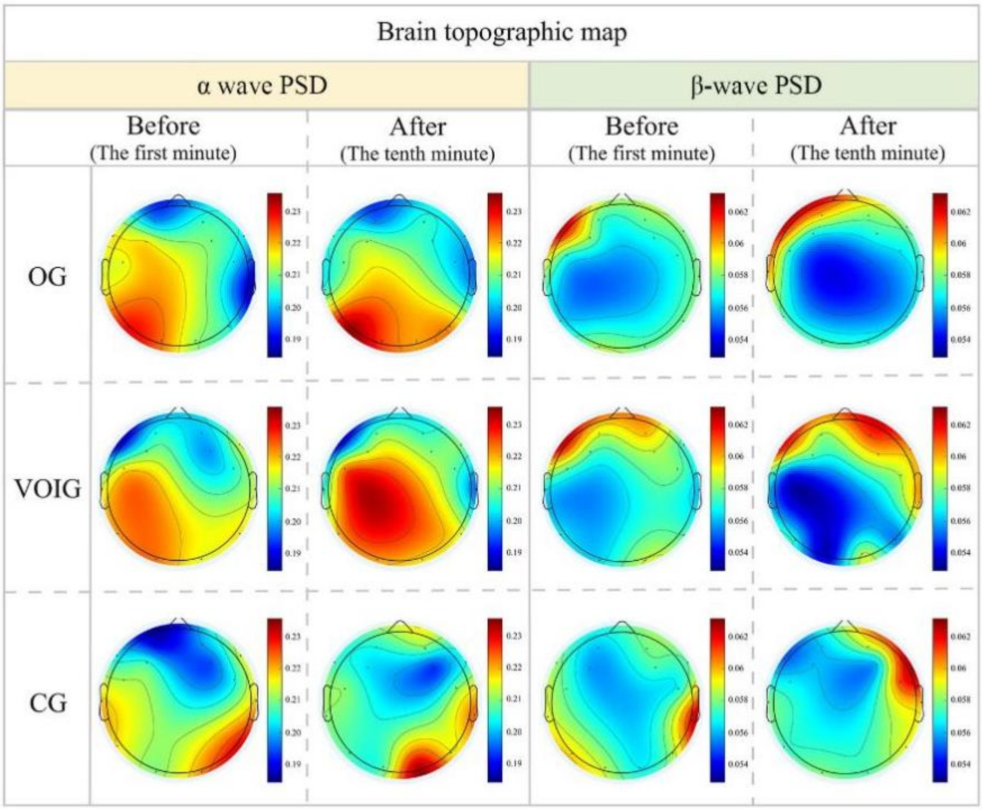


Figure 6. *Brain topography of the changes in alpha and beta wave energies before and after the experiment (OG: Olfactory Group; VOIG: Visual-olfactory Interaction Group; CG: Control Group)*

The differences in the mean values of 10-minute EEG emotional efficacy indexes between the three groups before and after the experiment are illustrated in *Figure 7*. Notably, there were no significant changes in any of the six emotional parameters in the CG group. Analyzing the results of the EEG emotional efficacy indexes revealed that the VOIG group exhibited significant differences compared to the OG group in various aspects. Specifically, the VOIG group showed significant improvements in 'Engagement' (OG $p < 0.05$, $d = 0.861$; VOIG $p < 0.001$, $d = 1.527$), 'Relaxation' (OG $p < 0.05$, $d = 0.573$; VOIG $p < 0.001$, $d = 1.527$), 'Interest' (OG $p > 0.05$; VOIG $p < 0.01$, $d = 0.661$), 'Focus' (OG $p < 0.05$, $d = 0.598$; VOIG $p < 0.01$, $d = 0.759$), 'Excitement' (OG $p < 0.01$, $d = 0.704$; VOIG $p < 0.01$, $d = 0.709$), and 'Stress' (OG $p < 0.01$, $d = 0.709$). These findings suggest that the VOIG group experienced overall enhancement in emotional efficacy compared to the OG group. Similar trends were observed in ' Excitement ' and 'Stress' levels between the two groups.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2302_18311852

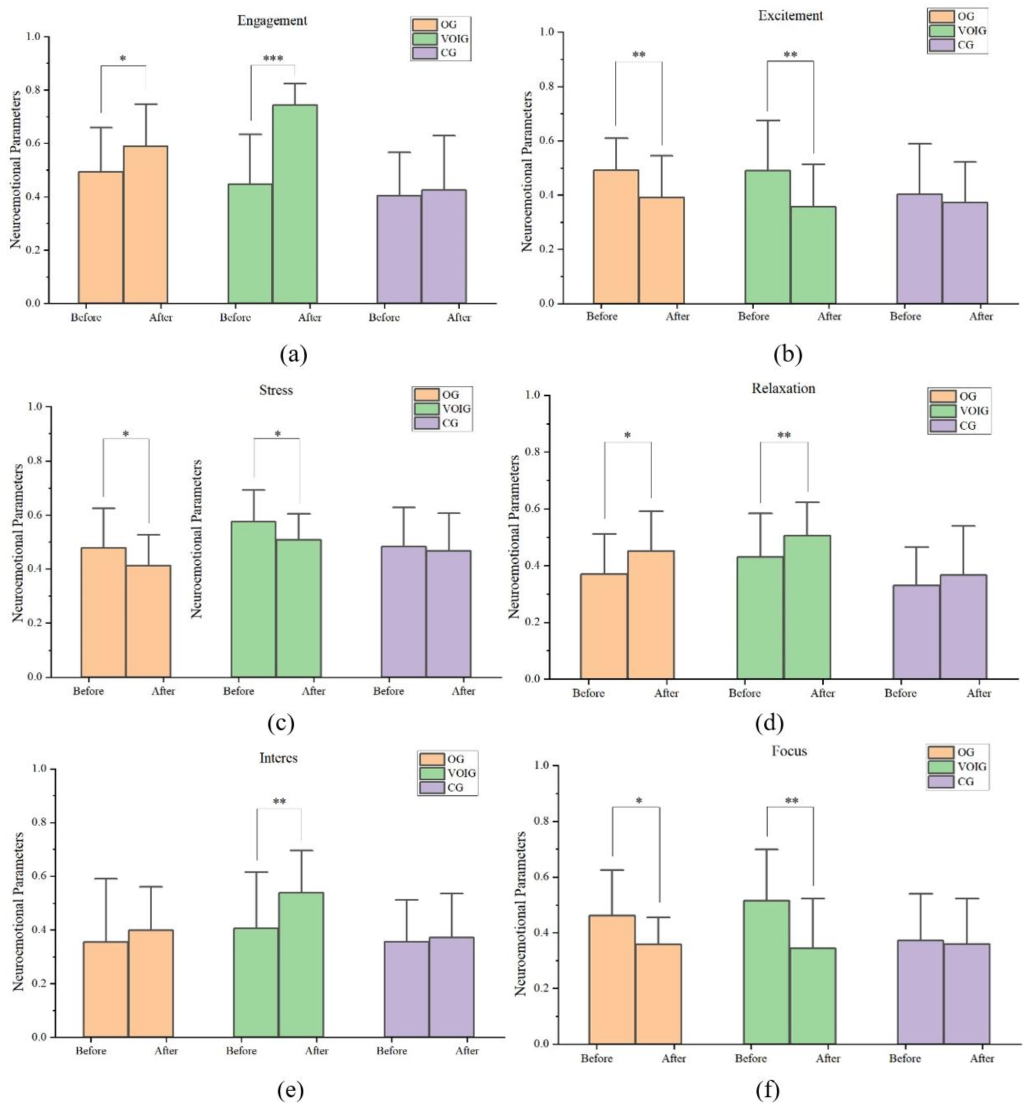


Figure 7. *Six emotional parameter values of Group OG, Group VOIG and Group CG. (a) Change in Engagement; (b) Changes in Excitement; (c) Change in Stress; (d) Changes in Relaxation; (e) Change in Interest; (f) Changes in Focus (OG: Olfactory Group; VOIG: Visual-olfactory Interaction Group; CG: Control Group; *** p < 0.001. ** p < 0.01. * p < 0.05)*

Analysis of the results of the effect of Oriental lilies on human physiological indicators

The t-test results for the seven emotional factors of the Profile of Mood States (POMS) in the OG group indicated a significant reduction in scores for tension ($p < 0.05$, $d = 0.632$), fatigue ($p < 0.01$, $d = 0.789$), depression ($p < 0.05$, $d = 0.588$), and confusion ($p < 0.001$, $d = 1.920$) post-experiment, with a significant increase in ener ($p < 0.05$, $d = 0.582$). However, scores for anger ($p > 0.05$) and self-esteem ($p > 0.05$) did not show significant changes. Similarly, participants in the VOIG group exhibited significant decreases in tension ($p < 0.001$, $d = 1.952$), fatigue ($p < 0.001$, $d = 1.447$), depression ($p < 0.05$, $d = 0.605$), and confusion ($p < 0.001$, $d = 1.95$) scores after the experiment, along with a significant increase in vigor scores ($p < 0.001$, $d = 1.370$). However, anger ($p > 0.05$) and self-esteem ($p > 0.05$) scores did not change significantly. In contrast, scores in the CG group remained unchanged before and after the experiment.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2302_18311852

The changes in TMD values of the three groups before and after the experiment are depicted in *Figure 8(k)*. Significant decreases in TMD scores were observed in the OG group ($p < 0.001$, $d = 1.237$) and the VOIG group ($p < 0.001$, $d = 1.751$). Conversely, there was no significant change in the CG group's pre- and post-experiment TMD scores ($p > 0.05$). Overall, exposure to sniffing lilies and engaging in visual and olfactory interactive perception of lilies exhibited restorative properties on moods related to tension, fatigue, depression, and confusion, effectively restoring participants' vigor levels. However, these interventions did not show significant restorative effects on moods associated with anger and self-esteem. Notably, both visual and olfactory co-stimulation induced relaxation of moods, and the combination of these stimuli demonstrated an additive effect with improved restorative outcomes.

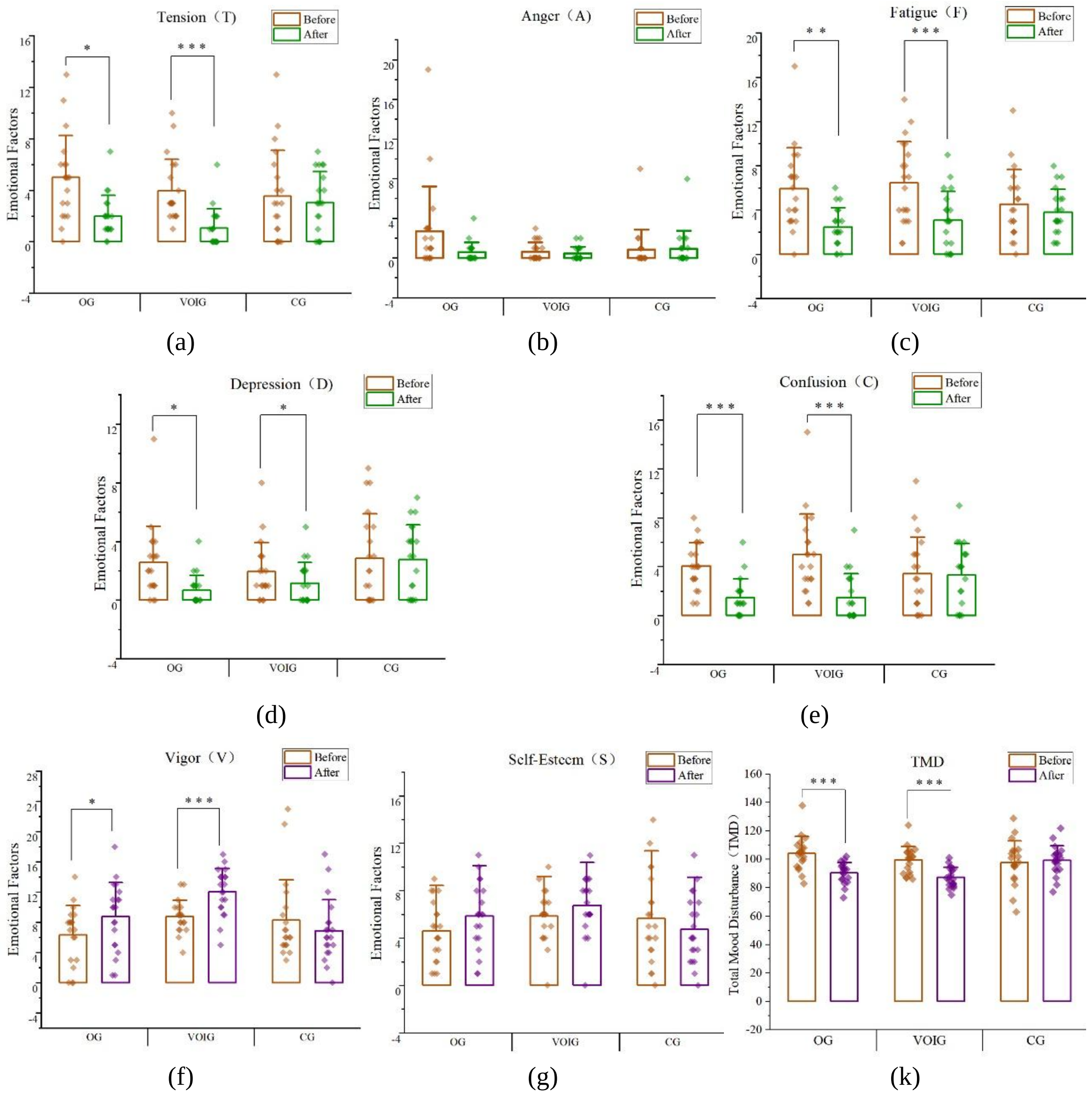


***Figure 8.** The change of emotional factors before and after exposure. (a) Change in tension; (b) Changes in anger; (c) Change in fatigue; (d) Changes in depression; (e) Change in confusion; (f) Changes in vigor; (g) Change in self-esteem; (k) Changes in TMD (OG: Olfactory Group; VOIG: Visual-olfactory Interaction Group; CG: Control Group; *** p < 0.001. ** p < 0.01. * p < 0.05)*

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2302_18311852

Analysis of aroma components and BVOCs results of Oriental lily flowers

The volatiles of Oriental lily were analyzed using GC-MS SPME, resulting in the identification of 12 species with a match of ≥90% (*Table 2*). Among the identified compounds, linalool had the highest relative mass fraction at 41.62%, followed by esters (29.20%), alkenes (23.64%), phenols (3.98%), and aldehydes (0.46%). The retention times of peaks for each component can be observed in *Figure 9* of the particle flow diagram. Terpenoids, particularly monoterpene (C10) and sesquiterpene (C15), are the major classes of plant floral volatiles and play a significant role in floral aroma. Monoterpenes, specifically linalool, constitute the main aroma components of Oriental lilies, accounting for 66.17% of the total share. The volatile emission rates from one hour of quantitative extraction analysis, excluding the standard decyl acetate, are depicted in *Figure 10.* Linalool exhibited the highest emission rate at 45.758ng and 4.024ng $g^{-1}h^{-1}$, followed by Methyl benzoate at 16.362ng and 1.439ng $g^{-1}h^{-1}$, respectively. Other compounds such as β-Ocimene, Ethyl benzoate, Myrcene, trans-β-Ocimene, 2-Methoxy-5-methylphenol, Benzyl benzoate, para-Menthatriene, 2,4,6-Octatriene, Benzaldehyde, and trans-Isoeugenol also showed varying emission rates.

Table 2. *Analysis of the chromatogram of Oriental lily using GC-MS techniques*

No.	Type	Compound	Match Quality	Molcular Formula	CAS Number	Retention Time	Relative Content （%）	Emission Rate (ng $g^{-1}h^{-1}$)
1	Alcohols	Linalool	97.98	$C_{10}H_{15}O$	78-70-6	12.746	41.62	4.024
2	Alkenes	β-Ocimene	97.91	$C_{10}H_{16}$	13877-91-3	10.817	19.89	0.620
3	Alkenes	Myrcene	94.44	$C_{10}H_{16}$	123-35-3	6.224	1.41	0.462
4	Alkenes	trans-β-Ocimene	98.04	$C_{10}H_{16}$	3779-61-1	13.962	1.21	0.381
5	Alkenes	para-Menthatriene	95.40	$C_{10}H_{14}$	18368-95-1	8.051	0.66	0.028
6	Alkenes	2,4,6-Octatriene	92.82	$C_{10}H_{16}$	57396-75-5	4.697	0.47	0.026
7	Aldehyde	Benzaldehyde	95.14	$C_{10}H_{16}$	100-52-7	18.584	0.46	0.023
8	Esters	Methyl benzoate	95.62	$C_8H_8O_2$	93-58-3	11.227	25.44	1.439
9	Esters	Benzyl benzoate	95.95	$C_{14}H_{12}O_2$	120-51-4	14.600	2.34	0.051
10	Esters	Ethyl benzoate	98.65	$C_9H_{10}O_2$	93-89-0	10.127	1.42	0.477
11	Phenols	2-Methoxy-5-methylphenol	97.67	$C_8H_{10}O_2$	1195-09-1	9.136	3.06	0.366
12	Phenols	trans-Isoeugenol	95.83	$C_{10}H_{12}O_2$	5932-68-3	22.267	0.92	0.022

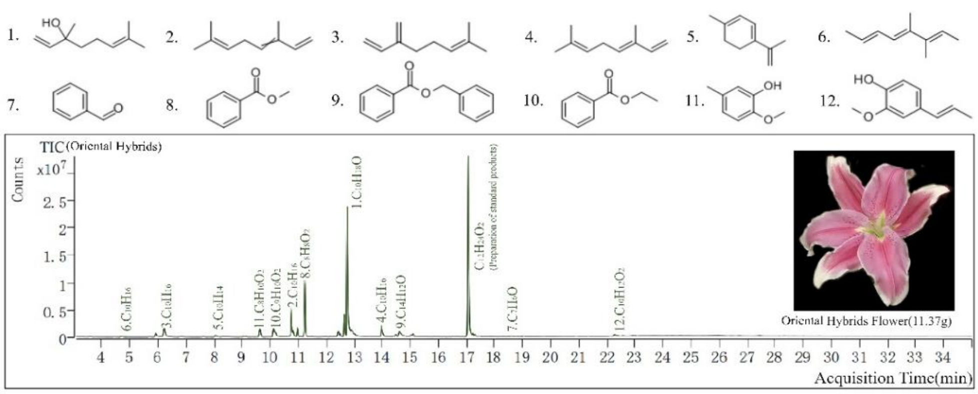


Figure 9. *Analysis of the chromatogram of Oriental lily using GC-MS techniques*

APPLIED ECOLOGY AND ENVIRONMENTAL RESEARCH 23(2):1831-1852.
http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2302_18311852

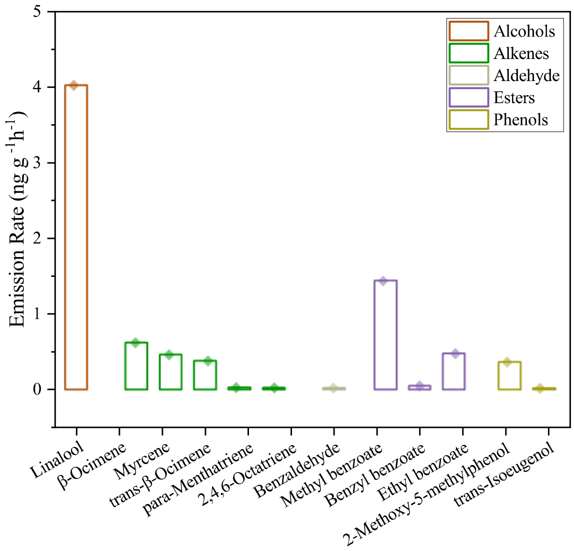


Figure 10. *Emission rate of each component*

Discussion

Sniffing Oriental lilies helps to relieve the stress state

Compared to the CG group, both the OG and VOIG groups exhibited a significant decrease in SBP, DBP, and P indexes, as well as a reduction in HRV and GSR. Additionally, there was an increase in α-wave PSD and a decrease in β-wave PSD, indicating a gradual relaxation of the brain in response to the fragrance of Oriental lilies. The EEG emotional efficacy index parameters 'engagement' and 'relaxation' showed increased values, similar to previous research on the psychological effects of Japanese cypress leaf essential oil (Song et al., 2019). Moreover, 'Excitement', 'Stress', and 'Concentration' levels decreased, leading to restored directed attention and reduced fatigue among the subjects, aligning with findings on the aroma of Plum Blossom (Wang et al., 2024). Notably, the VOIG group demonstrated superior physiological recovery (Hedblom et al.) compared to the OG group, with improvements in DBP, P, HRV indices, and EEG β-wave PSD. Visual stimulation was found to enhance overall recovery, consistent with previous studies on the psychophysiological recovery of coriander plants that highlighted the benefits of multisensory stimulation (Li et al., 2024).

Inhalation of rose oil has been demonstrated to alleviate menopausal stress and anxiety (Miljkovic et al., 2024). Essential oils such as lavender (Lavandula Angustifolia) (Lavandula stoechas), peppermint (Mentha Piperita), and chamomile (Matricaria recutita) are recognized for their stress and anxiety-reducing properties (Ebrahimi et al., 2022; Rudyana et al., 2023). A study utilizing refrigerated oil blends of lavender (Lavandula officinalis), Roman chamomile (Chamomile roman), and neroli (Citrus aurantium) showed a decrease in blood pressure among patients undergoing percutaneous coronary intervention in the intensive care unit (Cho et al., 2013). Sniffing Oriental lilies has been found to alleviate stress and anxiety symptoms in specific populations, similar to the effects of inhaling essential oils in aromatherapy.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2302_18311852

Sniffing Oriental lilies is beneficial in increasing positive emotions

The study found that the scores for tension (T), fatigue (F), depression (D), and confusion (C) were significantly reduced in the OG and VOIG groups compared to the CG group. Additionally, the score for vigor (V) increased significantly, while the TMD value decreased significantly. This indicates that exposure to the Oriental lily aroma led to improved positive mood and reduced depression, the research hypothesis was supported, which aligns with previous research on odour landscapes of grass, cinnamon, moonflower, and pine needles (Guo, 2022). The significant decreases in the POMS tension (T) and confusion (C) factor scores were consistent with the changes in blood pressure, pulse, and HRV data, while the decreases in fatigue (F) scores and increases in energy (V) were consistent with the changes in the EEG data, suggesting that the physiological and psychological results corroborate each other. Notably, the OG group showed a stronger reduction in confusion (C) compared to the VOIG group, suggesting that olfactory perception may be more calming when eyes are closed. Both the OG and VOIG groups demonstrated similar effects on anger (A) and self-esteem (S) without significant changes. However, the VOIG group showed better recovery in mood indicators related to tension (T), fatigue (F), and vigor (V) than the OG group, possibly due to the influence of plant color on mood regulation (Michels et al., 2022).

Effects of volatile components and emission rates of Oriental lily of the valley on human beings

The main aroma components represented by linalool are monoterpenes, known for their sweet and refreshing aroma (Kong et al., 2012). Linalool has been reported to have anxiolytic, anticonvulsant, and antidepressant effects, aiding in tranquillizing the mind, improving sleep, and calming the mood. Additionally, it can also impact the neuroendocrine system (Dos Santos et al., 2018). Among other components with higher emissions and emission rates, β-rolerene exhibits antibacterial and antimanic activity (Sousa et al., 2023), while lauric acid is known for its anxiolytic, antioxidant, antiaging, anti-inflammatory, and analgesic properties (Surendran et al., 2021). Based on this, we propose that inhaling these beneficial volatile constituents not only improves physical well-being but also has psychological effects that resonate with the observed results.

Limitations of the study

The study has several limitations. Firstly, it did not specifically investigate which visual factors influence the recovery effect. Secondly, the research was carried out with college students; future studies could include participants of varied ages, cultures, and health conditions. Lastly, the concentration of flower scents was not regulated, and the study was conducted under constant temperature conditions; different types of lilies have varying volatile compositions, and the rates of volatilization were time-dependent. Therefore, future research could explore the impacts of different varieties of lily flowers, natural aroma volatile concentrations, thermal olfactory interactions, and olfaction at different times of the day on the recovery effect.

Conclusion

The health of indoor environments is currently a prominent research focus, particularly regarding the potential health benefits of using aromatic plants for horticultural therapy

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2302_18311852

and aromatherapy. In this study, in order to investigate the effects of the natural aroma of Oriental lilies on human physiology and psychology, the following main conclusions were obtained by using Oriental lily flowers as olfactory materials, conducting olfactory, visual and olfactory interaction and controlled perception experiments, and at the same time analysing the aroma components and emission rates of Oriental lily flowers: Firstly, it was found that Oriental lilies have a restorative impact on various human physiological and psychological parameters including blood pressure, pulse rate, heart rate variability, brain activity, and mood. Secondly, the perception of Oriental lilies through both visual and olfactory senses exhibited a more positive restorative effect when compared between experimental and control groups. Lastly, the study identified specific components of Oriental lily volatiles, such as linalool, β-borylene, and lauricene, with higher emission rates that may significantly contribute to the observed restorative effects on physical and mental health. The results of the study were consistent with the hypothesis.

The research can be applied to different scenarios, such as placing aromatic plants in classrooms, libraries, laboratories, etc. in schools to help students relax and improve their learning efficiency; placing aromatic plants in offices, meeting rooms, etc. in workplaces to help employees soothe their moods and alleviate their stress; and using aromatic plants in hospital wards, waiting areas, etc. in healthcare settings to improve the moods of patients and improve the effectiveness of treatments. The use of aromatic plants in wards and waiting areas in healthcare facilities can improve patients' moods and enhance treatment effects. Meanwhile, relevant policies have been formulated, such as encouraging the planting and placing of aromatic plants in public places; incorporating aromatherapy into the construction of the public health system, carrying out mental health education, popularising the knowledge of aromatherapy, and promoting its application in the prevention of diseases, rehabilitation, and so on. In the future, the methods used in this study can be used to explore the effects of other indoor aromatic plants on physical and mental health.

REFERENCES

[1] Alarcão, S. M., Fonseca, M. J. (2019): Emotions Recognition Using EEG Signals: A Survey. – IEEE Transactions on Affective Computing 10(3): 374-393. DOI: 10.1109/TAFFC.2017.2714671.

[2] Baik, H., Kim, H. J., Jae, S. Y., Yi, B. (2018): Effects of Fragrance Components of Abies holophylla Max. on Stress Relief and Improvement of Vascular Function. – Journal of People, Plants, and Environment 21(3): 223-232.

[3] Başar, E. (2012): A review of alpha activity in integrative brain function: Fundamental physiology, sensory coding, cognition and pathology. – International Journal of Psychophysiology 86: 1-24. DOI: https://doi.org/10.1016/j.ijpsycho.2012.07.002.

[4] Chandharakool, S., Koomhin, P., Sinlapasorn, J., Suanjan, S., Phungsai, J., Suttipromma, N., Songsamoe, S., Matan, N., Sattayakhom, A. (2020): Effects of Tangerine Essential Oil on Brain Waves, Moods, and Sleep Onset Latency. – Molecules 25(20): 4865.

[5] Chang, C.-Y., Chen, P.-K. (2005): Human Response to Window Views and Indoor Plants in the Workplace. – HortScience HortSci 40: 1354-1359. DOI: 10.21273/HORTSCI.40.5.1354.

[6] Chang, Y.-J., Kim, M.-K., Ryu, H. W. (2017): Effects of inhalation of oxides (caryophyllene oxide, eucalyptol, and linalool oxide), the major ingredient of essential oils, on human emotions and EEG responses. – Journal of Odor and Indoor Environment 16: 410-422.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2302_18311852

[7] Cheng, C.-F., Lin, C.-J. (2023): Building a Low-Cost Wireless Biofeedback Solution: Applying Design Science Research Methodology. – Sensors (Basel) 23(6): 2920. DOI: 10.3390/s23062920. 23(6):2920.

[8] Cho, M.-Y., Min, E. S., Hur, M.-H., Lee, M. S. (2013): Effects of Aromatherapy on the Anxiety, Vital Signs, and Sleep Quality of Percutaneous Coronary Intervention Patients in Intensive Care Units. – Evidence-Based Complementary and Alternative Medicine 2013: 381381. DOI: 10.1155/2013/381381.

[9] Deng, L., Deng, Q. (2018): The basic roles of indoor plants in human health and comfort. – Environ Sci Pollut Res Int 25: 36087-36101. DOI: 10.1007/s11356-018-3554-1.

[10] Dobetsberger, C., Buchbauer, G. (2011): Actions of essential oils on the central nervous system: An updated review. – Flavour and Fragrance Journal 26: 300-316.

[11] Dos Santos, É. R. Q., Maia, C. S. F., Fontes Junior, E. A., Melo, A. S., Pinheiro, B. G., Maia, J. G. S. (2018): Linalool-rich essential oils from the Amazon display antidepressant-type effect in rodents. – J Ethnopharmacol 212: 43-49. DOI: 10.1016/j.jep.2017.10.013.

[12] Ebrahimi, H., Mardani, A., Basirinezhad, M. H., Hamidzadeh, A., Eskandari, F. (2022): The effects of Lavender and Chamomile essential oil inhalation aromatherapy on depression, anxiety and stress in older community-dwelling people: A randomized controlled trial. – Explore (NY) 18: 272-278. DOI: 10.1016/j.explore.2020.12.012.

[13] Finnerty, P. B., McArthur, C., Banks, P., Price, C., Shrader, A. M. (2022): The Olfactory Landscape Concept: A Key Source of Past, Present, and Future Information Driving Animal Movement and Decision-making. – BioScience 72: 745-752. DOI: 10.1093/biosci/biac039.

[14] Fraigneau, V. (2019): La sensorialité olfactive du paysage, médiatrice d'une reliance sensible. – VertigO 19.

[15] Giles-Corti, B., Vernez-Moudon, A., Reis, R., Turrell, G., Dannenberg, A. L., Badland, H., Foster, S., Lowe, M., Sallis, J. F., Stevenson, M., Owen, N. (2016): City planning and population health: a global challenge. – Lancet 388: 2912-2924. DOI: 10.1016/S0140-6736(16)30066-6.

[16] Gong, P., Liang, S., Carlton, E. J., Jiang, Q., Wu, J., Wang, L., Remais, J. V. (2012): Urbanisation and health in China. – The Lancet 379: 843-852. DOI: https://doi.org/10.1016/S0140-6736(11)61878-3.

[17] Guo, J. Y. (2022): Effects of different plant landscapes on physical and psychological health of college students based on olfactory and visual perception. – DOI: 10.27409/d.cnki.gxbnu.2022.001304.

[18] Hassan, A., Tao, J., Li, G., Jiang, M., Aii, L., Jiang, Z., Liu, Z., Chen, Q. (2018): Effects of Walking in Bamboo Forest and City Environments on Brainwave Activity in Young Adults. – Evid Based Complement Alternat Med 2018: 9653857.

[19] Hedblom, M., Gunnarsson, B., Iravani, B., Knez, I., Schaefer, M., Thorsson, P., Lundström, J. N. (2019): Reduction of physiological stress by urban green space in a multisensory virtual experiment. – Sci Rep 9: 10113. DOI: https://doi.org/10.1038/s41598-019-46099-7.

[20] Hongratanaworakit, T., Buchbauer, G. (2006): Relaxing effect of ylang ylang oil on humans after transdermal absorption. – Phytother Res 20: 758-763. DOI: 10.1002/ptr.1950.

[21] Hongratanaworakit, T. (2009): Relaxing effect of rose oil on humans. – Nat Prod Commun 4: 291-296.

[22] Igarashi, M., Song, C., Ikei, H., Ohira, T., Miyazaki, Y. (2014): Effect of olfactory stimulation by fresh rose flowers on autonomic nervous activity. – J Altern Complement Med 20: 727-731. DOI: 10.1089/acm.2014.0029.

[23] Jahan, I., Sadia, E., Tuz Zohora Lima, M., Boby, F. A., Islam Patwary, S. (2024): Deciphering the Mysteries of Aromatic Incentive of Lemongrass Essential Oil Inhalation on Brain Activities in Healthy Adults. – International Journal for Multidisciplinary Research 6(1).

[24] Jiang, S., Deng, L., Luo, H., Li, X., Guo, B., Jiang, M., Jia, Y., Ma, J., Sun, L., Huang, Z. (2021): Effect of Fragrant Primula Flowers on Physiology and Psychology in Female College Students: An Empirical Study. – Frontiers in Psychology 12.

[25] Jo, H.-J., Fujii, E., Cho, T. (2010): An Experimental Study on Physiological and Psychological Effects of Pine Scent. – Journal of the Korean Institute of Landscape Architecture 141.

[26] Jo, H., Rodiek, S., Fujii, E., Miyazaki, Y., Park, B.-J., Ann, S.-W. (2013): Physiological and Psychological Response to Floral Scent. – HortScience horts 48: 82-88. DOI: 10.21273/HORTSCI.48.1.82.

[27] Jung, S., Huh, M. R., Lee, B., Choon, P. J. (2006): Effect of Horticultural Therapy on the Self-Esteem of Geriatric Patients. – Journal of People, Plants, and Environment.

[28] Kaplan, S. (1995): The restorative benefits of nature: Toward an integrative framework. – Journal of Environmental Psychology 15: 169-182. DOI: https://doi.org/10.1016/0272-4944(95)90001-2.

[29] Kikuchi, A., Yamaguchi, H., Tanida, M., Abe, T., Uenoyama, S. (1993): Effects of Odors on Cardiac Response Patterns and Subjective States in A Reaction Time Task. – Tohoku Psychologica Folia 52: 74-82.

[30] Kilonzi, F., Shen, X., Nakagawa, T., Gianfagna, T., Shimizu, K., Goto, S. (2019): A Pilot Study on the Effects of Chrysanthemum Scent on Memory and Mood. – AHTA Journal 29: 1.

[31] Kim, S. C., Lee, M. H., Jang, C., Kwon, J. W., Park, J. W. (2013): The effect of alpha rhythm sleep on EEG activity and individuals' attention. – J Phys Ther Sci 25: 1515-1518.

[32] Kim, S. M., Park, S., Hong, J., Jang, E. J., Pak, C. H. (2016): Psychophysiological Effects of Orchid and Rose Fragrances on Humans. – Korean Journal of Horticultural Science & Technology 34: 472-487.

[33] King, J. D. (2018): Air pollution, mental health, and implications for urban design: a review. – Journal of Urban Design and Mental Health 4: 6. DOI: https://www.researchgate.net/publication/323485741.

[34] Kong, Y., Sun, M., Pan, H.-T., Zhang, Q.-X. (2012): Composition and Emission Rhythm of Floral Scent Volatiles from Eight Lily Cut Flowers. – Journal of the American Society for Horticultural Science 137: 376-382. DOI: 10.21273/JASHS.137.6.376.

[35] Krbot Skorić, M., Adamec, I., Jerbić, A. B., Gabelić, T., Hajnšek, S., Habek, M. (2015): Electroencephalographic Response to Different Odors in Healthy Individuals: A Promising Tool for Objective Assessment of Olfactory Disorders. – Clin EEG Neurosci 46: 370-376. DOI: 10.1177/1550059414545649.

[36] Kritsidima, M., Newton, T., Asimakopoulou, K. (2010): The effects of lavender scent on dental patient anxiety levels: a cluster randomised-controlled trial. – Community Dent Oral Epidemiol 38: 83-87. DOI: 10.1111/j.1600-0528.2009.00511.x.

[37] Laohakangvalvit, T., Sripian, P., Nakagawa, Y., Feng, C., Tazawa, T., Sakai, S., Sugaya, M. (2023): Study on the Psychological States of Olfactory Stimuli Using Electroencephalography and Heart Rate Variability. – Sensors 23: 4026.

[38] Lee, B.-G., Lee, B.-L., Chung, W.-Y. (2014): Mobile Healthcare for Automatic Driving Sleep-Onset Detection Using Wavelet-Based EEG and Respiration Signals. – Sensors 14: 17915-17936.

[39] Lei, G. Y. (2011): Preliminary Study on the Combinations of Specific Aromatic Plants for Hypotensive Healthcare. – Chinese Landscape Architecture.

[40] Li, Z., Zhang, W., Cui, J., Wang, L., Liu, H., Liu, H. (2024): Biophilic environment with visual-olfactory stimuli contributes to psychophysiological restoration and cognitive enhancement. – Building and Environment 250: 111202. DOI: https://doi.org/10.1016/j.buildenv.2024.111202.

[41] Liu, M., Liu, X., Huang, Y., Ma, Z., Bi, J. (2017): Epidemic transition of environmental health risk during China's urbanization. – Sci Bull (Beijing) 62: 92-98. DOI: 10.1016/j.scib.2016.12.004.

[42] Lu, S., Liu, J., Xu, M., Xu, F. (2023): Horticultural therapy for stress reduction: A systematic review and meta-analysis. – Front Psychol 14: 1086121.
[43] Manisalidis, I., Stavropoulou, E., Stavropoulos, A., Bezirtzoglou, E. (2020): Environmental and Health Impacts of Air Pollution: A Review. – Front Public Health 8: 14.
[44] Michels, N., Debra, G., Mattheeuws, L., Hooyberg, A. (2022): Indoor nature integration for stress recovery and healthy eating: A picture experiment with plants versus green color. – Environ Res 212: 113643. DOI: 10.1016/j.envres.2022.113643.
[45] Miljkovic, A., Acimovic, M., Biljana, B., Lončar, B., Raičević, V., Šovljanski, O., Travičić, V., Pezo, M., Pezo, L. (2024): Inhalation and Topical Application of Rose Essential Oil – A Systematic Overview of Rosa damascena Aromatherapy. – Journal of Agronomy Technology and Engineering Management (JATEM) 7: 998-1020. DOI: 10.55817/ASIJ6404.
[46] Min Ching, A. S., Kim, J., Davis, C. (2019): Auditory-visual integration during nonconscious perception. – Cortex 117: 1-15.
[47] Mirón, J., Casteràs, D. P., Gil, M. V., Ventura, G. N., Álvarez, N. C., Goldberg, X. (2019): Perceived stress, anxiety and depression among undergraduate students. – European Neuropsychopharmacology 29: S589.
[48] Münzel, T., Sørensen, M., Schmidt, F., Schmidt, E., Steven, S., Kröller-Schön, S., Daiber, A. (2018): The Adverse Effects of Environmental Noise Exposure on Oxidative Stress and Cardiovascular Risk. – Antioxid Redox Signal 28: 873-908.
[49] Neuper, C., Pfurtscheller, G. (2001): Event-related dynamics of cortical rhythms: frequency-specific features and functional correlates. – International Journal of Psychophysiology 43: 41-58. DOI: https://doi.org/10.1016/S0167-8760(01)00178-7.
[50] Nitidara, N. P. A., Sarwono, J., Suprijanto, S., Soelami, F. X. N. (2021): The multisensory interaction between auditory, visual, and thermal to the overall comfort in public open space: A study in a tropical climate. – Sustainable Cities and Society 78: 103622. DOI: https://doi.org/10.1016/j.scs.2021.103622.
[51] Oh, Y-A., Park, S-A., Ahn, B-E. (2018): Assessment of the psychopathological effects of a horticultural therapy program in patients with schizophrenia. – Complement Ther Med 36: 54-58. DOI: 10.1016/j.ctim.2017.11.019.
[52] Ohno, I. (2017): The Interrelationship Between Asthma and Brain Activities: Psychological Stress-Related Asthma as a New Asthma Phenotype. – Arerugi 66: 153-160. DOI: 10.15036/arerugi.66.153.
[53] Robin, O., Alaoui-Ismaïli, O., Dittmar, A., Vernet-Maury, E. (1998): Emotional Responses Evoked by Dental Odors: An Evaluation from Autonomic Parameters. – Journal of Dental Research 77: 1638-1646. DOI: 10.1177/00220345980770081201.
[54] Rudyana, T. E., Purwanti, N., Firdaus, Rohmawati, R. (2023): The aromatherapy relaxation effect of lavender (Lavandula angustifolia) and peppermint (Mentha piperita) against decreased stress in patients with pulmonary tuberculosis. – Bali Medical Journal.
[55] Schwartz, G. E., Weinberger, D. A., Singer, J. A. (1981): Cardiovascular differentiation of happiness, sadness, anger, and fear following imagery and exercise. – Psychosom Med 43: 343-364. DOI: 10.1097/00006842-198108000-00007.
[56] Song, X., Li, H., Li, C., Xu, J., Hu, D. (2016): Effects of VOCs from leaves of Acer truncatum Bunge and Cedrus deodara on human physiology and psychology. – Urban Forestry & Urban Greening 19: 29-34.
[57] Song, C., Ikei, H., Miyazaki, Y. (2019): Physiological effects of forest-related visual, olfactory, and combined stimuli on humans: An additive combined effect. – Urban Forestry & Urban Greening 44: 126437.
[58] Song, X., Wu, Q. (2022): Study on smellscape perception and landscape application of fragrant plants. – Urban Forestry & Urban Greening 67: 127429. DOI: https://doi.org/10.1016/j.ufug.2021.127429.

[59] de Sousa, J. M. S., de Lima Nunes, T. A., Rodrigues, R. R. L., de Sousa, J. P. A., da Conceicao Albuquerque Val, M., da Rocha Coelho, F. A., Dos Santos, A. L. S., Maciel, N. B., de Souza, V. M. R., Machado, Y. A. A., de Araújo Sousa, P. S., de Araújo, A. R., Rocha, J. A., de Sousa, D. P., da Silva, M. V., Arcanjo, D. D. R., da Franca Rodrigues, K. A. (2023): Cytotoxic and Antileishmanial Effects of the Monoterpene β-Ocimene. – Pharmaceuticals 16: 183.

[60] Sowndhararajan, K., Cho, H., Yu, B., Kim, S. (2015): Effect of olfactory stimulation of isomeric aroma compounds, (+)-limonene and terpinolene on human electroencephalographic activity. – European Journal of Integrative Medicine 7: 561-566. DOI: 10.1016/j.eujim.2015.08.006.

[61] Stojanovich, L., Marisavljevich, D. (2008): Stress as a trigger of autoimmune disease. – Autoimmun Rev 7: 209-213. DOI: 10.1016/j.autrev.2007.11.007.

[62] Surendran, S., Qassadi, F., Surendran, G., Lilley, D., Heinrich, M. (2021): Myrcene-What Are the Potential Health Benefits of This Flavouring and Aroma Agent? – Front Nutr 8: 699666.

[63] Tugade, M. M., Fredrickson, B. L. (2004): Resilient individuals use positive emotions to bounce back from negative emotional experiences. – Journal of Personality and Social Psychology 86: 320-333.

[64] Ulrich, R. S. (1979): Visual landscapes and psychological well-being. – Landscape Research 4: 17-23.

[65] Ulrich, R. S., Simons, R. F., Losito, B. D., Fiorito, E., Miles, M. A., Zelson, M. (1991): Stress recovery during exposure to natural and urban environments. – Journal of Environmental Psychology 11: 201-230. DOI: https://doi.org/10.1016/S0272-4944(05)80184-7.

[66] Vásquez, R. L., Carrión-Jumbo, J., Riofrío-Luzcando, D., Guevara, C. (2023): Emotion classification using EEG headset signals and Random Forests. – Iberian Conference on Information Systems and Technologies (CISTI): 1-7.

[67] Wang, H., Yao, L., Song, S., Wang, H., Sun, M., Liu, Q., Yu, C., Feng, T. (2024): Aroma release regularities of Rosa damascena from Xuancheng via HS-GC-IMS and P&T-GC–MS. – Flavour and Fragrance Journal 39(3): 146-157.

[68] Wang, Y. F., Jin, H. X., Zhou, Y. H., Zhang, L. H., Lu, L. (2024): A Study of Human Mood and Stress Recovery by Auditory and Olfactory Stimulation of Plum Blossoms in Urban Green Space. – Chinese Landscape Architecture 40(01): 47-53. DOI: 10.19775/j.cla.2024.01.0047.

[69] Wu, L., Luo, S., Li, D., Chen, Q., Li, J., Wen, J. (2023): Effects of Deciduous Forests on Adolescent Emotional Health in Urban Areas: An Example from the Autumn Ginkgo Forest in Chengdu. – Forests 14: 1099.

[70] Wang, Y. Y., Wang, C., Qie, G. F., Dong, J. H., Jiang, J. H. (2010): Effect of VOCs from Branch and Leaf of *Platycladus orientalis* and *Cinnamomum camphora* on Human Physiology. – Urban Environment & Urban Ecology 23(3):30-32.

[71] Zanstra, Y. J., Johnston, D. W. (2011): Cardiovascular reactivity in real life settings: measurement, mechanisms and meaning. – Biol Psychol 86: 98-105.

[72] Zhang, X., Guo, J., Zhang, X., Zhang, Q. (2023): Physiological Effects of a Garden Plant Smellscape from the Perspective of Perceptual Interaction. – Int J Environ Res Public Health 20(6): 5004. DOI: https://doi.org/10.3390/ijerph20065004.

[73] Zhao, J., Huang, Y., Wu, H., Lin, B. (2018): Olfactory effect on landscape preference. – Environmental Engineering and Management Journal 17: 1483-1489.

[74] Zhao, R., Zhang, G., Guo, L.-N., Zhang, B.-T., Niu, L.-X., Zhang, Y. (2019): The Effects of Olfactory Stimulation by Tree Peony Flowers on Autonomic Nervous System, Emotional States, and Brain Electrical Activity. – Environmental Science. DOI: 10.21203/rs.2.17998/v1.

[75] Zhao, R. L., Zhang, G., Wang, X., Zhang, B. T., Guo, L. N., Niu, L. X., Zhang, Y. L. (2019): Psycho-Physiological Effects of a Peony-Viewing Program on Middle-Aged and Elderly Individuals at Different Phenological Stages. – Int J Environ Res Public Health 16.
[76] Zhu, B. L. (1995): Brief Introduction of Poms Scale and Its Model for China. – Journal of Tianjin Institute of Physical Education 10(1): 35-37.
[77] Zhu, H., Yang, F., Bao, Z., Nan, X. (2021): A study on the impact of Visible Green Index and vegetation structures on brain wave change in residential landscape. – Urban Forestry & Urban Greening 64: 127299. DOI: https://doi.org/10.1016/j.ufug.2021.127299.
[78] Zouaoui, N., Chenchouni, H., Bouguerra, A., Massouras, T., Barkat, M. (2020): Characterization of volatile organic compounds from six aromatic and medicinal plant species growing wild in North African drylands. – NFS Journal 18: 19-28.
DOI: https://doi.org/10.1016/j.nfs.2019.12.001.

APPENDIX

Table 1. *Changes in blood pressure and pulse in the three groups before and after the experiment*

OG	Before	After	P	d
SBP	121.800±6.486	116.300±4.256	0.002	0.825
DBP	74.600±6.715	67.9±7.376	0.001	0.869
P	81.45±6.370	76.250±4.575	0.01	0.519

VOIG	Before	After	P	d
SBP	120.650±8.634	116.250±8.045	0.000	0.989
DBP	73.25±5.665	66.7±6.097	0.00	1.197
P	83.20±9.440	75.8±5.890	0.000	1.456

CG	Berore	After	P	d
SBP	122.316±6.421	121.736±6.419	0.731	
DBP	79.684±6.156	78.947±9.922	0.777	
P	90.158±10.262	89.158±9.996	0.574	

Table 2. *Changes in heart rate variability index between the three groups before and after the experiment*

OG	Before	After	P	d
HRV	4.574±0.977	4.211±1.157	0.012	0.621

VOIG	Before	After	P	d
HRV	4.575±0.991	4.096±1.218	0.002	0.820

CG	Before	After	P	d
HRV	4.718±1.040	4.632±1.114	0.289	

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2302_18311852

Table 3. *Changes in galvanic skin signals in the three groups before and after the in the three groups before and after the experiment*

OG	Before	After	P	d
GSR	71.495±12.221	48.946±13.148	0.00	1.436

VOIG	Before	After	P	d
GSR	71.258±7.728	53.875±8.144	0.00	1.581018

CG	Before	After	P	d
GSR	77.730±5.770	75.775±5.913	0.202	

Table 4. *Power spectral density of alpha and beta wave before and after exposure*

OG	Before	After	P	d
α-wave PSD	0.2082±0.007	0.2115±0.0079	0.01	0.625
β-wave PSD	0.0595±0.00083	0.0592±0.00086	0.029	0.469

VOIG	Before	After	P	d
α-wave PSD	0.2056±0.004	0.2112±0.0053	0.001	0.890
β-wave PSD	0.0606±0.00088	0.0596±0.00056	0	1.254

CG	Before	After	P	d
α-wave PSD	0.2082±0.007	0.2115±0.0079	0.01	0.625
β-wave PSD	0.0595±0.00083	0.0592±0.00086	0.029	0.469

Table 5. *Six emotional parameter values of Group OG, Group VOIG and Group CG*

OG	Before	After	P	d
Engagement	0.434±0.165	0.589±0.157	0.026	0.861
Excitement	0.492±0.118	0.392±0.154	0.005	0.704
Stress	0.478±0.146	0.412±0.115	0.046	0.479
Relaxation	0.369±0.144	0.452±0.140	0.018	0.573
Interest	0.354±0.237	0.399±0.162	0.367	
Focus	0.462±0.164	0.358±0.098	0.015	0.598

VOIG	Before	After	P	d
Engagement	0.447±0.187	0.744±0.079	0	1.527
Excitement	0.490±0.185	0.357±0.156	0.005	0.709
Stress	0.575±0.117	0.508±0.991	0.011	0.626
Relaxation	0.430±0.156	0.506±0.117	0.009	0.644
Interest	0.407±0.209	0.538±0.158	0.008	0.661
Focus	0.515±0.183	0.344±0.178	0.003	0.759

CG	Before	After	P	d
Engagement	0.404±0.161	0.424±0.204	0.701	
Excitement	0.404±0.186	0.372±0.149	0.572	
Stress	0.483±0.145	0.467±0.139	0.678	
Relaxation	0.329±0.137	0.366±0.173	0.358	
Interest	0.355±0.156	0.372±0.163	0.681	
Focus	0.371±0.168	0.359±0.164	0.797	

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2302_18311852

Table 6. *The change of emotional factors before and after exposure*

OG	Before	After	P	d
Tension	5.000±3.244	3.05±1.905	0.011	0.632
Anger	2.7±4.52	0.6±0.995	0.052	
Fatigue	5.9±3.726	3.55±2.139	0.002	0.789
Depression	2.55±2.481	1.3±1.380	0.016	0.588
Confusion	4.05±1.905	1.450±1.538	0.000	1.920
Vigor	6.350±3.870	8.75±4.518	0.017	0.582
Self-esteem	4.600±2.542	5.25±2.531	0.137	
TMD	104.250±11.755	90.550±7.287	0.000	1.237

VOIG	Before	After	P	d
Tension	3.9500±2.460	1.05±1.5	0.000	1.952
Anger	0.65±0.933	0.45±0.686	0.104	
Fatigue	6.4500±3.734	3.050±2.625	0.000	1.447
Depression	1.950±1.986	1.150±1.424	0.014	0.605
Confusion	5.000±3.309	1.450±1.959	0.000	1.95
Vigor	8.750±2.149	12.05±3.069	0.000	1.37
Self-esteem	5.85±2.23	6.750±2.425	0.092	
TMD	99.450±9.517	87.30±6.967	0.000	1.751

CG	Before	After	P	d
Tension	3.55±3.561	3.050±2.395	0.320	
Anger	0.900±1.832	0.850±2.033	0.804	
Fatigue	4.500±3.154	3.800±2.067	0.239	
Depression	2.850±3.048	2.750±2.381	0.766	
Confusion	3.400±3.033	3.300±2.598	0.839	
Vigor	8.250±5.379	6.850±4.120	0.143	
Self-esteem	5.650±3.801	4.750±2.918	0.387	
TMD	99.700±15.328	99.150±10.419	0.476	