

Research on Restorative Benefits of Rose Landscapes Through Visual and Olfactory Perception

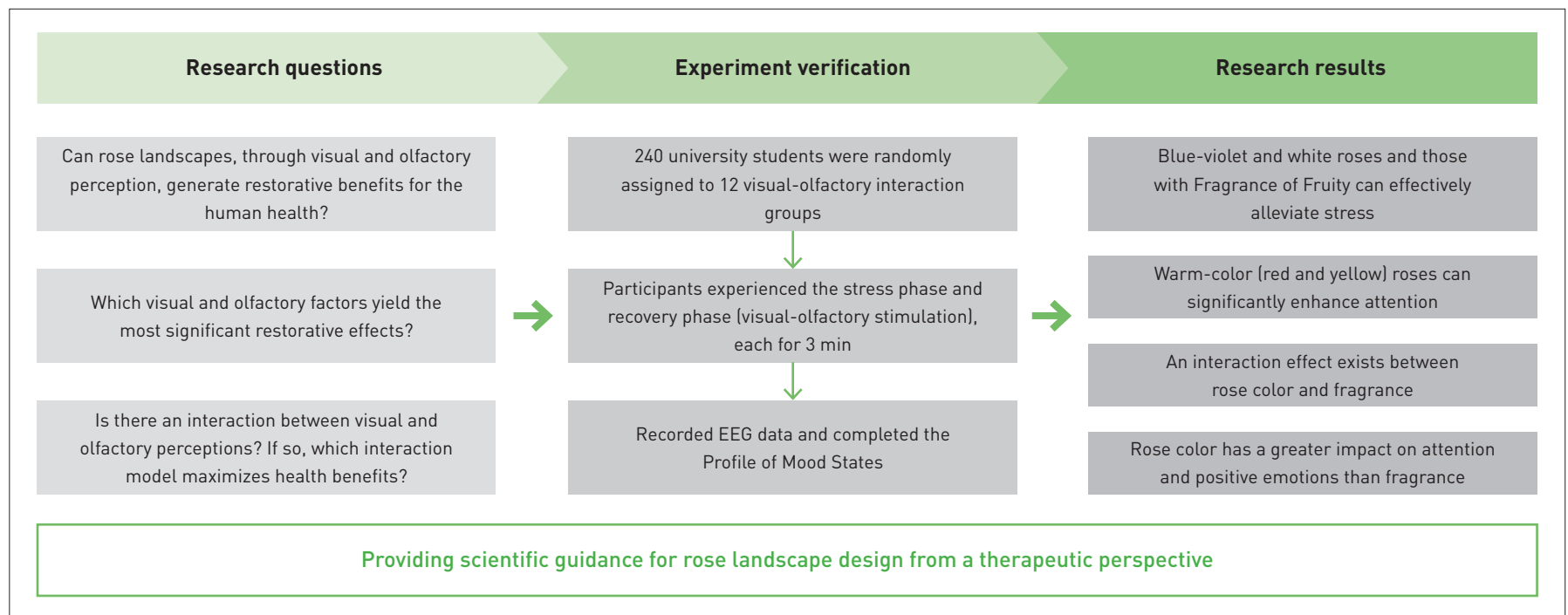
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GRAPHICAL ABSTRACT



ABSTRACT

Plant landscapes play a vital role in promoting physical and mental health. *Rosa chinensis*, commonly known as “Chinese rose” and with diverse colors and fragrances, is widely used in urban landscaping and home gardening. However, its restorative benefits have yet to be explored from a sensory interaction perspective. This study investigated the effects of rose landscapes on stress relief, attention recovery, and emotional regulation. Participants (university students) were randomly assigned to 12 sensory groups combining six color series (white, orange, pink, red, yellow, and blue-violet) with

two fragrance types—Fragrance of Rose (FR) and Fragrance of Fruity (FF). Through stress-inducing tasks followed by visual-olfactory recovery experiments, physiological and psychological data—including EEG and mood states—were analyzed. Results showed that white and blue-violet roses significantly alleviated stress, with the FF roses outperforming the FR ones. Warm colors (e.g., red, yellow), particularly the red–FR and yellow–FF combinations, excelled in boosting attention and positive emotions. Furthermore, visual stimuli had a greater impact on attention recovery and improvement of emotional health

than olfactory stimuli. The study also confirmed the potential of sensory interactions in optimizing landscape perception and enhancing health benefits. Based on these findings, practical design strategies were proposed to maximize the therapeutic value of rose landscapes for various land uses. This research offers critical insights into leveraging plant landscapes for health promotion and provides new directions for designing urban green spaces and therapeutic environments.

KEYWORDS

Rose Landscape; Visual-Olfactory Perception; Color; Fragrance; Restorative Benefits; Stress Relief; Attention Recovery

HIGHLIGHTS

- White and blue-violet roses significantly alleviate stress, with Fragrance of Fruity (FF) roses outperforming Fragrance of Rose (FR) ones
- Red and yellow roses, particularly the red–FR and yellow–FF combinations, are more effective in attention recovery and enhancing positive emotions
- Visual stimuli have a significantly greater impact on attention and emotional improvement than olfactory stimuli
- Exploring the restorative benefits of rose landscapes from a visual-olfactory perception perspective can support the design of therapeutic environments

RESEARCH FUNDS

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1 Introduction

The fast-paced urban lifestyle has significantly reduced opportunities for people to engage and interact with nature, which has negatively affected human physical and mental health, well-being, and social cohesion^[1]. In recent years, sub-health conditions have become increasingly prevalent, especially among young people, including university students. Studies show that university students are prone to health issues such as sleep disorders and deteriorating physical fitness^[2]. Being in a critical period of psychological development, they face multiple pressures from family, academics, interpersonal relationships, and future employment^[3].

The 2016 National Health and Wellness Conference of China outlined key environmental health goals, emphasizing the urgent need to address pressing environmental issues affecting public health^[4]. According to the World Health Organization, health encompasses three dimensions: physical, mental, and social well-being, meaning that good physical function, sound psychological health, and harmonious social relationships are essential^[5]. Therefore, creating environments that provide continuous positive interventions is crucial. Existing research has demonstrated that natural environments positively affect human physiology, emotions, and attention^{[6][7]}.

Green spaces, as a type of natural environment, offer a wide range of health benefits related to recreational and ecological well-being^[8]. Plants, the most important component of green spaces, significantly promote human health—for example, exposure to flowers has been shown to foster positive emotions, alleviate stress, and aid in attentional restoration^[9]. During the COVID-19 pandemic, close contact with plants provided therapeutic effects^[10]. *Rosa chinensis* (commonly known as “Chinese rose,” referred to as “rose” hereafter) is widely used in landscape design due to its rich variety of colors and fragrant scents. Its volatile compounds have high therapeutic value, making it an important resource for aromatherapy and healthcare.^{[11]–[13]} Thus, exploring the health intervention effects of rose landscapes, as well as their variability, is critical for creating healthy living environments.

2 Literature Review

2.1 Landscape Perception

Perception forms the foundation for human interaction with the environment, and landscape experiences involve the coordination of multisensory modalities^[14]. Plants, as a key medium for human

interaction with the natural environment, provide rich sensory stimuli. For instance, the color and shape of plant organs provide visual stimuli, the scent of flowers, leaves, and fruits generate olfactory stimuli, while the sounds produced by wind or rain on leaves offer auditory stimuli. In some cases, edible plants may even evoke taste stimuli.

Visual perception, one of the most significant human sensory modalities, offers abundant environmental cues^{[15][16]}. The visual characteristics of a landscape typically include color, shape, size, as well as horizontal and vertical structures^[17]. For plant visual perception, users primarily process physical information such as shape, size, color, and posture. Studies have pointed out that plant color has the most profound visual impact, often being the first feature to attract attention, followed by growth form and size^[18]. Human sensitivity to different plant colors also varies^[19], and plant colors directly affect sensory experiences, eliciting both physiological and emotional responses^[20]. In contrast, olfactory perception is often underappreciated. Unlike other sensory pathways, olfactory sensory neurons are directly connected to the central nervous system, which controls language, memory, and emotions. Therefore, compared with other senses, olfaction can more directly evoke deep emotional responses, and scents can significantly influence emotions, cognition, and behaviors^[21].

Moreover, interactions between sensory modalities can influence landscape perception. Studies indicate that visual stimuli can enhance olfactory perception^[22], and olfactory input can alter perceptions of environmental atmosphere^[23]. The involvement of olfactory perception significantly enhances individuals' awareness of environmental biodiversity, amplifying the restorative effects of the environment on health^[24]. The distinct qualities of olfactory stimuli can also modulate visual attention^[25]; for instance, certain scents may heighten attention to visually congruent objects^[26], and a higher consistency between modalities enhances the overall pleasantness of the environment^[27]. Research on forest landscape perception has demonstrated that combined visual and olfactory stimuli produce significantly greater physiological and psychological relaxation compared with single sensory stimulation^[28], and that the congruence between visual and olfactory inputs can improve evaluations of plant landscapes^[29].

Human perception also affects landscape preference, satisfaction, and pleasure^[30]. Preferences arise from individuals' evaluations on landscape through sensory perception and cognitive processing^[31]. These preferences are linked not only to psychological states induced by cognitive and emotional responses to the environment^[32], but also to the restorative benefits the

environment provides for physical and mental well-being^[33]. Research has shown that plant landscape preferences significantly aid psychological recovery^[34]. The presence of trees and flowers enhances landscape ratings and reduces mental stress^[35].

Although some studies have explored the combined effects of visual and olfactory stimuli on health, or how visual-olfactory perceptions influence public landscape experiences, research on the health benefits of plant landscapes from a multisensory interaction perspective remains limited.

2.2 Plant Landscapes and Physical and Mental Health

Physiological assessments, utilizing EEG, blood pressure, heart rate variability, etc., along with psychological assessment tools like the Profile of Mood States (POMS), are commonly used to explore the relationship between plant landscapes and human physical and mental health.^{[36]~[38]} For example, one study employing eye-tracking technology and semantic differential scales found that yellow-green and bright green leaves attract more attention than other colors, inducing feelings of pleasure and relaxation. In contrast, green-and-white mixed leaves often evoke negative emotions^[39]. Another study analyzed the impact of plant community images with varying colors and proportions on relaxation. Its results showed that green and yellow plant communities were found to be more relaxing than the red ones, with the best relaxation effect achieved at a color ratio of 55% green, 25% yellow, and 20% red^[40].

Furthermore, numerous physiological and psychological experiments confirmed the health benefits of inhaling plant fragrances. For example, Hexian Jin et al. reported that the scents of *Prunus mume* and *Osmanthus fragrans* could reduce muscle electrical activity and body temperature, while improving attention and memory after exposure to the *Osmanthus* fragrance^[41]. Other studies have shown that inhaling *Perilla frutescens* for a period of time can relax university students and alleviate negative emotions^[42], while *Gardenia jasminoides* fragrance reduces stress and improves mood^[43]. The scent of *Gelsemium sempervirens* helps relieve anxiety, enhance attention, and regulate blood pressure^[44]. The plant *Jasminum polyanthum* triggers positive emotions and relaxation at different times of day, with evening exposure particularly effective in alleviating depression^[45].

2.3 Rose Landscape

The *Rosa* genus, a member of the Rosaceae family, includes perennial evergreen or deciduous shrubs with a variety of flower colors, forms, and extended flowering periods, and is renowned

for its rich fragrance and cultural significance^[46]. As one of the Ten Famous Traditional Flowers in China, roses are widely applied in landscape greening and home gardening. Their growth forms include shrub, tree, and climbing vine. Shrub roses are typically used for ground cover or in flower beds, often planted in clusters or patches. Tree-type roses, through a unique triple-grafting technique, are ornamental flower trees commonly seen in parks and gardens. Compared with shrub-type roses, tree roses are closer to human olfactory senses and emit more intense, lasting fragrances. The climbing vine type is ideal for vertical landscaping, and can be used in flower trellises and other structures to create floral walls, hedges, arches, pergolas, and gates^[47], creating romantic spatial atmospheres.

Most studies on roses have focused on their environmental resilience and ornamental value. For example, some proposed landscape configuration strategies based on regional characteristics^[48], or used analytic hierarchy process to evaluate rose varieties suitable for specific regions^[49]. Other studies employed scenic beauty estimation method and network analytic hierarchy process to assess rose landscapes in specialized gardens, providing insights into community configuration models of roses^{[50][51]}. Meanwhile, with the continuous development and popularization of horticultural therapy^[52], the therapeutic potential of rose landscapes is gaining recognition. However, the therapeutic benefits of rose color and fragrance have not been fully explored. Previous studies have found that rose essential oils can modulate sympathetic activity, thereby exerting calming and anti-anxiety effects^{[53][54]}. But the specific factors in rose landscapes that contribute to these therapeutic effects and their mechanisms of action and pathways for promoting human health remain unclear.

Thus, this study raises the following questions. 1) Can rose landscapes, through visual and olfactory perception, generate restorative benefits for the human health? 2) Which visual and olfactory factors yield the most significant restorative effects? And 3) is there an interaction between visual and olfactory perceptions? If so, which interaction model maximizes health benefits?

3 Research Materials and Methods

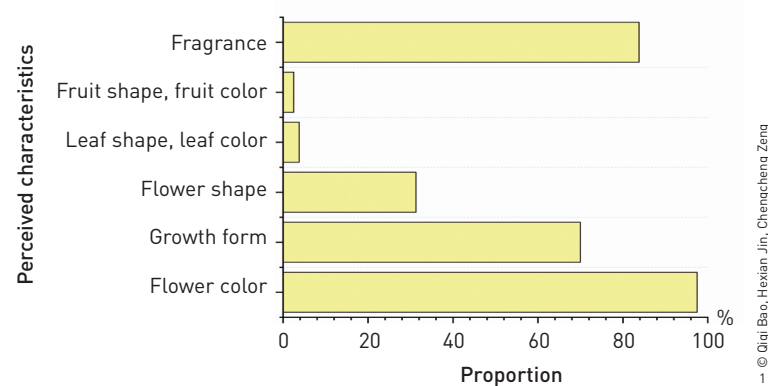
3.1 Preliminary Research

Given the representativeness of rose landscapes, the preliminary research of this study selected rose landscape sites in Hangzhou and Ningbo, China including the Rose Garden in the

Flower Square of Hangzhou Flower Nursery, the Rose Garden in Baima Lake Park, Dagan Park, and the Rose Garden in Ningbo Botanical Garden, known for their diverse rose varieties and landscaping styles. To investigate the public's visual and olfactory perceptions of rose landscapes, questionnaires and semi-structured interviews were conducted at each site. The questionnaires were distributed on April 22 ~ 23, 2023, with 20 for each site, totaling 80 responses. Respondents included university students, office workers, and retirees aged 17 to 65 years, comprising 32 males and 48 females.

According to the survey results (Fig. 1), flower color and fragrance type in rose landscapes were identified as the primary factors influencing visual and olfactory perception (as over 80% participants perceived). Therefore, this study selected color and fragrance type as visual and olfactory variables, respectively. In terms of visual traits, previous studies have categorized roses into ten primary color series: red, scarlet, white, yellow, orange, pink, blue-violet, green, multicolored, and bicolor^[55]. For fragrance types, the Rose Fragrance Institute Corp. in Japan used gas chromatography-mass spectrometry (GC-MS) to analyze the fragrance components of roses and classified them into several categories, including Fragrance of Damask Classic (classic rose scent), Fragrance of Damask Modern (modern rose scent), Fragrance of Tea, Fragrance of Fruity, Fragrance of Spicy, Fragrance of Myrrh, and Fragrance of Blue. Based on field surveys, this study found that white, orange, pink, red, yellow, and blue-violet roses were more commonly observed. Therefore, the visual variables in this research were defined as six color series, including white, orange, pink, red, yellow, and blue-violet. Semi-structured interviews conducted after the questionnaire survey revealed that the classic and modern rose scents were observed

1. Questionnaire results of the visual and olfactory perception of rose landscapes.



similar, while these two rose fragrances (“Fragrance of Rose” hereafter) and the Fragrance of Fruity were easily identifiable. Thus, the olfactory variables in this study were the Fragrance of Rose (FR) and Fragrance of Fruity (FF).











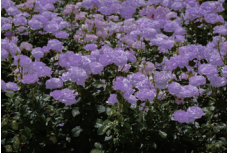

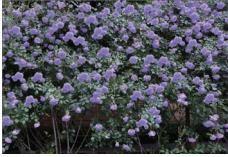
3.2 Experimental Material Collection and Processing

Visual landscape stimuli can be presented through real environmental experiences or simulated images. Since the latter is often conducted in controlled laboratory settings, it is more suitable for exploring interaction mechanisms between complex variables^[36]. In this study, the research team visited the study sites from April 25 to 30, 2023 (peak bloom time for roses), during clear weather conditions, specifically at 10:00 ~ 11:00 and 13:00 ~ 14:00. Using a Sony A6000 camera, photos of various colored rose landscapes were taken at a shooting height of around 1.6 m (close to typical human visual level) with a front-lit angle to minimize the impact of lighting. Each color series included three growth forms: shrub, tree, and climbing vine. To eliminate the interference of unrelated factors, such as differences in growth status, the colors of rose landscapes captured in photos were processed using ColorImpact and Photoshop software. This ensured consistency within each color series across different growth forms, and the color ratios for each series were standardized. As a result, six color series were processed into a total of 18 simulated rose landscape images, each with dimensions of 5,650 × 3,809 pixels (Table 1).

For olfactory materials, based on relevant research^[56], the following were selected: *Rosa* ‘Crimson Glory,’ a small climbing vine with dark red flowers and a cup-shaped bloom, for FR type; *Rosa* ‘Golden Celebration,’ a shrub with golden-yellow flowers and a cup-shaped bloom, for FF type.

The main compounds responsible for the rose fragrances were found in the petals and pollen^{[57][58]}. Therefore, fresh petals were collected as the olfactory source material. A pre-experiment was conducted to determine the optimal fragrance concentration. To ensure that the fragrance concentration approximated the actual scent experienced in the environment, fresh petals were placed in 500 ml sealed opaque, odorless, cylindrical polyethylene (PE) containers, with an opening on one side to allow olfactory testing. This method effectively simulated the natural volatile effect of the fragrance^[59], while preventing visual interference during the olfactory evaluation. Six different weights (120 g, 100 g, 80 g, 60 g, 40 g, and 20 g) were tested to evaluate the perceived fragrance concentration. The results indicated the highest perception scores at 60 g and 40 g, for which an average value of 50 g was chosen for

Table 1: Experiment materials for visual variables of rose landscapes

Color	Growth form		
	Shrub	Tree	Climbing vine
White			
Orange			
Pink			
Red			
Yellow			
Blue-violet			

the olfactory concentration. For accuracy concern, rose petals were collected half or an hour before the experiment, with equal weights prepared for both fragrance types.

3.3 Experiment Location and Timing

The experiment was conducted in the engineering laboratory at the Donghu Campus of Zhejiang A&F University. During the experiment, doors and windows were closed, and the curtains were drawn to eliminate the impact of noise and lighting differences.

The experiment was carried out from May 10 to 24, 2023, during specific periods of 8:30 ~ 11:30, 13:30 ~ 16:30, and 18:30 ~ 21:30. The indoor temperature and humidity were maintained at around 26°C and 55%, respectively.

3.4 Participants

A total of 240 university student volunteers were recruited via campus posters. Participants were aged between 18 and 25, with normal body mass index, olfactory and visual abilities, and none had taken hormonal medications in the past six months. They were instructed to get sufficient sleep 24 hours before the experiment and to avoid consuming alcohol, tobacco, or coffee. Before the experiment, the staff explained the procedure and equipment usage in detail, and all participants signed an informed consent form.

3.5 Experiment Procedure

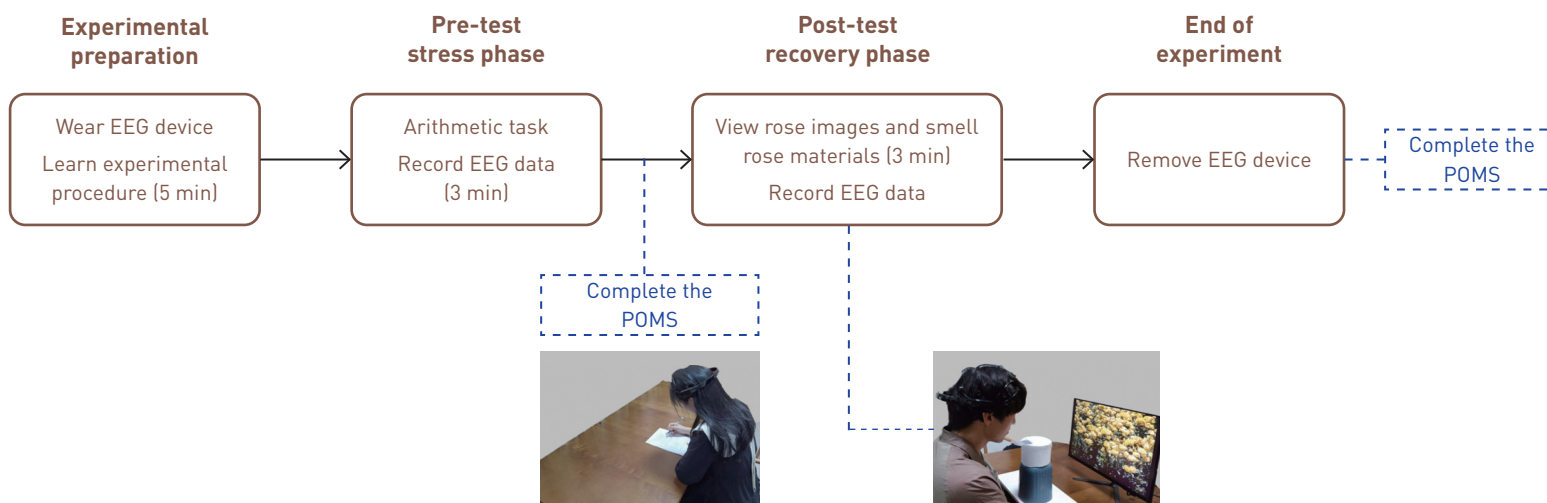
Previous research has indicated that exposure to natural environments for 3 ~ 5 min can yield better restorative effects^[60]. This experiment consisted of two phases: a pre-test stress phase and a post-test recovery phase, each lasting 3 min, with a total experiment duration of 20 min. The 240 participants were randomly assigned to 12 sensory groups combining the six color series with the two fragrance types (20 participants per group). Before the experiment, participants wore the EMOTIV EPOC-X device to collect EEG data and sat quietly for 5 min. The experiment began with a series of arithmetic tasks designed to induce stress while EEG data was collected. After the pre-test phase, participants completed the POMS to assess their emotional state. During the post-test recovery phase, participants viewed rose images (three images for each color series, with each displayed for 1 min) on

a screen while smelling rose materials placed in the opaque containers. EEG data continued to be collected during this phase. Afterward, participants removed the EEG devices and completed the POMS scale (Fig. 2). Between each session, the room was ventilated for 5 min to remove residual odors.

3.6 Physiological and Psychological Data Collection

Physiological indicators were analyzed using EEG data collected from the EMOTIV EPOC-X device. The device's 14 electrodes cover four brain regions: the parietal lobe, responsible for sensory processing and language function; the occipital lobe, which processes visual information; the frontal lobe, reflecting emotions, language, cognition, and behavior; and the temporal lobe, supporting auditory processing and language functions^[61]. Different EEG frequency bands reflect specific states: Alpha waves (8 ~ 13 Hz) represent relaxation and are highly associated with pleasure; Beta waves (14 ~ 30 Hz) reflect mental alertness and attention, as well as emotions such as anxiety, anger, tension, focus, and excitement^[62]; Theta waves (4 ~ 7 Hz) indicate low physiological arousal (fatigue, lack of vitality). The β/α ratio describes the impact of stress on the nervous system^[63], with a higher ratio indicating higher stress or alertness. The θ/β ratio assesses attention-related neural performance^[64], with a lower ratio indicating better focus. Thus, this study used the β/α ratio to assess stress levels and the θ/β ratio to evaluate attention levels.

Psychological indicators were primarily assessed using the POMS to evaluate emotional states. This study employed a simplified version of the POMS^[65], which includes 7 emotional states (40 feelings) rated on a 5-point scale (1 = very little, 5 = very much). These emotional states, i.e. tension, anger, fatigue,



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2. Experimental procedure.

depression, energy, panic, and self-esteem^①, were further combined into three indicators: positive emotion score, negative emotion score, and total mood disturbance score (Table 2).

3.7 Statistical Analysis

Data analysis was conducted using SPSS 26.0 software. Firstly, paired sample *t*-tests were performed to analyze changes in the β/α and θ/β ratios and POMS emotional states during the stress and recovery phases. Then, a covariance analysis was conducted on the physiological and psychological indicators of the 12 groups, using corresponding indicators from the stress phase as a covariate to eliminate baseline differences and to assess the main effects of the visual and olfactory variables. Simple effects analysis was performed for significant interactions observed between visual and olfactory variables.

4 Research Results

4.1 Physiological Recovery Benefits of Visual-Olfactory Perception

The results of the paired sample *t*-test^② revealed significant differences in the β/α and θ/β ratios across four brain regions during the stress ($p = 0.015$)^③ and recovery ($p = 0.021$) phases (Fig. 3). During the recovery phase, following exposure to the 12 combinations of different rose-colored and scented landscapes, the β/α and θ/β ratios significantly decreased compared with the stress phase. This indicates a marked improvement in participants' stress levels and a notable increase in their attention levels.

4.1.1 Stress-Related Indicators

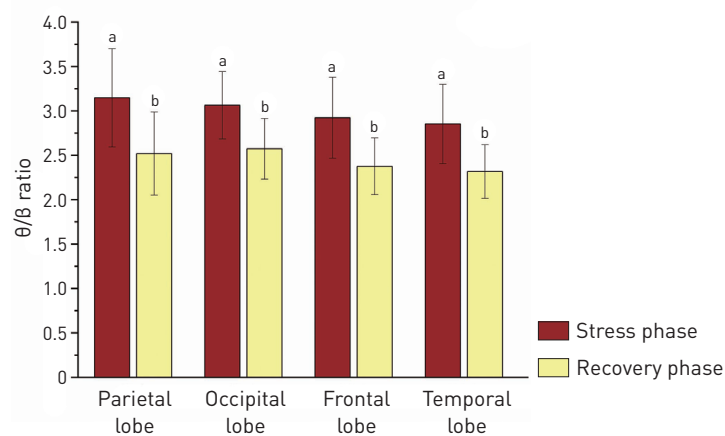
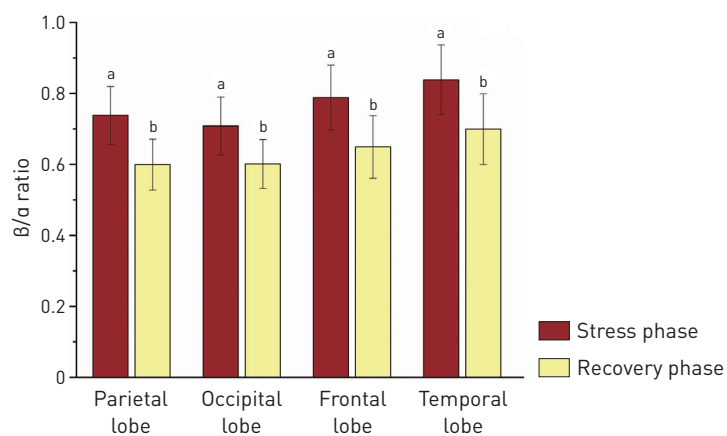
Covariance analysis of the β/α ratios in the four brain regions showed a significant main effect^④ of color in the parietal ($p = 0.011$), occipital ($p = 0.023$), and frontal ($p = 0.026$) regions, but no

Table 2: Calculation methods for psychological indicators

Indicator	Calculation method
Positive emotion score	Total score of "energy" and "self-esteem"
Negative emotion score	Total score of "tension," "anger," "fatigue," "depression," and "panic"
Total mood disturbance score	Negative emotion score – positive emotion score + 100 score

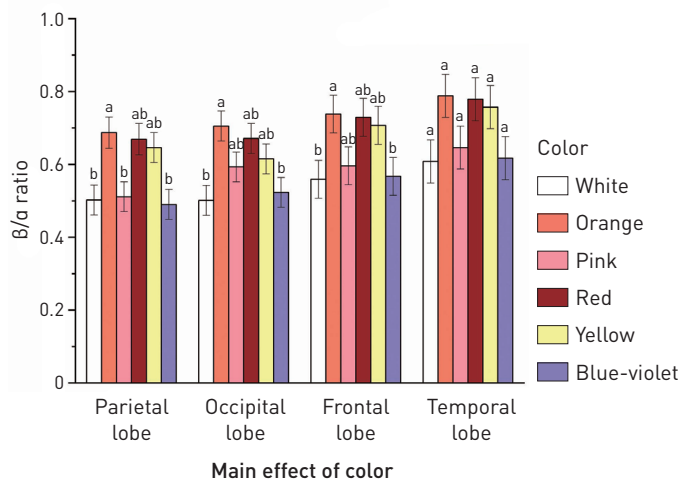
- ① Detailed content of the POMS used in this study is provided in the supplementary materials.
- ② In the paired sample *t*-test analysis results, letters a and b indicate statistical significance—same letters between groups indicate no significant difference ($p > 0.05$), while different letters indicate significant difference ($p < 0.05$).
- ③ The significance values used in this study were based on the median.
- ④ In the main effect analysis results, letters a and b indicate statistical significance—same letters between groups indicate no significant difference ($p > 0.05$), while different letters indicate significant difference ($p < 0.05$).

significant effect in the temporal region ($p = 0.080$). Specifically, the orange series exhibited the highest β/α ratios in the parietal ($M = 0.687$), occipital ($M = 0.705$), and frontal ($M = 0.738$) regions, while the white color had the lowest β/α ratios in the occipital ($M = 0.501$) and frontal ($M = 0.559$) regions. The blue-violet color also displayed lower β/α ratios in the occipital ($M = 0.523$) and frontal ($M = 0.567$) regions (Fig. 4-1). These results suggest that white and blue-violet roses are more effective in alleviating stress. However, the main effect of fragrance was not significant in the occipital, frontal, or temporal brain regions ($p > 0.05$), with only a significant main effect found in the parietal region ($p = 0.031$). In particular, FR ($M = 0.621$) had a significantly higher β/α ratio than FF ($M = 0.548$) (Fig. 4-2), suggesting that the latter fragrance

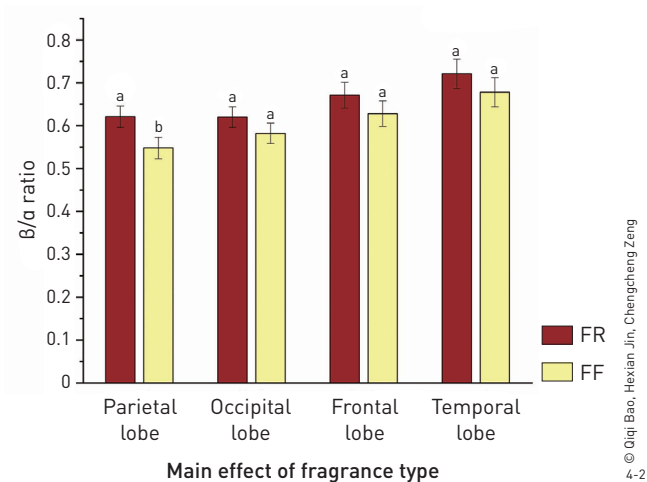


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3. Paired sample *t*-test results for β/α and θ/β ratios.

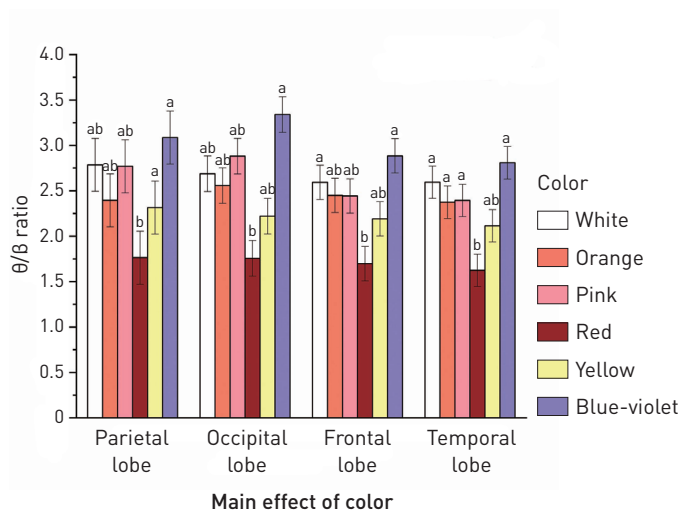


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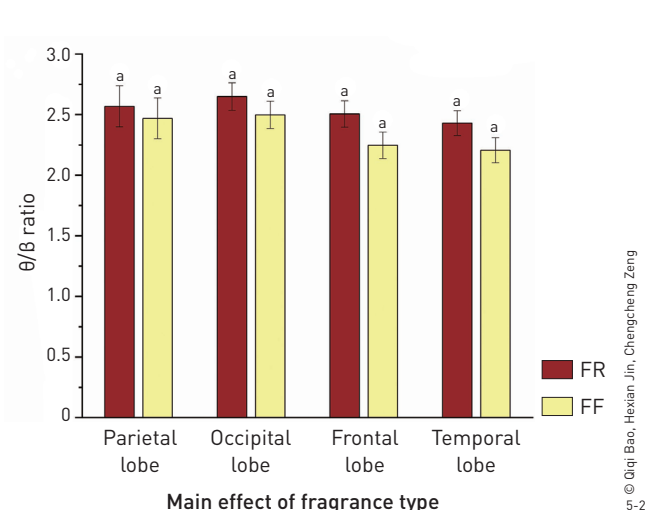


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4. Main effect analysis results for B/a ratios.
5. Main effect analysis results for θ/β ratios.



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- ⑤ In the simple effects analysis results, letters a and b indicate statistical significance—same letters between groups indicate no significant difference ($p > 0.05$), while different letters indicate significant difference ($p < 0.05$).

is more effective in relieving stress. Furthermore, no significant interaction effects were found between color and fragrance type in any brain regions ($p > 0.05$), indicating no notable interaction between these factors in terms of stress indicators.

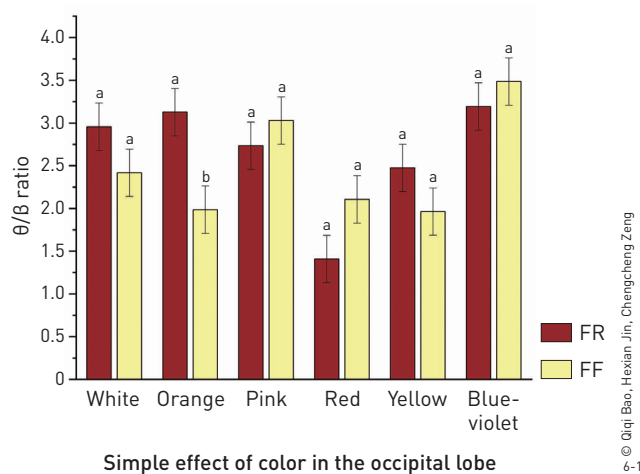
4.1.2 Attention-Related Indicators

Covariance analysis of the θ/β ratios showed no significant main effect of fragrance in any of the four brain regions ($p > 0.05$), but a significant main effect of color was found in all regions ($p = 0.029$, $p = 0.014$, $p = 0.021$, and $p = 0.017$, respectively). Interaction effects between color and fragrance were significant in the occipital ($p = 0.010$) and temporal ($p = 0.036$) regions. The color analysis showed that the red color had the lowest θ/β ratios across all regions, while the blue-violet color had the highest (Fig. 5), indicating that red roses are most effective in restoring attention. Simple effects analysis^⑤ of the significant interactions revealed the following results: 1) In the occipital region, FR with the orange color had significantly higher θ/β ratios than FF, with

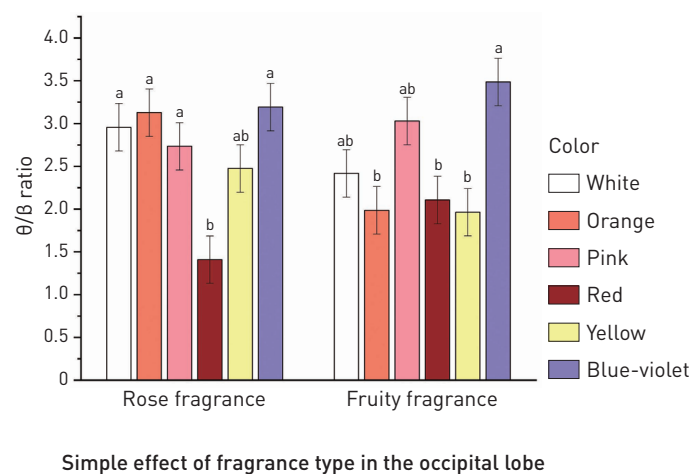
no significant difference between the two fragrances in other colors (Fig. 6-1). In the FR condition, the blue-violet color had the highest θ/β ratios, but the red color had the lowest; while under FF, the blue-violet color had the highest and the yellow had the lowest (Fig. 6-2). In the temporal region, FR with the orange color had significantly higher θ/β ratios than FF (Fig. 7-1). Under FR, the orange color had the highest θ/β ratios, but the red had the lowest; while under FF, the blue-violet color had the highest and the orange had the lowest (Fig. 7-2). These results suggest that yellow and orange colors with FF, and red color with FR, are more effective in enhancing attention.

4.2 Psychological Recovery Benefits of Visual-Olfactory Perception

The paired t -test results for the POMS indicators during the stress and recovery phases showed significant changes in tension ($p = 0.025$), anger ($p = 0.015$), fatigue ($p = 0.011$), depression ($p = 0.035$), energy ($p = 0.042$), panic ($p = 0.033$), self-esteem

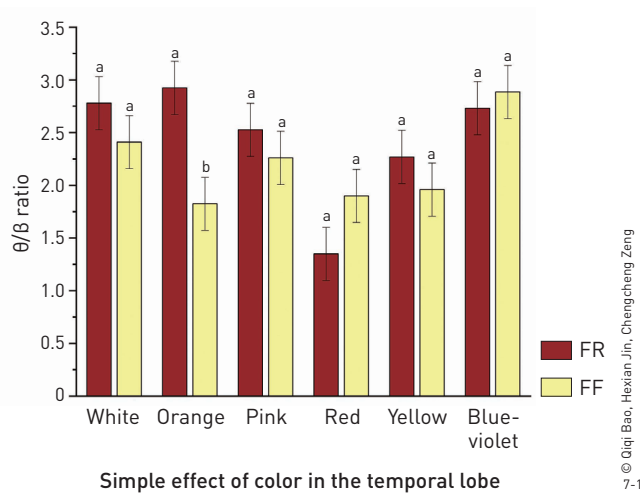


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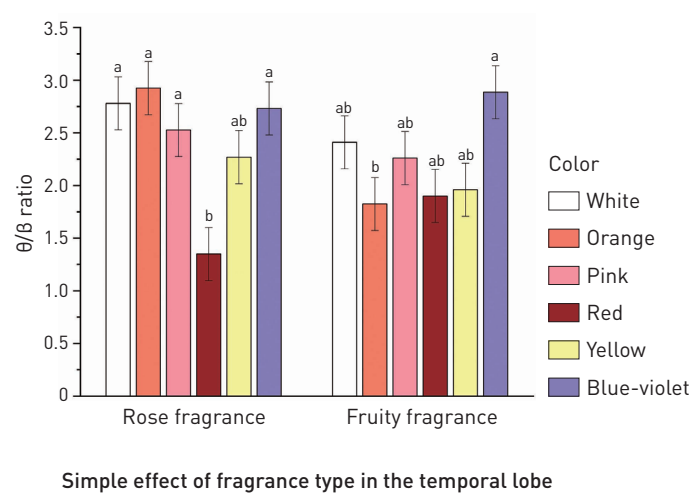


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6. Simple effect analysis results for θ/β ratios in the occipital lobe.
7. Simple effect analysis results for θ/β ratios in the temporal lobe.



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($p = 0.036$), as well as positive emotion score ($p = 0.039$), negative emotion score ($p = 0.022$), and total mood disturbance score ($p = 0.019$) before and after the experiment (Fig. 8). During the recovery phase, following visual-olfactory stimulation with rose-colored and scented landscapes, participants exhibited a significant increase in positive emotions, while negative emotions and total mood disturbance showed a decreasing trend.

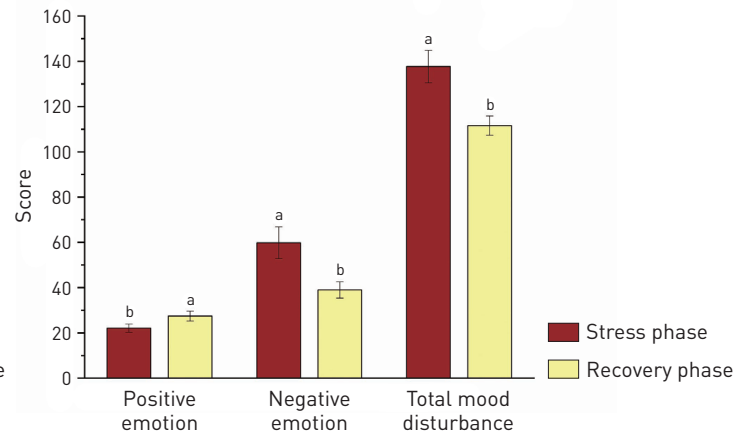
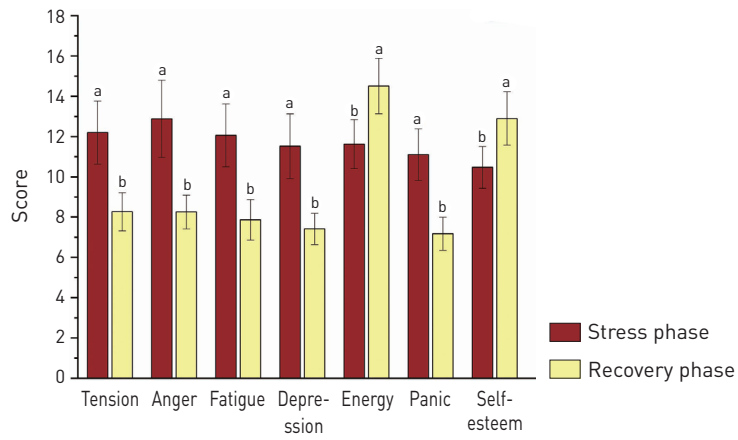
Covariance analysis of the POMS emotional indicators across different visual-olfactory interaction groups revealed no significant differences between the FR and FF types for three emotional indicators ($p > 0.05$). However, a significant main effect of color was found for self-esteem and energy ($p = 0.010$), along with a significant interaction effect between color and fragrance type ($p = 0.013$). As shown in Fig. 9, the blue-violet color induced the lowest positive emotion scores, while the red and yellow colors induced the highest positive emotion scores. Simple effects analysis of the significant interaction effect for positive emotions revealed the following results. 1) In the orange color, FF induced significantly

higher positive emotion scores than FR, whereas the reverse was observed in the red color. No significant differences were found between the two fragrance types in other colors (Fig. 10). 2) In the FR type, the red color induced the highest positive emotion scores, while the orange color induced the lowest. In the FF type, the yellow color induced the highest positive emotion scores, while the white and blue-violet colors induced the lowest.

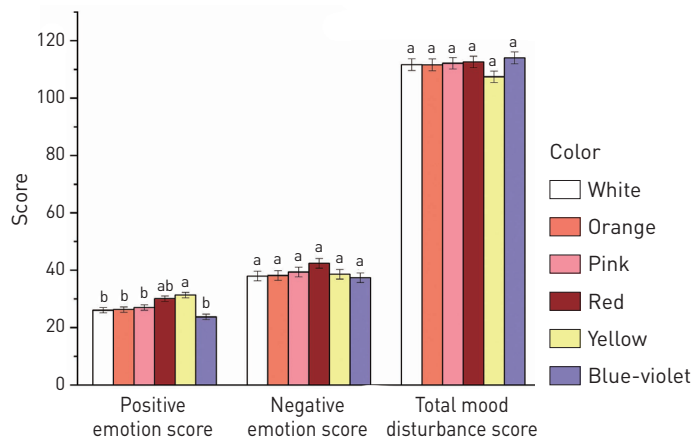
In conclusion, different colors, fragrance types, and their interactions had varying degrees of impact on participants' mental and physical health indicators, including stress, attention, and emotional states.

5 Conclusions and Discussion

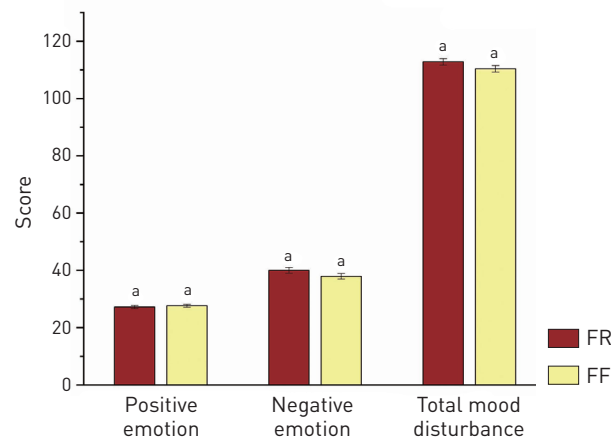
This study, based on the perspective of visual-olfactory interactive perception, explored the restorative benefits and differences experienced by participants when exposed to different color and fragrance combinations of rose landscapes. The findings



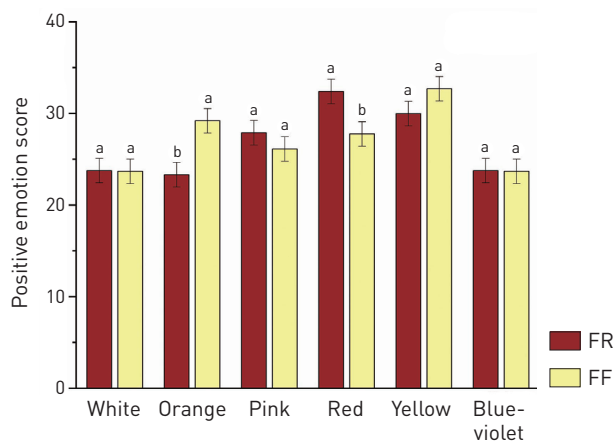
8. Paired sample t-test results for emotional indicators in POMS.
9. Main effect analysis results for emotional indicators in POMS.
10. Simple effect analysis results for emotional indicators in POMS.



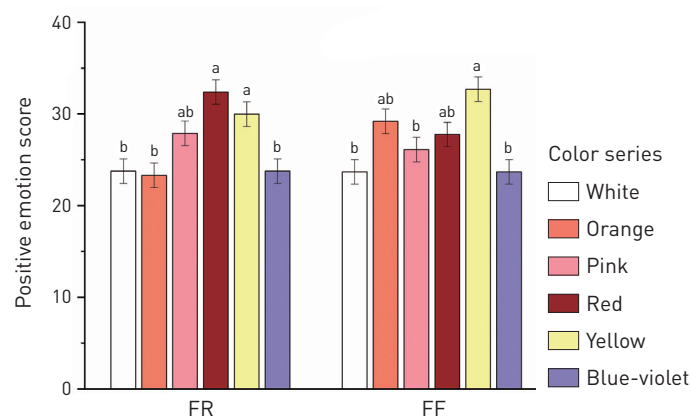
Main effect of color



Main effect of fragrance type



Simple effect of color



Simple effect of fragrance type

provide scientific evidence on how the appropriate pairing of colors and fragrances in rose landscapes can maximize the health benefits. The results showed significant differences in stress reduction, attention recovery, and improvement of emotional health among various combinations. The main conclusions are as follows.

1) Visual-olfactory perception of rose landscapes generates positive restorative effects. The experimental results demonstrated

positive changes in participants' mental health indicators when exposed to different color and fragrance combinations in rose landscapes. Specifically, the β/α ratio, which represents stress levels, significantly decreased, and the θ/β ratio, representing attention levels, also showed a significant reduction. The POMS results revealed a significant increase in positive emotions and a decrease in negative emotions. According to the Stress Reduction

Theory, humans have evolved with a long-term dependence on natural environments, and a pleasant natural setting (such as beautiful plant landscapes) can activate parasympathetic nervous activity, significantly relieving mental stress and promoting emotional relaxation^[61]. The Attention Restoration Theory suggests that natural environments, characterized by features such as “being away,” “fascination,” “extent,” and “compatibility,” help enhance cognitive function and attention levels^[66]. Previous research has also confirmed the positive health benefits of flowering plants^[67]. Therefore, the visual stimulation from the rich colors of roses, combined with the olfactory stimulation from their pleasing fragrances, can improve well-being, reduce sympathetic nervous activity, alleviate stress, and promote attention recovery.

2) Cool-toned and fruity-scented roses relieve physiological stress more effectively. The findings showed that white and blue-violet roses induced lower β/α ratios in the parietal, occipital, and frontal lobes, suggesting that these colors, compared with warmer colors like red and orange, are more effective in improving the brain’s stress response. Similarly, roses with FF showed a lower β/α ratio in the parietal region compared to those with FR, demonstrating stronger stress relief effects. Existing studies have also found that white and blue flowers are most effective in relieving tension and stress^[68], which aligns with the results of this study. Additionally, research on the effects of rose essential oils on emotions showed that rose oils can effectively reduce anxiety and improve sleep quality among healthcare workers^[69]. In this study, FF roses were found to alleviate stress more effectively than FR roses, possibly due to the presence of volatile substances like hexyl acetate, which have a calming effect and significantly promote relaxation^[70].

3) Warm-toned roses and their combinations with both fragrances enhance attention recovery and positive emotions. According to the results of this study, the red color generated the lowest θ/β ratio across four brain regions, indicating that red roses are the most effective for attention recovery. Moreover, interaction results revealed that combinations such as red–FR, yellow–FF, and orange–FF significantly enhance attention recovery. Relevant studies suggest that red plants can activate brain regions that control attention and focus, making them particularly effective for improving attention levels^{[71][72]}. Yellow flowers, by enhancing relative Theta power spectrum in the occipital region, can also effectively improve attention and boost pleasant feelings^[71]. Additionally, the fragrance of roses contributes to the enhancement of Beta waves, creating an environment conducive to concentration and calmness^[73]. As previously mentioned, the interaction between

visual and olfactory stimuli affects perceptual preferences and attention, which explains the outstanding performance of the red–FR combination in attention recovery.

The POMS results showed that red and yellow roses produced the highest scores for positive emotions. Interaction results indicated that the red–FR and yellow–FF combinations produced higher positive emotion scores than other combinations. This is consistent with many studies. For example, an experiment on the association between emotional words and colors found that the color of yellow was most frequently linked to positive emotions, while red was associated with passion^[74]. Another study on the effects of different colored cut flowers on psychological states reported that red flowers elicited feelings of “intensity” and “vitality,” while yellow flowers were associated with “warmth” and “energy”^[75]. After exposure to red and yellow flowers, participants showed a significant increase in parasympathetic nervous activity and positive emotional states such as energy^[76]. Furthermore, a study found that after 4 min of exposure to pink roses, the high-frequency components of participants’ heart rate variability significantly increased, and their comfort levels noticeably improved^[77], which aligns with the findings of this study. Some scholars have pointed out that color not only influences the pleasantness of a fragrance but also activates corresponding olfactory images, often involving a blend of all scents associated with that color. For example, yellow is commonly associated with the scent of lemon, i.e. the fragrance that matches this color the most dominates the perception, while combinations that contradict sensory expectations are less pleasant^[78]. Therefore, color and fragrance combinations that align with sensory expectations tend to elicit positive emotional responses.

4) Color has a greater effect on attention and positive emotions than fragrance. In this study, the main effects of colors on the θ/β ratios and positive emotion scores were significant, while those of fragrance were not. This suggests that in rose landscapes, color has a much greater impact on attention and positive emotions than fragrance. Related studies have found that visual stimuli from *Osmanthus* landscapes have a more pronounced effect on sympathetic nervous activity than olfactory stimuli, meaning that viewing *Osmanthus* flowers is more effective in promoting attention recovery and arousing emotions than smelling the flowers^[79]. This difference supports the view that vision is the primary sensory channel for receiving environmental information^[80].

In planning and designing rose landscapes, it is recommended

to prioritize sensory experiences, including visual and olfactory perceptions, and tailor designs to specific health needs to maximize the therapeutic value of rose gardens. Based on the analysis results of main and interaction effects together with practical applications of roses, it is suggested to increase the proportion of white, blue-violet, and FF roses in spaces for rest and meditation, while strategically incorporating yellow-FF roses to create floral corridors, pergolas, and archways that help relieve stress and soothe emotions. Alternatively, rose pathways can be designed through patch or mass planting, with seating provided for meditation and relaxation. For spaces requiring focus, vitality, and creativity, red and yellow roses should dominate, where the FR and FF varieties should be appropriately combined. These can be used to create flowerbeds and borders. Another option is to plant tree-shaped roses in rows to form a fragrant plant barrier, fully utilizing the attention-enhancing and emotional awakening benefits of such landscapes. Additionally, fountains and other dynamic water features can be added to these spaces to diffuse fragrances across a broader area through evaporation, thus enhancing the aromatherapy effects.

6 Limitations and Future Directions

Despite the valuable findings, this study has several limitations. Firstly, regarding the experimental design, landscape images combined with fresh flowers were used to simulate the environment, which may differ from real-world experiences. Therefore, future research could consider using virtual reality technology to create more realistic landscape experiences. Secondly, this study focused on university students as participants, lacking a comparative study of different age groups. Future research should evaluate individuals from various age groups, educational backgrounds, and cultural contexts to broaden the applicability of the results. Previous research has pointed out that the intensity of visual and olfactory stimuli varies with the duration of exposure: initially, vision predominates, while the olfactory effect is weaker; but as exposure time increases, the impact of olfaction gradually strengthens^[28]. This study only examined the immediate effects during the stress and recovery phases (both lasting 3 min), for which future studies can explore the long-term restorative effects or the sustained recovery processes. Finally, this study only observed the immediate effects of roses during their peak blooming period. Given that the flower shapes, colors, and fragrance compositions of roses differ at various growth stages, further research should

focus on their long-term restorative effects across different growth cycles, and delve deeper into the mediating effects and interaction mechanisms to derive conclusions that are more widely applicable.

ELECTRONIC SUPPLEMENTARY MATERIAL

Supplementary material is available in the online version of this article at <https://doi.org/10.15302/J-LAF-1-020104>.

Competing interests | The authors declare that they have no competing interests.

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视嗅感知下月季景观的恢复性效益研究

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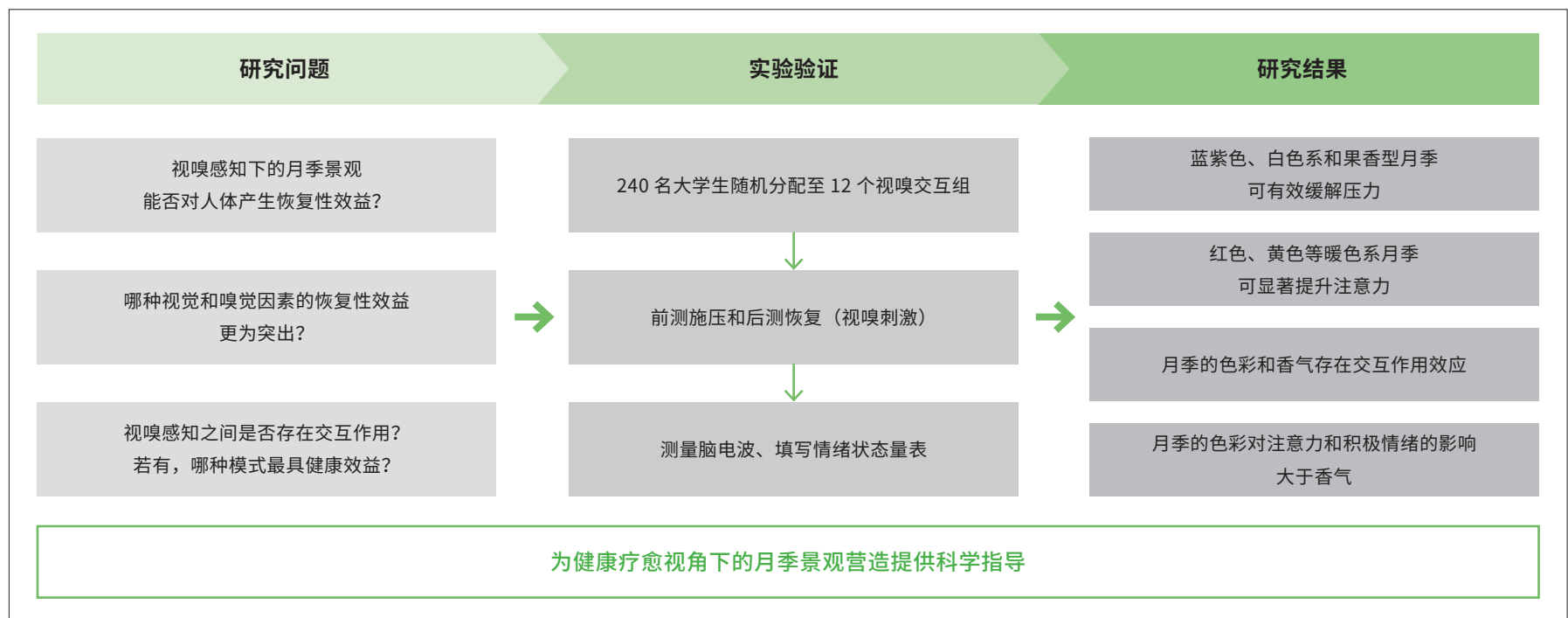
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图文摘要



摘要

植物景观在促进人体身心健康方面具有重要作用。月季具有丰富的花色和香气, 在城市绿化和家庭园艺中应用广泛。但以往研究尚未从感知交互视角探讨月季景观的健康恢复性效益。本研究选取大学生群体为受试者, 将其随机分配到由白色、橙色、粉色、红色、黄色、蓝紫色6种色系和玫瑰、果香2种香型组成的12个色彩与香气交互组中, 通过压力刺激和视嗅感知恢复实验, 结合脑电波和情绪状态等生理、心理数据分析, 评估了不同色系和香型月季对压力缓解、注意力恢复及情绪调节的具体影响。研究结果表明, 白色系和蓝紫色系月季在缓解压力方面表现突出, 果香型月季的压力缓解效果优于玫瑰香型; 而红色和黄色等暖色系月季在恢复注意力和提升积极情绪方面具有更佳的表现, 尤其是红色系-玫瑰香型及黄色系-果香型组合的效果最优。此外, 研究发现, 视

觉刺激在注意力恢复和积极情绪诱导中的作用显著大于嗅觉刺激。本研究还验证了视嗅交互作用在优化景观感知和增强健康效益中的潜力。基于上述发现, 本研究提出了月季景观的规划设计建议, 包括在不同功能用地中合理搭配色系和香型, 以充分发挥月季景观的疗愈价值。本研究为促进植物景观的健康疗愈功能提供了重要的科学依据, 同时为城市绿地及疗愈环境设计提供了新的思路。

关键词

月季景观; 视嗅感知; 色彩; 香气; 恢复性效益; 压力缓解; 注意力恢复

文章亮点

- 白色系和蓝紫色系月季能够显著缓解压力，且果香型优于玫瑰香型
- 红色系和黄色系月季，特别是红色系 - 玫瑰香型及黄色系 - 果香型组合，对注意力恢复和积极情绪提升效果更佳
- 视觉刺激对注意力和情绪的改善作用显著大于嗅觉刺激
- 探究视嗅感知视角下月季景观的恢复性效益可为疗愈环境设计提供支持

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1 引言

城市快节奏的生活导致人们与自然接触的机会大幅减少、频率逐渐降低，这对身心健康、人类福祉和社会凝聚力均产生了负面影响^[1]。近年来，亚健康状态在年轻人，尤其是大学生群体中愈发凸显。相关研究显示，大学生群体易出现睡眠障碍、身体素质下降等健康问题^[2]。大学生群体处于心理健康发展的重要时期，面临着家庭、学业、人际交往和就业等多方面的压力^[3]。

2016年中国卫生与健康大会明确了“切实解决影响广大人民群众健康的突出环境问题”等环境健康目标^[4]。根据世界卫生组织相关文件的定义，健康包括身体、心理及社会交往三个维度，即身体机能正常、心理状态良好和社会关系和谐^[5]。因此，构建能持续发挥积极干预效果的良好环境至关重要。已有研究证明，自然环境对人的生理、情感和注意力具

有积极影响^{[6][7]}。

绿地作为一种自然环境，在休闲娱乐和生态保健等方面具有广泛的健康效益^[8]。而植物作为绿地中最重要的组成部分，能够有效促进人体健康——例如，接触花卉可产生积极情绪，缓解压力、促进注意力恢复^[9]。在新冠疫情爆发期间，与植物的亲密接触发挥了一定的疗愈作用^[10]。月季花（*Rosa chinensis*，以下简称为“月季”）作为园林设计中广泛应用的植物，具有丰富的花色和迷人的花香，其挥发物成分具有较高的康养价值，是芳香疗法和医疗保健的重要资源。^{[11]-[13]}因此，充分探究月季景观对人体的健康干预效果及差异，对于健康人居环境的营造意义重大。

2 文献综述

2.1 景观感知

感知是人与环境交互的基础，而景观的体验则是通过多感官协调作用来实现的^[14]。植物作为人与自然环境接触的重要媒介，能提供丰富的感官刺激。例如，植物不同器官的色彩、形态带来视觉刺激，花、叶、果散发的香气产生嗅觉刺激，风吹、雨打枝叶产生听觉刺激，以及品尝可食植物从而产生味觉刺激等。

视觉感知是人体最主要的感知方式之一，为我们提供了丰富的环境信息^{[15][16]}。景观的视觉特征通常包括颜色、形状、大小，以及水平和垂直结构等^[17]。在植物的视觉感知中，使用者主要接收形状、大小、色彩和姿态等物理信息。相关研究指出，植物的色彩对观察者的视觉神经刺激程度最深，最先引起关注，其次是生长形态、大小等性状^[18]。同时，人类对不同色彩的植物具有不同的视觉敏感性^[19]，植物色彩直接作用于人的感官，产生生理和精神反应^[20]。相较于视觉景观感知，嗅觉感知往往被忽视。然而，与其他感官神经不同的是，嗅觉感知神经与大脑中枢神经直接相连，而中枢神经掌控人的语言沟通、记忆及情绪。因此，相比其他感官，嗅觉能更直接地激发人们的情感，气味通过嗅觉系统对情绪、认知和行为产生显著影响^[21]。

此外，不同的感官之间可能产生交互作用，进而影响景观感知。已有研究证实，视觉可促进嗅觉感知^[22]，而嗅觉也能在一定程度上影响对环境氛围的感知^[23]。相比单一的视觉感知，嗅觉的参与能显著提升人体对环境生物多样性的感知，进而提高环境对健康的恢复效果^[24]。嗅觉的不同特性也可调节视觉注意力^[25]，如气味可以增强对视觉一致对象的注意力^[26]，且随着二者一致性的提高，相应场景下的愉悦度也会有所提升^[27]。一项针对森林景观感知的研究表明，视嗅耦合的感知方式对生理和心理的放松效果显著高于单一感知刺激^[28]，且视嗅感知的一致性可以提高人们对植物景观的评价^[29]。

值得注意的是，人的感知还会影响景观偏好，以及对满意度和舒适度的评价^[30]。其中，景观偏好源于参与者经过“感”和“知”后对景观

的喜好或厌恶等评价^[31]，不仅与人暴露于环境中的认知和情感反应等心理状态有关^[32]，也与环境中的身心恢复效益相关^[33]。有研究指出，植物景观偏好对心理恢复存在显著积极影响^[34]，树木、花卉的存在不仅提高了受访者对景观的评价，还有助于精神压力的恢复^[35]。

尽管已有少数研究关注到视觉和嗅觉刺激组合对身心健康的影响，或探讨视嗅感知刺激如何影响大众的景观体验，但从多感官交互角度探究植物景观对身心健康效益的研究仍较少。

2.2 植物景观与身心健康

脑电波、血压、心率变异性等生理评估，以及情绪状态量表（POMS）等心理评估工具常被用于探索植物景观与人体身心健康之间的关联。^{[36]-[38]}有研究使用眼动追踪技术和语义差异量表，证明黄绿色和亮绿色的植物叶片相比其他颜色更能吸引人的注意力，且这两种颜色的叶片可以诱导愉快和放松的情绪，而绿白相间的叶片则会带来负面情绪^[39]。另有研究分析了不同色系和比例的植物群落图像对人体放松程度的影响，指出绿色和黄色植物群落的放松效果优于红色植物，且当颜色比例为绿色55%、黄色25%和红色20%时，放松效果最佳^[40]。

此外，许多学者通过生理、心理实验证实，嗅闻植物香气会对人体健康产生积极影响。例如，金荷仙发现，梅花（*Prunus mume*）和桂花（*Osmanthus fragrans*）的香气均能降低人的肌电值和体温，且嗅闻桂花香气后的注意力和记忆力均有所提升^[41]。另有研究表明，嗅闻紫苏（*Perilla frutescens*）一段时间后能使大学生精神放松并减少其消极情绪^[42]，嗅闻栀子（*Gardenia jasminoides*）香气能缓解压力、改善情绪^[43]，嗅闻常绿钩吻藤（*Gelsemium sempervirens*）则可缓解焦虑情绪、提高注意力水平并调节血压^[44]。在不同时段嗅闻多花素馨（*Jasminum polyanthum*）均能激发积极情绪、使人放松，且晚间时段对缓解抑郁有更好的效果^[45]。

2.3 月季景观

月季属蔷薇科，是多年生的常绿或落叶灌木，其花色、花型多样，花期长，花香馥郁且文化内涵丰富^[46]，是中国传统十大名花之一，已广泛应用于城市绿化和家庭园艺。月季的生长形态主要分为灌木型、树状型和攀援藤本型。灌木型可作地被，多应用于园林中的花境或花边，常以片植、丛植形式出现。树状月季通过独特的三重嫁接技术形成具有观赏价值的花树，常见于公园和庭院；相较于灌木型月季，与人的嗅闻感官高度更为接近，且花香更加浓郁、持久。藤本攀援型是垂直绿化的良好材料，利用花架等可形成花墙、树篱、拱门、廊架、花门和花柱^[47]，营造烂漫的空间氛围。

多数研究主要关注月季所具备的环境韧性和观赏性。例如，根据不同地域特点制定针对性的景观配置策略^[48]，或使用层次分析法综合评价

并推荐适合该地区应用的月季品种^[49]。亦有研究使用美景度评价法、网络层次分析法构建月季景观评价模型，对月季专类园中的月季景观进行评价，总结出可参考借鉴的月季植物群落配置模式^{[50][51]}。与此同时，随着园艺疗法的不断普及与发展^[52]，月季景观的健康疗愈潜力逐渐受到关注。然而，目前月季的丰富花色和香气所具备的疗愈效益尚未得到充分挖掘。虽有研究发现月季精油可降低交感神经活性，从而发挥镇静及抗焦虑作用^{[53][54]}，但关于月季景观中的哪些因素具有疗愈作用、各因素间的作用机制及其对人体健康的干预途径仍不明确。

综上，本研究提出以下问题：1）视嗅感知下的月季景观能否对人体产生恢复性效益？2）哪种视觉和嗅觉因素的恢复性效益更为突出？3）视嗅感知之间是否存在交互作用？若有，哪种模式最具健康效益？

3 研究材料和方法

3.1 前期调研

从月季景观的代表性出发，本研究选择了月季品种繁多、造景形式丰富的位于杭州市主城区的杭州花圃茼花广场月季园、白马湖公园月季园、大关公园，以及位于宁波市的宁波植物园月季园作为研究样地。为探究公众对月季景观的视觉和嗅觉感知情况，研究在多样地发放问卷并进行半结构访谈。问卷发放时间为2023年4月22~23日，每个场地发放20份，共计80份。受访者包括大学生、上班族、退休人员等，年龄区间为18~65岁，其中男性32名、女性48名。

由问卷调查结果（图1）可知，月季景观中的花色和香型是最主要的视嗅感知因素（80%以上受访者认同），因此本研究将色系和香型分别作为视觉和嗅觉变量。就视觉性状而言，有研究者按花色将月季划分为红、朱红、白、黄、橙、粉、蓝紫、绿、混色及表里双色等十大色系^[55]。在香型方面，日本蓬田蔷薇香味研究所使用气相色谱/质谱（GC/MS）技术分析月季的香气成分，并将其分为大马士革古典香型（经典玫瑰香型）、大马士革现代香型（现代玫瑰香型）、茶香型、果香型、辛香型、没药香型和蓝香型。根据实地调研结果，本研究发现白、橙、粉、红、黄和蓝紫色月季较为常见，故视觉变量包括白色系、橙色系、粉色系、红色系、黄色系和蓝紫色系。问卷调查后开展的半结构访谈结果表明，两种玫瑰香型的嗅感相近，受访者能明确识别出玫瑰香型和果香型，因此嗅觉变量为玫瑰香型和果香型。

3.2 实验材料采集和处理

视觉景观刺激可通过真实环境体验或模拟图像体验的方式进行，由于后者常在条件可控的实验室中开展，因而更适合变量复杂且需探究其相互作用机制的情境^[36]。研究团队于2023年4月25~30日（月季盛花期）前往样地，选择天气晴朗的上午10:00~11:00以及下午1:00~2:00，使用

Sony A6000相机拍摄不同色系的月季景观，保证拍摄高度距离地面1.60m左右（此高度基本符合人的视觉习惯），且选择顺光角度以避免光照因素的影响。每个色系均包含灌木、树状和攀援藤本三种生长形态。为排除生长状态差异等因素的干扰，本研究根据拍摄而得的真实月季景观色彩，在现实生长形态的基础上使用ColorImpact和Photoshop软件进行图像处理，确保每种色系下不同生长形态月季的色彩基本一致、每种色系色彩比例相当。经过上述处理，得到6个色系共18张模拟月季景观图片作为视觉刺激变量，所有图片的尺寸均为5 650×3 809像素（表1）。

而后，根据相关研究^[56]选择墨红月季（*Rosa* ‘Crimson Glory’，小型藤本、花深红色、杯状花型）作为玫瑰香型材料，选择黄金庆典月季（*Rosa* ‘Golden Celebration’，灌木、花金黄色、杯状花型）作为果香型材料。

月季气味的主要化合物存在于花瓣和花粉中^{[57][58]}，因此研究选取新鲜花瓣作为嗅源材料。为确保气味浓度更接近实际环境中闻到的气味，在正式试验前开展嗅觉感知预实验，将新鲜花瓣置于容量为500ml的不透明无味圆柱形聚乙烯（PE）封闭容器中保存，容器一侧的开口于嗅觉测试时开启——该方法可有效模拟挥发性物质的真实作用^[59]，不透明装置亦可消除视觉刺激对嗅觉判断产生的干扰。设置6种气味浓度（花瓣重量分别为120g、100g、80g、60g、40g和20g）供志愿者评分。结果显示，60g和40g条件下的感知评分最高，故取其平均值50g作为嗅觉浓度。为保证实验中植物气味的准确性，在实验开始前0.5~1小时内采集月季花瓣，且确保两种香型花瓣重量一致。

3.3 实验地点与时间

实验在浙江农林大学东湖校区的工程实验室中进行，过程中关闭门窗并拉上窗帘，以规避噪声和光线差异等因素的影响。实验于2023年5月10~24日进行，具体时段为上午8:30~11:30、下午1:30~4:30，以及晚间6:30~9:30。室内温度和湿度分别保持在26℃、55%左右。
















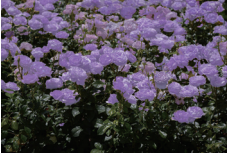

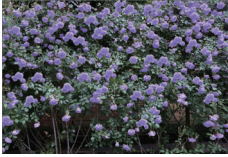
3.4 受试者

通过校园海报招募大学生志愿者共240名。受试者年龄为18~25岁，体重指数、嗅觉和视力均在正常范围内，且最近半年内未服用任何激素药物。所有受试者被要求在实验前24小时保持充足睡眠、不摄入烟酒和咖啡。在实验开始前，工作人员还需向每位受试者介绍完整实验流程及相关设备的佩戴要求，并签署知情同意书。

3.5 实验流程

相关研究表明，接触自然环境3~5分钟可以得到较好的恢复效果^[60]。本实验分为前测施压和后测恢复两个阶段，时长各3分钟，实验总时长为20分钟。240名受试者被随机分配到由6个色系和2种香型组成的12个交互

表1：月季景观视觉变量实验材料

色系	生长形态		
	灌木	树状	攀援藤本
白色系			
橙色系			
粉色系			
红色系			
黄色系			
蓝紫色系			

组中，每组20人。实验开始前，受试者在工作人员的帮助下佩戴用于采集脑电数据的EMOTIV EPOC-X设备，静坐5分钟后开始实验。首先进行计算题施压任务，同时采集脑波数据；前测结束后，受试者填写POMS量表以评估情绪状态。在后测恢复阶段，受试者观看显示屏上播放的月季图片（每个色系3张图、每张播放1分钟），同时嗅闻不透明盒子中的月季材料，采集脑波数据。实验结束后，由工作人员帮助摘除脑电设备，受试者填写POMS量表（图2）。每次实验结束后，打开门窗通风5分钟，去除空气中的残留气味。

3.6 生理和心理数据采集

本研究采用EMOTIV EPOC-X设备收集的脑电信号进行生理指标分析。设备的14个电极覆盖4个大脑区域：顶叶区支持感觉处理和语言功能，枕叶区反映视觉信息，额叶区反映情绪、语言、认知和行为，颞叶区支持听觉处理和语言功能^[61]。不同的脑电波段反映特定的状态： α 波（8~13Hz）代表放松状态，与愉悦高度相关； β 波（14~30Hz）反映精神警觉性和注意力，以及焦虑、愤怒、紧张、专注和兴奋等情绪^[62]； θ 波（4~7Hz）频率低，反映低生理唤醒状态（疲倦、缺乏活力）。 β/α 指标用于描述压力对神经系统的影响^[63]，二者呈正相关，当比值较高时，表示压力或警觉性较高； θ/β 指标用于描述与注意力相关的神经表现^[64]，二者呈负相关，当比值较低时，表示注意力越集中。因此，本研究采用 β/α 指标评估压力水平， θ/β 指标评估注意力水平。

心理指标主要通过POMS量表评估情绪状态。本研究采用祝蓓里修订的简式POMS量表^[65]，包含7类共40种感受。采用五级评分法（1~5分别表示“非常少”“较少”“适中”“较多”“非常多”）对40种感受进行打分，所得得分用于计算紧张、愤怒、疲劳、抑郁、精力、恐慌和自尊7类情绪状态的分值^①。最后，这些情绪状态将被进一步组合为3项指标，即积极情绪分值、消极情绪分值和情绪纷乱总值（表2）。

3.7 统计分析

使用SPSS26.0软件进行数据分析。首先，采用配对样本 t 检验分析施压阶段和恢复阶段的 β/α 和 θ/β 指标，以及POMS量表显示的情绪状态变化情况。再对12个组受试者的生理和心理指标进行协方差分析，以施压阶段的对应指标作为协变量，消除基线的差异，分析视觉变量和嗅觉变量的主效应。对存在显著交互效应的视嗅变量进一步进行简单效应分析。

4 研究结果

4.1 视嗅感知的生理恢复效益

配对样本 t 检验^②分析结果显示，四个脑区的 β/α 和 θ/β 指标在施压阶段（ $p=0.015$ ）^③和恢复阶段（ $p=0.021$ ）存在显著差异（图3）。在恢

复阶段，受试者受到12组不同色系和香型月季景观的刺激后， β/α 和 θ/β 指标较施压阶段均显著下降，表明受试者压力状态明显改善，同时注意力水平显著提升。

4.1.1 压力相关指标

四个脑区 β/α 指标的协方差分析结果显示，色系在颞叶区的主效应^④不显著（ $p=0.080$ ），但在顶叶区（ $p=0.011$ ）、枕叶区（ $p=0.023$ ）和额叶区（ $p=0.026$ ）存在显著的主效应。具体而言，橙色系在顶叶（ $M=0.687$ ）、枕叶（ $M=0.705$ ）、额叶（ $M=0.738$ ）区的 β/α 比值均最高，白色系在枕叶（ $M=0.501$ ）、额叶（ $M=0.559$ ）区的 β/α 比值均最低，蓝紫色系在枕叶（ $M=0.523$ ）、额叶（ $M=0.567$ ）区的 β/α 比值也较低（图4-1），说明白、蓝紫等色系对压力的缓解作用更佳。然而，香型在枕叶、额叶、颞叶三个脑区的主效应均不显著（ $p>0.05$ ），仅在顶叶区的主效应显著（ $p=0.031$ ）：玫瑰香型（ $M=0.621$ ）的 β/α 比值显著高于果香型（ $M=0.548$ ）（图4-2），说明果香型对于大脑压力缓解的效果更好。此外，色系和香型的交互效应在四个脑区均不显著（ $p>0.05$ ），说明在压力指标上，色系和香型不存在显著相互作用。

4.1.2 注意力相关指标

θ/β 指标的协方差分析结果显示，香型在四个脑区的主效应均不显著（ $p>0.05$ ），但色系在四个脑区均存在显著的主效应（ p 值分别为0.029、0.014、0.021和0.017），且两者在枕叶区（ $p=0.010$ ）和颞叶区（ $p=0.036$ ）的交互效应显著。有关色系的主效应结果显示，红色系在四个脑区的 θ/β 比值均最低，蓝紫色系均最高（图5），表明红色系月季对于注意力的恢复效果最佳。对枕叶区和颞叶区存在显著交互效应的色系和香型进行简单效应分析^⑤，结果显示：1）就枕叶区而言，在橙色系中，玫瑰香型的 θ/β 比值显著高于果香型，其余色系中两种香型的比值无显著差异（图6-1）。在玫瑰香型中，蓝紫色系的 θ/β 比值最高，红色系最低；在果香型中，蓝紫色系的 θ/β 比值最高，黄色系最低（图6-2）。2）对于颞叶区，在橙色系中，玫瑰香型的 θ/β 比值显著高于果香型（图7-1）。在玫瑰香型中，橙色系的 θ/β 比值最高，红色系最

表2：心理指标计算方法

指标	计算方法
积极情绪分值	“精力”与“自尊”分值之和
消极情绪分值	“紧张”“愤怒”“疲劳”“抑郁”“恐慌”分值之和
情绪纷乱总值	消极情绪分值 - 积极情绪分值 +100

① 本研究所使用 POMS 量表的详细内容请见补充材料。

② 在本文配对样本 t 检验分析结果示意图中，a 和 b 均表示显著性——组间字母相同表示差异不显著（ $p > 0.05$ ），组间字母不同表示差异显著（ $p < 0.05$ ）。

③ 本研究中使用的显著性数值为中位数。

④ 在本文主效应分析结果示意图中，a 和 b 均表示显著性——组间字母相同表示差异不显著（ $p > 0.05$ ），组间字母不同表示差异显著（ $p < 0.05$ ）。

⑤ 在本文简单效应分析结果示意图中，a 和 b 均表示显著性——组间字母相同表示差异不显著（ $p > 0.05$ ），组间字母不同表示差异显著（ $p < 0.05$ ）。

低；在果香型中，蓝紫色系的 θ/β 比值最高，橙色系最低（图7-2）。由此可见，黄、橙色系和果香型、红色系和玫瑰香型的组合对于注意力的恢复效果更好。

4.2 视嗅感知的心理恢复效益

施压和恢复阶段POMS指标的配对 t 检验结果显示，紧张（ $p=0.025$ ）、愤怒（ $p=0.015$ ）、疲劳（ $p=0.011$ ）、抑郁（ $p=0.035$ ）、精力（ $p=0.042$ ）、恐慌（ $p=0.033$ ）、自尊（ $p=0.036$ ），以及积极情绪分值（ $p=0.039$ ）、消极情绪分值（ $p=0.022$ ）和情绪纷乱总值（ $p=0.019$ ）在实验前后存在显著变化（图8）。在恢复阶段，经月季景观视嗅刺激后，受试者的积极情绪显著提升，消极情绪分值和情绪纷乱总值呈下降趋势。

对不同视嗅交互组的POMS情绪指标进行协方差分析，主效应分析结果表明玫瑰香型和果香型在三个情绪指标上均无显著差异（ $p>0.05$ ）。在自尊和精力两种积极情绪中，色系的主效应显著（ $p=0.010$ ），且色系和香型存在显著的交互效应（ $p=0.013$ ）。由图9可见，蓝紫色系诱导了较低的积极情绪分值，红色系和黄色系诱导了较高的积极情绪分值。对交互效应显著的积极情绪进一步进行简单效应分析，结果显示：1）在橙色系中，果香型诱导的积极情绪值显著高于玫瑰香型；在红色系中，玫瑰香型诱导的积极情绪值显著高于果香型；其他色系中两种香型的差异不具显著性（图10）。2）在玫瑰香型中，红色系诱导的积极情绪分值最高，而橙色系诱导的最低；在果香型中，黄色系诱导的积极情绪分值最高，白色系和蓝紫色系诱导的最低。

综上，不同色系和香型及其交互对受访者的压力、注意力及情绪等身心健康指标皆产生了不同程度的干预效果。

5 结论与讨论

本研究基于视嗅感知视角，探讨了受试者在体验不同色系和香型组合的月季景观后的恢复性效益及其差异。研究结果可为未来如何通过合理搭配月季的色彩和香气以最大化植物景观的健康效益提供科学依据。结果表明，不同色系和香型组合在缓解压力、恢复注意力和改善情绪状态方面有显著差异。主要结论如下。

1）月季景观的视嗅感知可产生积极恢复性效益。实验结果表明，在不同色系和香型组合的月季景观刺激下，受试者的身心健康指标呈现积极变化。具体表现为：脑电波中代表压力水平的 β/α 指标显著下降，代表注意力水平的 θ/β 指标也显著降低；POMS量表的结果显示，积极情绪显著上升，消极情绪显著下降。根据压力缓解理论，人类长期依赖自然环境而进化，良好的自然环境（如美丽的植物景观）可激活副交感神经活动，明显缓解精神压力并放松情绪^[61]。而注意力恢复理论则指出，

具有“远离感”“迷人感”“广度”及“兼容性”特征的自然环境有助于提升认知功能和注意力水平^[66]。以往研究也已证实，开花植物具有积极的健康效益^[67]。因此，月季丰富的花色带来的视觉刺激及其迷人芳香产生的嗅觉刺激能令人愉悦，减少交感神经活动，缓解压力并促进注意力恢复。

2）白色系、蓝紫色系和果香型月季更能缓解生理压力。本研究结果显示，白色系和蓝紫色系在大脑顶叶、枕叶和额叶区诱导产生的 β/α 比值较低，表明这些颜色相较红、橙等暖色系更能显著改善大脑的压力状态。同样，果香型月季在大脑顶叶区产生的 β/α 比值低于玫瑰香型，表现出更强的压力缓解效果。既有研究亦发现，白色和蓝色花卉在缓解紧张和压力方面效果最佳^[68]，与本研究结果一致。此外，一项针对玫瑰精油对情绪的干预研究表明，玫瑰精油可有效缓解医护人员的焦虑并改善睡眠质量^[69]。本研究中果香型月季比玫瑰香型月季更能舒缓压力，可能是因为前者含有乙酸己酯等具有镇静作用的挥发性物质，能显著提高放松程度^[70]。

3）暖色系和两种香型的组合有利于注意力恢复和积极情绪的产生。根据本研究结果，红色系在四个脑区产生的 θ/β 比值最低，表明红色系月季对于注意力的恢复效果最佳。同时，交互作用结果显示，红色系—玫瑰香型、黄色系—果香型、橙色系—果香型组合能显著提升注意力恢复效益。相关研究表明，红色植物能够激活大脑控制注意力和专注力的判断区域，适用于提高注意力水平^{[71][72]}。通过提升枕叶区的相对 θ 功率谱，黄色花卉则可有效改善受试者注意力，并显著提升愉悦感^[71]。此外，月季的香气也有助于 β 波的增强，能营造有利于集中和平静的环境^[73]。如前文所述，视觉和嗅觉的交互作用会影响感知偏好与注意力，这也解释了红色系—玫瑰香型组合在注意力恢复中的突出表现。

POMS量表的结果显示，红色系和黄色系月季诱导的积极情绪分值最高。交互作用结果表明，红色系—玫瑰香型、黄色系—果香型月季产生的积极情绪值高于其他组合。这一结果与许多已有研究一致。例如，一项针对情绪词与颜色关联性的实验要求参与者为每个所呈现的单词提供第一个联想到的颜色，结果显示，积极情绪词最常见的对应颜色是黄色，红色则与激昂情绪相关^[74]。另有关于不同颜色切花对心理状态影响的实验报告指出，红色切花最能让参与者感受到“强烈”和“活力”，而黄色切花最能让参与者感受到“温暖”和“精力”^[75]；观赏红色和黄色花朵后，受试者的副交感神经活动显著增强，精力等积极情绪状态显著提升^[76]。此外，有研究发现，接触粉色月季4分钟后，受试者心率变异性的高频成分显著上升，舒适感也明显提高^[77]，这与本研究结果相符。有学者指出，颜色不仅会影响气味的愉悦性，还可以激活与其相对应的嗅觉图像，这些感知往往是与该颜色相关的所有气味的组合。例如，黄色常让人联想到柠檬香，即与该颜色关联更紧密的气味会占主导地位，而违背感官期望的组合则会令人不快^[78]。因此，符合感官期望的色彩和香

气组合更容易让人产生积极情绪。

4) 色彩对注意力和积极情绪的影响效应大于香气。本研究中,在表征注意力的 θ/β 指标和积极情绪指标上,色系的主效应均显著,而香型的主效应均不显著。这表明,在月季景观中,色彩对注意力和积极情绪的干预效应远大于香气。相关研究发现,桂花景观的视觉刺激对交感神经活动的影响比嗅觉刺激更明显,即观看桂花景观比嗅闻桂花更能促进注意力恢复、唤醒情绪,进而促进积极情绪^[79]。这种差异符合视觉是接收环境信息的主要感官这一观点^[80]。

基于上述结论,建议在月季景观的规划设计中充分考虑视觉和嗅觉的感知体验,因地制宜地根据具体的健康需求进行针对性规划,最大程度发挥月季景观的疗愈价值。结合主效应和交互效应的分析结果及月季景观的实际应用场景,建议在休憩区、冥想区等需要轻松、安静、舒适氛围的环境中,增加白色系、蓝紫色系和果香型月季的种植比例,合理配置黄色系—果香型的月季,营造有助于缓解压力、舒缓情绪的花廊、廊架和拱门景观;或通过片植、群植的方式打造月季步道,布置座椅以供冥想和放松活动。在需要集中注意力、提升活力和创造力的空间中,建议以红色系和黄色系月季为主,合理搭配玫瑰香型和果香型的品种,打造花坛、花境等景观形式;或将树状月季列植形成夹道,构建汇聚香气的植物屏障,充分发挥月季景观促进注意力提升和唤醒情绪的效益。另外,建议在这些景观空间中增加喷泉等动态水景,利用水的蒸发作用扩散香气,使其弥散至更广的空间,从而增强芳香疗愈效果。

6 不足与展望

本研究仍存在许多不足与局限。首先,在实验设计上,为了更好地控制变量,本研究采用了景观图片结合新鲜花材的模拟场景,与真实环境体验相比仍存在一定差异。因此,后续研究可考虑采用虚拟现实技术,以创建更为逼真的景观体验。其次,本研究选择大学生群体作为受试者,缺乏对更多年龄层群体的对比研究。未来研究应针对不同年龄、教育水平、生活文化背景的人群,使研究结果更具普适性。此外,有研究指出,视觉和嗅觉在刺激早期的作用强度存在差异:视觉占主导地位,而嗅觉的干预效应较弱;随着刺激时间的延长,嗅觉的作用逐渐增强^[28]。本研究仅考察了施压和恢复阶段各自的即时效应(均为3分钟),而未探讨恢复效应的持续性或长时间的恢复过程,这一局限性有待未来研究进一步解决。最后,本研究仅观察了盛花期月季的即时效应。鉴于月季在不同生长阶段的花型、花色和香气成分存在差异,未来研究应关注其在不同生长周期内的长期恢复性效益,并对其中介效应和交互机制进行更深入的研究,以获得更广泛适用的结论。

补充材料

可通过<https://doi.org/10.15302/J-LAF-1-020104>查看本文补充材料。

- 图 1. 月季景观的视嗅特征感知问卷调查结果图
- 图 2. 实验流程
- 图 3. β/α 和 θ/β 指标的配对样本 t 检验结果
- 图 4. β/α 指标的主效应分析结果
- 图 5. θ/β 指标的主效应分析结果
- 图 6. 枕叶区 θ/β 指标的简单效应分析结果
- 图 7. 颞叶区 θ/β 指标的简单效应分析结果
- 图 8. POMS 情绪指标的配对样本 t 检验结果
- 图 9. POMS 情绪指标的主效应分析结果
- 图 10. POMS 情绪指标的简单效应分析结果