STUDY ON THE PHYSIOLOGICAL AND EMOTIONAL RECOVERY EFFECT OF *MENTHA SPICATA* L. TO COLLEGE STUDENTS UNDER VISUAL-OLFACTORY INTERACTION

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Abstract. Aromatic plants have significant potential in promoting the health of college students. This study utilized the common and easy-to-cultivate *Mentha spicata* L. as the material to elucidate the recovery effects of its volatile substances on the physical and mental health of college students. A total of 60 college students were recruited for the experiment and participants were divided into three groups: the control group (CG), the olfactory group (EG1), and the olfactory combined group (EG2). Physiological indices were measured using the Emotiv Epoc X portable EEG instrument, HRV heart rate ear clip, GSR skin electrical sensor, and Omron blood pressure meter, while psychological indices were assessed using the POMS scale. The results indicated that the aroma of *Mentha spicata* L. positively influenced the emotions and physiological parameters of college students. Specifically, the α wave power of EG1 significantly increased by 5%, the GSR of EG2 significantly decreased by 3%, and the TMD values of both EG1 and EG2 decreased by 19%. In terms of odor perception, EG2 and EG1 exhibited significant differences in intensity, purity, cleanliness, preference, and naturalness. In addition, after the detection of the volatiles of *Mentha spicata* L., it was found that there were more terpenoids in the volatiles, accounting for 43% of the total volatiles. These findings provide a scientific basis for incorporating *Mentha spicata* L. into indoor plant odor landscapes and offer practical guidance for the application of aromatic plants containing terpenoid volatiles in horticultural therapy.
Keywords: *EEG, plant, emotions, moods, smell, BVOCS*

Introduction

Intense social competition and accelerated pace of life have placed college students under prolonged pressure in their academic pursuits, job search, and social interactions. Without timely relief and adequate social support, they may experience anxiety, depression, and other negative emotions (Yang and Yang, 2022). Nowadays, anxiety has become a prevalent psychological issue that needs attention. Other negative emotions like anger, self-blame, depression, and grief can also lead to significant physical and mental harm among college students (Kaufman and Feldman, 2004; Lovallo and Buchanan, 2017). Research has demonstrated that the interaction with plants can potentially calm individuals and improve their mood as well. Furthermore, exposure to various sensory stimuli from plants can positively impact both physical and mental well-being. The therapeutic benefits of aromatherapy, in particular, have gained increasing recognition for supporting recovery processes (Masuo et al., 2021; Qin et al., 2014).

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Sniffing aromatic plants have been shown to have a positive impact on both physical and mental well-being (Dravigne et al., 2008; Bringslimark et al., 2007). The aroma of plum blossoms, for example, can help induce relaxation and lower blood pressure (Jiang et al., 2021; Jo et al., 2013). Some scholars have also explored the benefits of indoor aromatic plants, in addition to studying outdoor plants. Research suggests that having aromatic plants indoors can help improve mood and increase feelings of happiness (Dravigne et al., 2008; Bringslimark et al., 2007). This is because the odor factors released by indoor aromatic plants can positively impact human health and evoke emotional memory in millisecond (Angioy et al., 2003; Burnett et al., 2004; Brawley, 2004). However, there is still a lack of scientific monitoring methods for studying the effects of indoor plants on human physical and mental health.

The aroma of plants activates nerves in the brain via the olfactory groove, triggering hormone secretion in the central nervous and endocrine systems, which in turn influences various physiological responses (Jo et al., 2013; Cui et al., 2022). The concept of 'Qinren Xinpi' elucidates the health benefits of odors by considering the central nervous system and the autonomic nervous system. Previous research often utilizes electroencephalogram (EEG) measurements to assess CNS-related parameters and gauge human physiological reactions based on EEG signals (Budzynski et al., 2009). Such as evaluating human responses in diverse thermal comfort settings using EEG (Wu et al., 2020). As a result, examining the impact of indoor aromatic plants on human physical and mental well-being through EEG analysis is a viable approach.

Mentha spicata L. is an aromatic plant known for its strong refreshing fragrance and edible twigs and leaves that are used as flavoring spices (Jirovetz et al., 2002). Rich in mineral elements and vitamins, this plant holds high nutritional and medicinal value (Brahmi et al., 2017; Park et al., 2016). Studies suggest that *Mentha spicata* L. may promote physical and mental health through antibacterial and anti-inflammatory effects (Mikaili et al., 2013; El Menyiy et al., 2022). However, the evidence supporting specific substances responsible for these effects is currently insufficient.

This experiment investigated the impact of smelling *Mentha spicata* L. on TMD (Total Mood Disturbance) value, α wave, β wave, HRV (heart rate variability) index, GSR (galvanic skin response) index, and blood pressure pulse of college students using EEG technology. By examining the relationship between odor composition, characteristics, perception dimensions, and recovery effects, the study elucidated how *Mentha spicata* L. influences the physical and mental well-being of college students. The findings offer insights and a scientific foundation for the design of indoor plant odor landscapes. The primary research questions addressed in this study are as follows:

1. Whether the *Mentha spicata* L. aroma has a physiological and psychological recovery effect, and enables college students to relax and alleviate negative emotions;
2. Which substances in the aroma volatiles of *Mentha spicata* L. have a positive effect on the physiological and psychological recovery of college students, and how the volatilization rate is;
3. Does single smell have the same recovery effect compared with visual-olfactory interaction perception? Is college students' perception of the smell of *Mentha spicata* L. related to resilience?

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Materials and methods

Experimental materials and objects

In this study, *Mentha spicata* L. was used as the experimental material, which was purchased from Qingyifang Flower Market in Changchun City in December 2023. The potted *Mentha spicata* L., with an average plant height of 15 cm (excluding pots) and in good growth status, was used in the experiment. Two pre-experiments were set up in turn. College students were randomly invited as subjects. The environment, experimental time and the number of subjects assigned to each group were the same. The first pre-experiment consisted of three groups: group 1 placed three pots of *Mentha spicata* L., group 2 placed six pots, and group 3 placed nine pots. The subjects were asked to observe and smell *Mentha spicata* L., and the odor comfort was graded from 0 to 5. The average score of group 1 was 3.5 points, group 2 was 4.4 points, and group 3 was 3.1 points. The second pre-experiment also included three groups: group 1 volunteers poked and left *Mentha spicata* L. for 10 s, and then let the subjects enter the room to start observing and smelling *Mentha spicata* L. and scoring the odor comfort level from 0 to 5, group 2 poked and left *Mentha spicata* L. for 20 s, group 3 poked and left *Mentha spicata* L. for 30 s, the average score of group 1 was 4.2 points, group 2 was 3.6 points, and group 3 was 3.1 points. The results showed that the average score of smelling was the highest after placing 6 pots of *Mentha spicata* L. and fiddling for 10 s, so we used this setting in the formal experiment.

The research indicates that college students, who often experience significant pressure and anxiety, were chosen as the participants for this experiment due to their extensive and scientific background. Previous studies have shown no significant difference in landscape preference between college students and other social groups (Karaman and Watson, 2017; Yao et al., 2012; Beiter et al., 2015). Following a Gpower prior test, a group of 20 individuals was selected. A total of 60 college students from Jilin Agricultural University, comprising 25 males and 35 females, were recruited for the experiment. Participants were required to have no auditory or olfactory disorders, and to wash their hair before the experiment (Campbell, 2009). All subjects participated voluntarily and were fully informed about the experimental procedures.

Experimental design

Sixty subjects were randomly divided into three groups: the control group (CG), olfactory group (EG1), and visual-olfactory group (EG2). Each group underwent a 10-min test at the experimental site located in the teaching and development center of Jilin Agricultural University. Two adjacent rooms were prepared, one serving as the preparation room and the other as the laboratory. To minimize environmental interference, the indoor lighting in the laboratory remained constant. Throughout the experiment, the doors and windows were kept closed, and the laboratory maintained a quiet atmosphere. Plants were positioned on the central table of the laboratory, with a white wall in front of the table. All subjects were tested under the same environmental conditions (*Fig. 1*). Confirming that informed consent was obtained from all participants. This study has received approval from the Ethics Committee of the College of Forestry and Grassland Science, Jilin Agricultural University. Confirms that all experiments were performed in accordance with relevant named guidelines and regulations.

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1. The participants arrived in the preparation room to complete the informed consent form, where the research assistant introduced the test procedures.
2. They were then asked to watch a documentary on the pressures of youth employment for 5 min under pressure. Subsequently, their blood pressure was measured, and the Profile of Mood States (POMS) scale was completed as a pre-test measure. The participants proceeded to the laboratory to wear the EEG instrument and undergo physiological index measurements.
3. 10 min experiment, first by the volunteers to keep the *Mentha spicata* L. 10 s so that it emits odor and volatiles, after the end of the poke invited subjects to the laboratory experiment, EG1 subjects closed their eyes to experiment, EG2 subjects open their eyes to experiment, CG subjects in the face of the white wall experiment (to avoid the influence of plant volatile residues, each group after the end of the window ventilation, this process in the preparation room when the subjects).
4. At the end of the whole experimental process, the EEG instrument and other instruments were taken down, the blood pressure of the subjects was measured, and the POMS scale and the odor perception scale were filled out again.

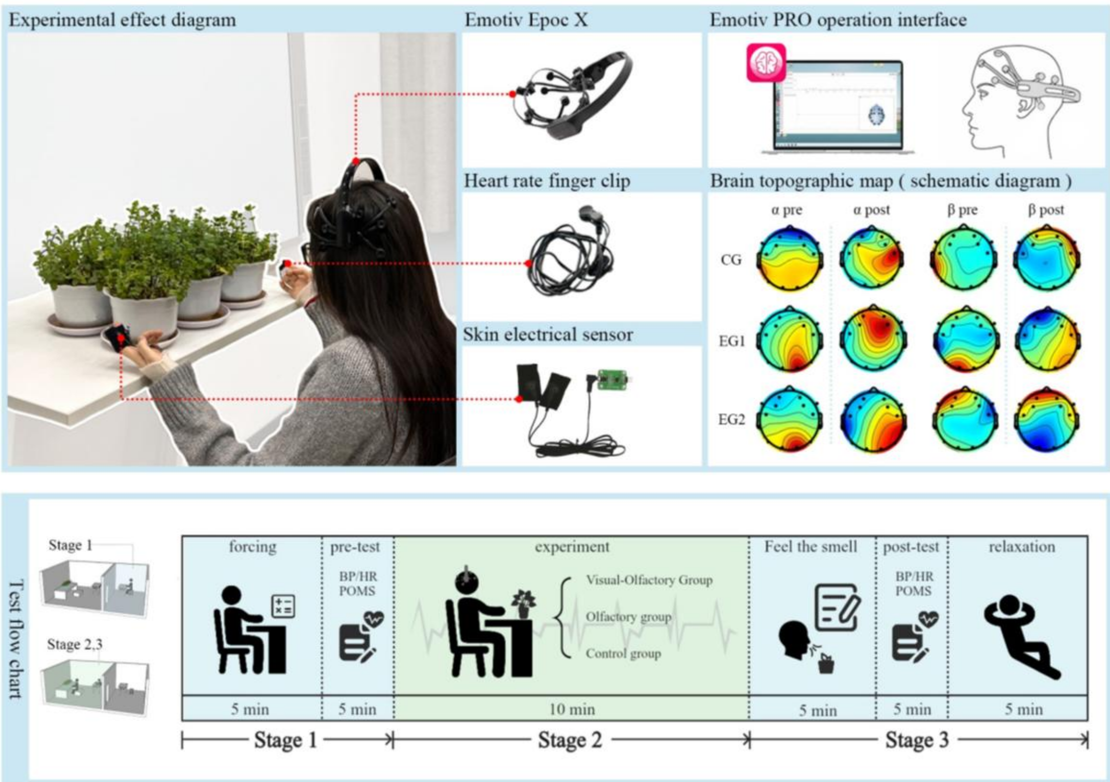

Figure 1. *The overall process and schematic diagram of the experiment*

Measurement method

Determination of physiological indexes

The Emotiv Epoc X portable EEG instrument was utilized to capture the brain waves of the participants. This device offers the advantage of multi-channel acquisition,

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featuring 14 electrodes (AF3, AF4, F3, F4, F7, F8, FC5, FC6, T7, T8, P7, P8, O1, and O2) that cover four brain lobes (frontal cortex, temporal cortex, parietal cortex, and occipital cortex). Brain waves can be categorized into four types based on frequency: α wave, β wave, δ wave, and θ wave (Ismail et al., 2016). Research has indicated that α waves are generated by the brain during relaxation (Marshall and Bentler, 1976; Başar, 2012; Fazio and Cooper, 1983), while β waves are produced when feeling tense (Ismail et al., 2016; Neuper and Pfurtscheller, 2001; Alarcao and Fonseca, 2017). This study focuses on the recovery state of the participants, thus α and β waves were chosen. The data collected by the electrodes is transmitted to a computer via Bluetooth, and the device's accuracy has been validated in prior research (Barham et al., 2017; Debener et al., 2012).

The Omron blood pressure meter was utilized to measure the diastolic blood pressure, systolic blood pressure, and pulse of the participants. The diastolic and systolic blood pressures were chosen as the indices for analyzing the pressure recovery.

The GSR skin electrical sensor is utilized for measuring the skin conductance response. Emotions trigger the human sympathetic nervous system, leading to an increase in sweat gland secretion. The level of skin conductance is directly proportional to the activity of sweat glands.

Heart rate variability index is measured using an HRV heart rate ear clip. This index provides information on the regulation of the cardiovascular system by neurohumoral factors and is primarily used to assess the autonomic nervous system. Studies suggest that HRV may help decrease morbidity rates.

Determination of psychological indicators

The psychological effects of *Mentha spicata* L. on the subjects were assessed using the Profile of Mood States (POMS) scale. The POMS scale is widely utilized in various research fields such as sports psychology, clinical psychology, and health promotion, as it offers a comprehensive measurement of an individual's emotional state. With its 40 evaluation indexes and 7 emotional factors (tension, anger, fatigue, depression, vitality, confusion, and self-esteem), the POMS questionnaire provides a more detailed understanding of emotional states compared to single-dimensional methods. Each factor is scored on a scale of 0-4, and the total emotional state evaluation (TMD) is derived from these factors. A higher TMD value indicates a more negative emotional state and mood (Bourgeois et al., 2010; Manfredini et al., 2004).

Determination of odor pleasure perception

The perception of odor was evaluated using the Scent Pleasure Perception Model Scale developed by Xiao Jieling. This scale consists of nine perceptual characteristics: strength, purity, cleanliness, freshness, calmness, preference, familiarity, suitability, and naturalness. Subjects were asked to score these nine indicators on a scale of 1-7 after the experiment.

Determination of volatile components in Mentha spicata L.

The volatile substances of *Mentha spicata* L. were extracted using headspace solid-phase microextraction (HS-SPME). The instruments employed in this process included gas chromatography-mass spectrometry (GC-MS) from Agilent (USA), a

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MW 40-275 extraction needle (50/30 μm coating thickness) from Supelco (USA), a gas bag from Beijing Bailingwei Technology Co., Ltd., a PC2440 electronic balance from Mettler (Switzerland), a glass sheet (2 cm × 2 cm), and a 50 mL glass bottle from Shanghai Medical Device Factory 5, along with ether and decyl acetate from Sigma-Aldrich (USA). The volatile compounds of *Mentha spicata* L. were extracted using headspace solid phase microextraction. BVOC (Biogenic Volatile Organic Compounds) sampling and population experiments were conducted concurrently. Initially, three leaves of *Mentha spicata* L. were harvested, with a dry weight of 0.5346 g. These leaves were then placed in a 2-L Teflon FEP membrane gas sampling bag for on-site sampling of BVOC emissions, while blank samples were collected to establish background values over a 30-min period. Following sample collection, all sampling bags were retrieved. Subsequently, the SPME fiber was introduced into the sampling bag to adsorb the volatiles for 40 min. The extraction needle was then transferred to GC-MS for analysis under specific conditions (chromatographic column: DB-624MS (60 m × 0.32 mm × 1.8 μm); temperature program: starting at 40°C for 3 min, increasing at a rate of 6°C per minute up to 250°C, held for 3 min, further increased to 270°C, and held for 5 min. MS conditions included electron ionization mode, with an electron energy of 70 eV, scanning range from 29 to 350 amu, interface temperature set at 250°C, ion source temperature at 230°C, and quadrupole temperature at 150°C). Qualitative analysis was performed by referencing the NIST08 spectrum library, combined with literature and substance properties, while the relative content of each volatile compound was determined using the peak area normalization method. Additionally, quantitative analysis was carried out using the internal standard method. This involved preparing a standard solution by dissolving 50 μl of decyl acetate in 20 ml of ether, evaporating and drying 10 μl of the solution on a glass sheet, placing it in a glass bottle, inserting it into the extraction needle, and allowing it to adsorb for 1 h.

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

Statistical analysis

The brain wave data was exported from the original EEG data using the Emotiv PRO software, and then processed in MATLAB R2021b (https://ww2.mathworks.cn/products/matlab.html) for filtering, segmentation, and other procedures before being imported into Excel (Microsoft Office Excel2021 https://www.microsoft.com/zh-cn/microsoft-365/excel). Additional data were statistically combined in Excel and further analyzed and processed in SPSS 25 (IBM SPSS Statistics 25 https://www.ibm.com/cn-zh/spss). The skin electrical signal, HRV index, and brain wave data were all averaged for the first and tenth minutes. SPSS 25 software was used to paired sample T-test the pre-test and post-test data of blood pressure, heart rate, POMS value, α-wave and β-wave power. The correlation between the odor perception scale and various physiological and psychological indicators was analyzed, and the experimental results were finally obtained. The test results were presented as mean ± standard deviation (mean ± SD). Significance was determined by a paired sample T-test ($P < 0.05$), with extreme significance denoted by $P < 0.01$.

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Results analysis

Analysis of the effect of smelling Mentha spicata L. on physiological indexes of college students

Olfactory analysis of the effect of Mentha spicata L. on the autonomic nervous system (ANS): blood pressure and pulse and HRV index, GSR activity

The results presented in *Figure 2* indicate a significant decrease in systolic blood pressure among EG2 subjects following the experiment ($P < 0.05$), with an average reduction of 2.900 mmHg. Similarly, there was a notable difference in diastolic blood pressure before and after the experiment ($P < 0.05$), showing an average decrease of 2.100 mmHg. However, there was no significant change in pulse rate pre- and post-experiment. In contrast, EG1 subjects exhibited significant variations in systolic blood pressure, diastolic blood pressure, and pulse compared to pre-experiment values ($P < 0.05$). Specifically, the average decreases were 5.300 mmHg, 4.050 mmHg, and 3.750 bpm, respectively. On the other hand, there were no significant alterations in systolic blood pressure, diastolic blood pressure, or pulse for CG subjects before and after the experiment. Overall, the findings suggest that exposure to *Mentha spicata* L. through watching and smelling could positively affect the blood pressure and pulse of college students.

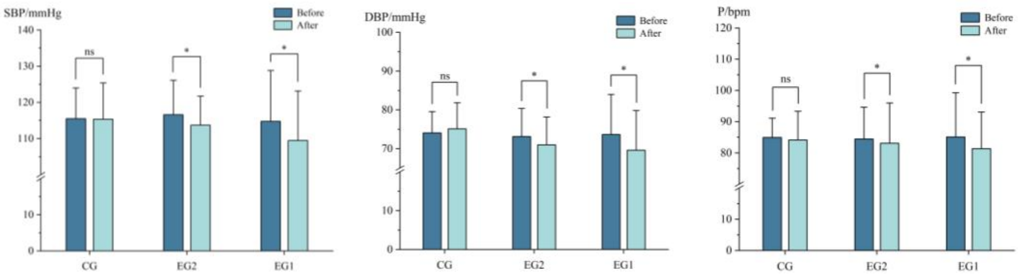

Figure 2. *Changes of blood pressure and pulse before and after the experiment. SBP: systolic blood pressure. DBP: diastolic blood pressure. P: pulse. ns: no significant. *At the 0.05 level (two-tailed), the correlation is significant*

The skin electrical signal of EG2 decreased significantly after the experiment ($P < 0.05$), with a decrease value of 1.815. Similarly, the skin electrical signal of EG1 also decreased significantly after the experiment ($P < 0.05$), with a decrease value of 1.860. In contrast, the skin electrical signal of the CG did not show a significant change before and after the experiment. The results are shown in *Figure 3*. These results indicate that observing and smelling *Mentha spicata* L. can reduce skin electrical signals and promote emotional calming.

Previous research has demonstrated a negative correlation between HRV index and anxiety and depression (Chen et al., 2014; Robin et al., 1998; Tugade and Fredrickson, 2004). The HRV indexes of EG1 and EG2 experienced a significant increase ($p < 0.05$), with EG2 increasing by 0.291 and EG1 by 0.262. Conversely, there was no notable change in the HRV index of the control group (CG) before and after the experiment. These findings suggest that exposure to the sight and scent of *Mentha spicata* L. may enhance HRV index and potentially alleviate symptoms of anxiety and depression. The results are shown in *Figure 3*.

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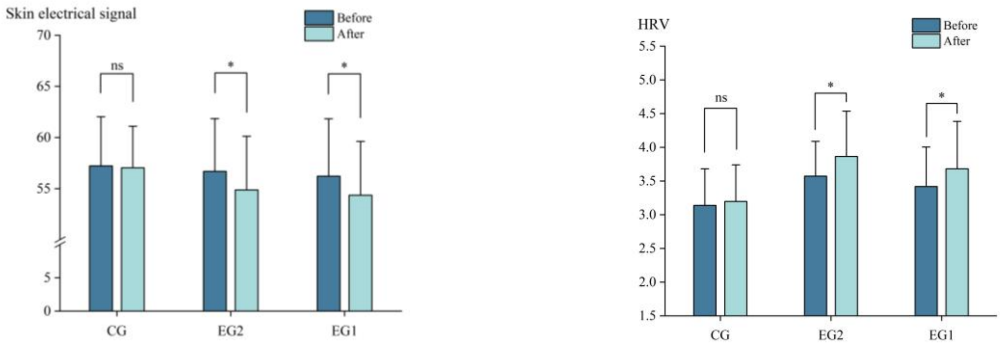

***Figure 3.** Changes of HRV index and skin electrical signal before and after the experiment. ns: no significant. * At the 0.05 level (two-tailed), the correlation is significant*

Analysis of the effect of smelling Mentha spicata L. on the central nervous system (CNS): brain activity

The brain generates spontaneous electrophysiological activity that can be measured through brain waves, which can be monitored using instruments (Niedermeyer and da Silva, 2005; MacNeill et al., 2018; He et al., 2011). There are two key bands of brain waves: α waves (8-13 Hz) and β waves (14-30 Hz). α waves indicate a relaxed brain state, while β waves are associated with cognitive activities. When α waves increase or β waves decrease, the brain is in a more relaxed state (Chang and Chen, 2005; Lee et al., 2014).

The changes in EG2 brain wave power are illustrated in *Figure 4*. The α brain wave power exhibited a significant increase ($P < 0.01$), with the post-test measuring 0.011 μV2/Hz higher than the pre-test. Conversely, the power of β brain wave significantly decreased ($P < 0.01$), with the post-test showing a decrease of 0.004 μV2/Hz compared to the pre-test. The alterations in EG1 brain wave power can also be observed in *Figure 4*. The α brain wave power displayed a significant increase ($P < 0.01$), with the post-test measuring 0.011 μV2/Hz higher than the pre-test. Additionally, the post-test for β brain wave power decreased by 0.001 μV2/Hz compared to the pre-test, and this change was deemed significant ($P < 0.05$). In contrast, there were no significant changes in CG α brain wave power and β brain wave power between the pre-test and post-test.

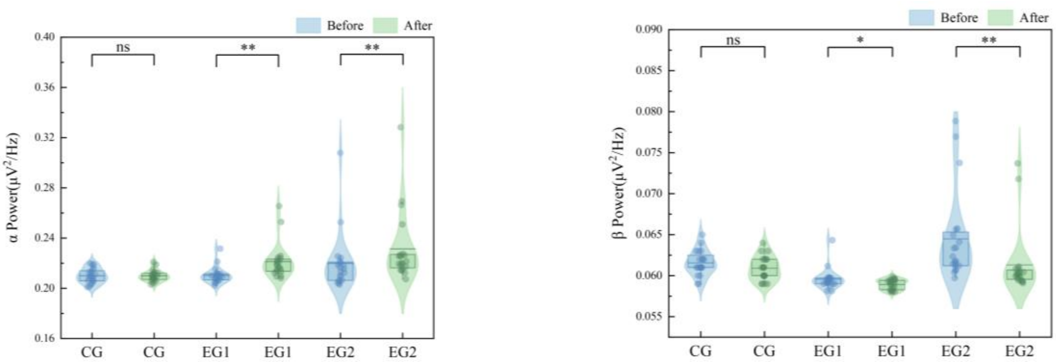

***Figure 4.** Changes of α wave and β wave before and after the experiment. ns: not significant. *At the 0.05 level (two-tailed), the correlation is significant. **At the 0.01 level (two-tailed), the correlation is significant*

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Analysis of the effect of smelling Mentha spicata L. on college students' psychological indicators

The seven factor scores of the POMS scale before and after the experiment with EG2 subjects indicated that after 10 min of exposure to *Mentha spicata* L. plants, negative emotional factors decreased while positive emotional factors increased significantly ($P < 0.01$).

Based on the POMS scale score of EG1, the factors of tension, anger, and fatigue exhibited a significant decrease, all reaching a highly significant level ($P < 0.01$). Following the experiment, positive emotions such as vitality and self-esteem saw a significant increase, with energy showing a highly significant improvement ($P < 0.01$) and self-esteem also displaying a significant growth ($P < 0.05$). The total emotional state score (TMD) indicated a significant reduction in negative emotions for both EG2 and EG1 after the experiment ($P < 0.01$).

Based on the seven factor scores of the POMS scale before and after the CG experiment, it was observed that only the tension factor exhibited a significant decrease ($P < 0.01$), while the other factors did not show significant changes. Although there was a slight decrease in the total emotional distress score post-experiment, the P value was greater than 0.05.

The results indicated that both smelling and watching *Mentha spicata* L. had a positive impact on individuals' psychological mood. However, only smelling *Mentha spicata* L. had a greater secondary effect on individuals' psychology compared to both smelling and watching *Mentha spicata* L. The detailed data are shown in *Figure 5*.

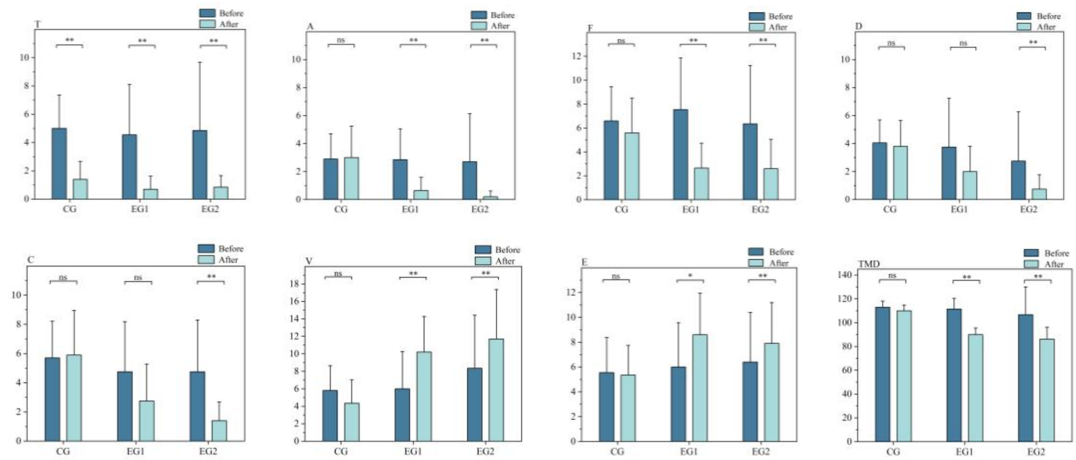

Figure 5. *Changes of emotional factors before and after the experiment. T: Tension, A: anger, F: fatigue, D: depression, V: vitality, C: confusion, E: self-esteem, TMD: overall assessment of emotion, ns: not significant. *At the 0.05 level (two-tailed), the correlation is significant. **At the 0.01 level (two-tailed), the correlation is significant*

Analysis of the main volatiles of Mentha spicata L.

A total of 28 compounds were detected in the analysis of volatiles from *Mentha spicata* L. after the removal of 5 influencing substances. These compounds included 6 monoterpenes, 6 sesquiterpenes, 4 alcohols, 4 esters, 3 ketones, 2 alkanes, 1 aldehyde,

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and 2 other compounds. The most abundant compounds found were (-)-Carvone, D-Limonene, Caryophyllene, Eucalyptol, and β-Myrcene (*Fig. 6*).

Following the removal of the internal standard and impurities, the highest emission rate observed was 22.516 $ng \cdot g^{-1} \cdot h^{-1}$ for (-)-Carvone. Additionally, the emission rates for D-Limonene, Caryophyllene, Eucalyptol, β-Myrcene, cis-b-Copaene were 9.725 $ng \cdot g^{-1} \cdot h^{-1}$, 6.326 $ng \cdot g^{-1} \cdot h^{-1}$, 6.088 $ng \cdot g^{-1} \cdot h^{-1}$, 4.534 $ng \cdot g^{-1} \cdot h^{-1}$, 2.401 $ng \cdot g^{-1} \cdot h^{-1}$, respectively. Furthermore, the emission rates for (+)-epi-Bicyclosesquiphellandrene, 1H-Cyclopropa[a]naphthalene, (1S)-(1)-β-Pinene acetate, (E)-β-Pinene were 2.077 $ng \cdot g^{-1} \cdot h^{-1}$, 1.613 $ng \cdot g^{-1} \cdot h^{-1}$, 1.587 $ng \cdot g^{-1} \cdot h^{-1}$, 1.3-Hexen-1-ol, 1.125 $ng \cdot g^{-1} \cdot h^{-1}$, respectively.

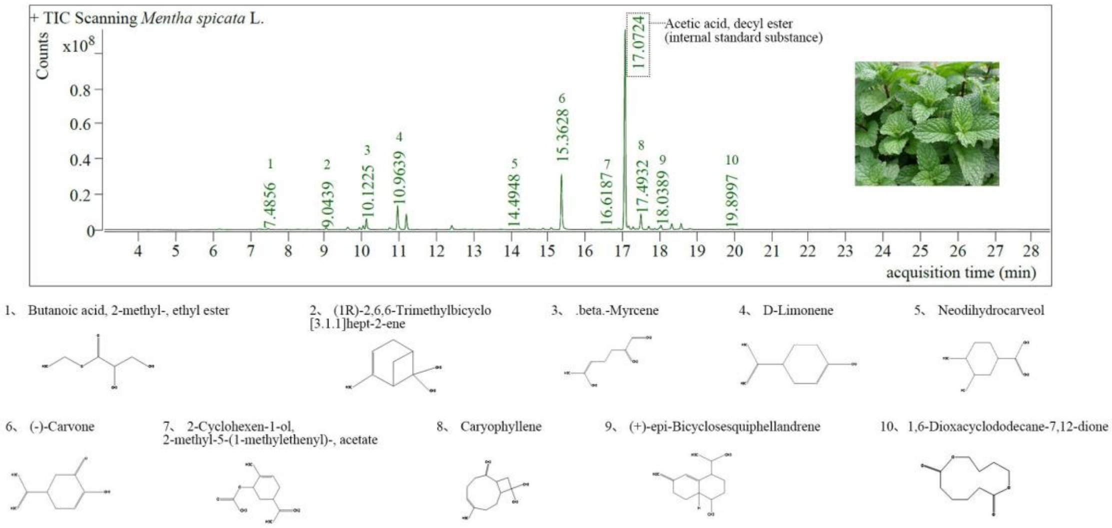

***Figure 6.** Particle flow diagram of volatiles determination of Mentha spicata L.*

Analysis of odor pleasure perception model scale results

Paired sample T-test showed that EG2 and EG1 had significant differences in intensity ($P = 0.035$), purity ($P = 0.015$), cleanliness ($P = 0.030$), preference ($P = 0.037$) and naturality ($P = 0.001$). Familiarity and suitability scores were not significantly different. EG2 had higher average scores for odor intensity, purity, and familiarity compared to EG1, while EG1 scored higher in cleanliness, freshness, preference, suitability, and naturalness. Specifically, EG2 had the highest mean purity score of 4.9 points, whereas EG1 had the highest mean naturalness score of 5.6 points (*Table 1*).

Correlation analysis of odor pleasure perception model scale and physical and mental health

Figure shows a significant correlation between EG1 intensity and changes in HRV ($r = 0.48$), and the cleanliness was significantly correlated with the change of β wave ($r = 0.56$) (*Fig. 7*). Additionally, as depicted in *Figure 8,* there was a significant correlation between EG2 familiarity and changes in SBP ($r = 0.55$), as well as a significant correlation between suitability and changes in DBP ($r = 0.47$), familiarity was significantly correlated with the change of β wave ($r = 0.51$), the intensity is significantly correlated with the change of β wave ($r = 0.60$), purity is significantly correlated with the change of α wave ($r = 0.47$) (*Fig. 8*).

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Table 1. *Two groups of odor perception evaluation*

Indicators	Group	Average	Standard deviation	Sig.
Intensity	EG1	3.60	1.273	0.035*
	EG2	4.60	1.273	
Purity	EG1	3.70	1.418	0.015*
	EG2	4.90	1.447	
Cleanliness	EG1	4.90	1.651	0.030*
	EG2	3.70	1.867	
Freshness	EG1	5.30	1.380	0.067
	EG2	4.65	1.268	
Quietness	EG1	4.40	1.603	1.000
	EG2	4.40	1.501	
Preference	EG1	4.85	1.348	0.037*
	EG2	3.75	1.713	
Familiarity	EG1	3.55	1.605	0.115
	EG2	4.35	1.461	
Suitability	EG1	5.05	1.317	0.209
	EG2	4.45	1.820	
Naturality	EG1	5.60	1.046	0.001**
	EG2	3.90	1.294	

Sig.: Significance level of hypothesis test. *At the 0.05 level (two-tailed), the correlation is significant. **At the 0.01 level (two-tailed), the correlation is significant

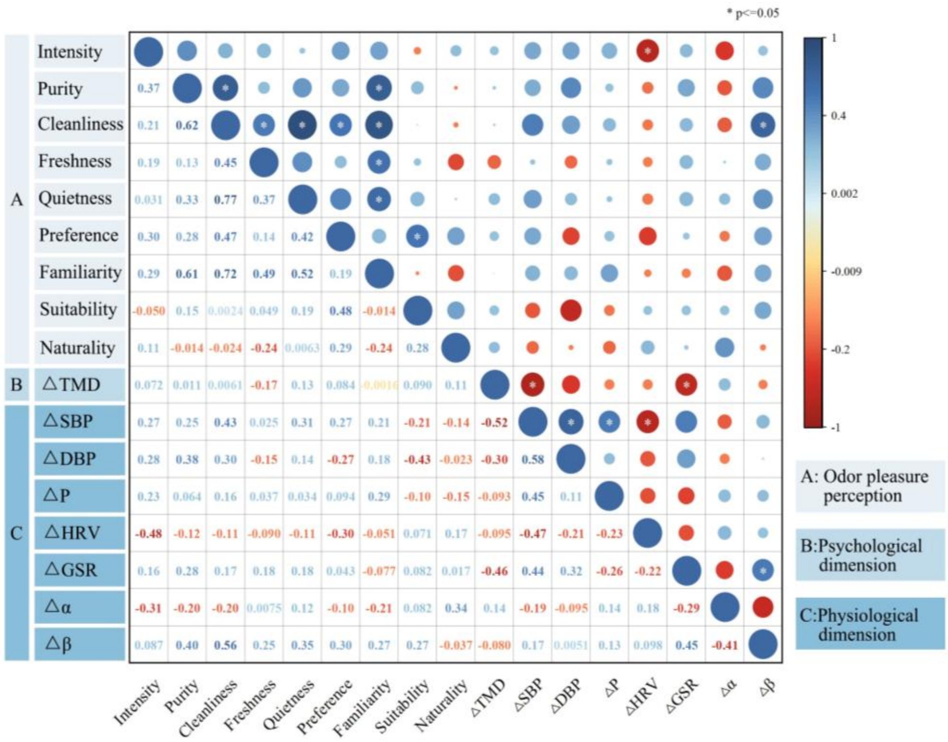

Figure 7. *Correlation between sensory evaluation and physical and mental recovery in the EG1 group. ΔTMD: TMD post-test value - TMD pre-test value. ΔDBP: diastolic blood pressure after the measured value - diastolic blood pressure before the measured value. ΔSBP: post-systolic blood pressure measurement - pre-systolic blood pressure measurement. ΔHRV: post-test value of heart rate variability - pre-test value of heart rate variability. ΔP: post-pulse measurement - pre-pulse measurement. ΔGSR: skin electrical post-test value - skin electrical pre-test value. Δα: α wave post-test measured value of brain - α wave pre-test measured value of brain. Δβ: β wave post-test measured value of brain - β wave pre-test measured value of brain*

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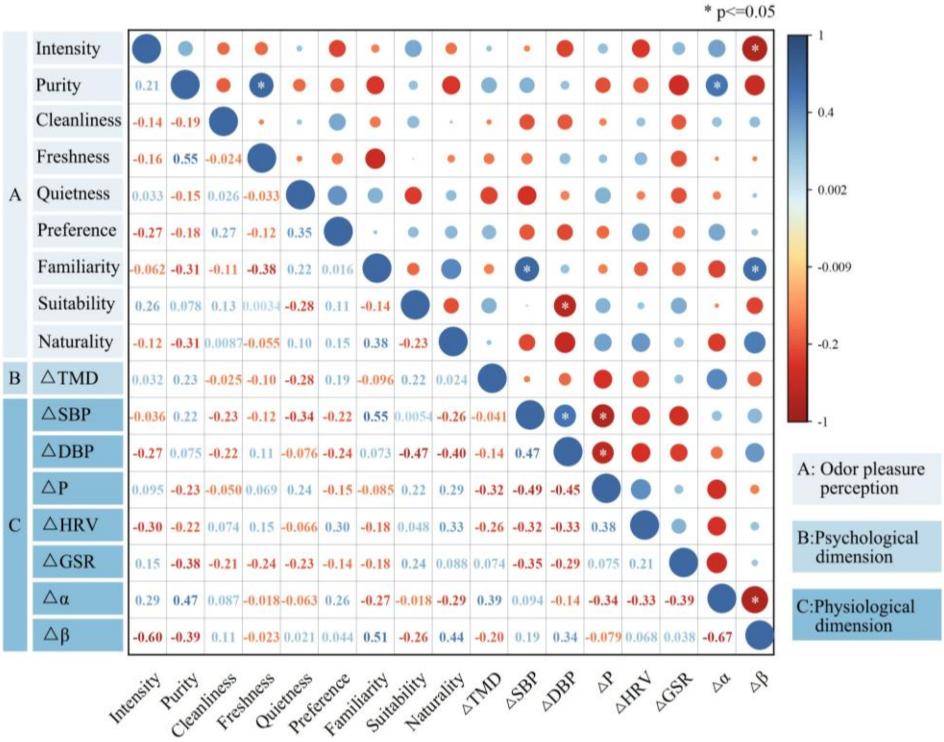

Figure 8. *Correlation between sensory evaluation and physical and mental recovery in EG2 group. △TMD: TMD post-test value - TMD pre-test value. △DBP: diastolic blood pressure after the measured value - diastolic blood pressure before the measured value. △SBP: post-systolic blood pressure measurement - pre-systolic blood pressure measurement. △HRV: post-test value of heart rate variability - pre-test value of heart rate variability. △P: post-pulse measurement - pre-pulse measurement. △GSR: skin electrical post-test value - skin electrical pre-test value. △α: α wave post-test measured value of brain - α wave pre-test measured value of brain. △β: β wave post-test measured value of brain - β wave pre-test measured value of brain*

Discussion

Mentha spicata L. volatiles are beneficial for college students to relax their brains and regulate their emotions

When individuals engage in cognitive processes, their brain generates biological signals known as brain waves, which serve as objective measures of human physiological functioning (Grassini et al., 2019). Previous research has utilized monitoring changes in brain waves to assess human comfort levels (Ma et al., 2024). In this particular study, the impact of visual and olfactory stimulation from plants on the human body was assessed through the analysis of α-wave and β-wave power. By comparing brain wave power data before and after exposure to *Mentha spicata* L. in both the experimental groups (EG1, EG2) and the control group (CG), it was observed that the scent and sight of *Mentha spicata* L. induced relaxation in the brain, leading to an increase in α wave power and a decrease in β wave power. These findings suggest a positive influence of *Mentha spicata* L. on the physiological well-being of college students. Furthermore, changes in blood pressure, pulse rate, GSR index, HRV index, and other physiological indicators among the participants further support this conclusion. Whether individuals were exposed to the scent with their eyes open or closed, the aroma of *Mentha spicata* L. was associated with improvements in blood pressure, heart rate, and mood stability.

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In summary, *Mentha spicata* L. has a positive impact on the physiological recovery of college students. In terms of psychology, the POMS scale is utilized to assess its effects on the emotions of college students. Previous research has established the reliability and validity of the POMS scale (Morfeld et al., 2007). The findings of this study indicate that the scent of *Mentha spicata* L. contributes to the emotional well-being of college students. These results align with previous research demonstrating that the aroma of *Mentha spicata* L. can significantly enhance mood in individuals (Raudenbush et al., 2009).

Therefore, from the changes in various physical and mental indicators, it is evident that *Mentha spicata* L. can enhance both physical and mental well-being by reducing blood pressure pulse, GSR index, β wave power, and TMD value, while also improving α wave power and HRV index. Previous research has highlighted the positive effects of olfactory interactions between individuals and plants, with findings showing that gardenia and cedar can lower diastolic blood pressure and alleviate fatigue (Yin and Liu, 2018; Azuma et al., 2016). Our study further supports these findings by demonstrating the beneficial effects of *Mentha spicata* L., another aromatic plant.

The terpenoids released by Mentha spicata L. have a positive impact on the health of college students

The different volatile compounds found in aromatic plants not only contribute to the plants' smell, but also impact the human body and mind through the olfactory system. When aromatic plants and humans share the same space, the specific types of volatiles and their emission rates can either promote or inhibit human health. The volatiles identified in this study included (-)-Carvone, D-Limonene, Caryophyllene, Eucalyptol, and β-Myrcene, which had the highest emission rates. These findings align with previous research (Jirovetz et al., 2002; Díaz-Maroto et al., 2003). Carvone, commonly used in food, feed, and medicine, is a significant spice (Pina et al., 2022); D-Limonene, also known as limonene, imparts a lemon and orange aroma and has demonstrated antibacterial and antioxidant properties in studies (Anandakumar et al., 2021; Miller et al., 2011); Caryophyllene, with a citrus and camphor-like scent, exhibits local anesthetic, anti-inflammatory, anti-tumor, and anti-depressant effects (Fidyt et al., 2016); Eucalyptol, characterized by a camphor and cool herbal aroma, possesses sterilizing and insecticidal properties and is commonly used in medicine and culinary spices (Seol and Kim, 2016; Juergens, 2014); Lastly, Laurene emits a pleasant light balsamic scent. The results of brain wave power, blood pressure pulse, and GSR index in EG1 and EG2 college students appear to be closely linked to the volatile compounds of *Mentha spicata* L. It is hypothesized that terpenoids, known for their various health benefits, particularly play a positive role.

The addition of visual senses affects college students' odor perception of Mentha spicata L.

The addition of vision makes the smell of *Mentha spicata* L. more closely related to the physical and mental recovery of college students. By comparing correlation heat maps between EG1 and EG2 groups, it was determined that the relationship between EG2 odor perception and physiological and psychological recovery was stronger. The results of the odor pleasure perception model scale indicated that the odor perception of *Mentha spicata* L. differs from that of a single scent, with the single scent evoking a

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greater sense of naturalness. It is speculated that this difference may be attributed to the immersive nature of the scent of *Mentha spicata* L.

Studies have shown that adolescents experience better health outcomes when spending time outdoors compared to indoors (Thompson Coon et al., 2011). Individuals tend to feel more relaxed in natural environments (Shibata and Suzuki, 2002). In today's society, college students often have limited opportunities to engage with the natural outdoor environment and spend a significant amount of time indoors. Introducing *Mentha spicata* L. indoors can have positive effects on both physical and mental well-being through visual-olfactory interactions and the appreciation of its scent, ultimately enhancing natural perception.

Mentha spicata L. can be used to create indoor restorative visual and olfactory landscape

Aromatic plants are beneficial for use in indoor restorative landscapes. From a pharmacological perspective, the aroma components produced by these plants circulate in the human body through the blood, regulating hormone secretion and metabolism. Additionally, the scent can stimulate the human nervous system via olfactory cells, helping to regulate both physical and mental states while enhancing human immunity (Hassan et al., 2018). *Mentha spicata* L., a fragrant plant commonly found in the northern flower market, not only adds ornamental value but also plays a significant role in horticultural therapy. Placing *Mentha spicata* L. pots in indoor environments can help people relax, reduce fatigue, and enhance work efficiency. These pots can be incorporated in indoor spaces like classrooms, dormitories, and offices frequently used by college students, along with other plants, to create a therapeutic and rejuvenating green landscape.

Limitations and prospects

In recent years, there has been a growing focus on using green plants to enhance indoor air quality. This study specifically examines the impact of one plant on college students. It is important to note that the study sample consists solely of college students, which limits the generalizability of the findings. Future research should aim to broaden the scope and depth of the investigation to provide more comprehensive results.

Conclusion

The utilization of aromatic plants in campus environments can enhance the health benefits of indoor landscapes for college students. This study primarily investigates the correlation between *Mentha spicata* L. volatiles and the physiological and psychological well-being of college students. Through the analysis of data on parameters such as blood pressure, brain wave power, GSR index, HRV index, and POMS scale, it is evident that *Mentha spicata* L., whether experienced through scent alone or through visual and olfactory combined stimuli, positively influences human physiology and psychology to varying extents, promoting relaxation of the brain and alleviating negative emotions. The pleasant and refreshing aroma of *Mentha spicata* L. contributes to emotional recovery, with the dominant terpenoids playing a significant role. In a broader context, this study offers initial evidence supporting the suitability of aromatic plants in enhancing indoor environments within campus settings.

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