Journal of Wood Science

https://doi.org/10.1186/s10086-026-02298-1

Article in Press

The design reconstruction of olfactory art and sleep healing spaces

Received: 04 Jan 2026

Accepted: 06 Aug 2026

Published online: 16 August 2026

Cite this article as: Zhang, N., Li, W., Wang, X. *et al.* The design reconstruction of olfactory art and sleep healing spaces. *J Wood Sci* (2026). https://doi.org/10.1186/s10086-026-02298-1

Ning Zhang, Weiting Li, Xinyi Wang, Zhixuan Chen, Sujia Yan, Yuepeng Li, Shiliang Yin & Zhiping Xu

We are providing an unedited version of this manuscript to give early access to its findings. Before final publication, the manuscript will undergo further editing. Please note there may be errors present which affect the content, and all legal disclaimers apply.

If this paper is publishing under a Transparent Peer Review model then Peer Review reports will publish with the final article.

ARTICLE IN PRESS

©The Author(s) 2026. **Open Access** This article is licensed under a Creative Commons Attribution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if changes were made. The images or other third party material in this article are included in the article's Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit http://creativecommons.org/licenses/by/4.0/

ARTICLE IN PRESS

The Design Reconstruction of Olfactory Art and Sleep Healing Spaces

Ning Zhang[1], Weiting Li[2], Xinyi Wang[3], Zhixuan Chen[3], Sujia Yan[3], Yuepeng Li[1], Shiliang Yin[3], Zhiping Xu[3*]

1 Hainan Normal University, No. 3, No. 1 School Road, Haikou, 571158, Hainan Province, China

2 Liaoning Vocational and Technical College of Economics, No.88 Shenbei Road, Shenyang, 110122, Liaoning, China

3 School of Pharmacy, Shenyang Medical College, Huanghe North Street, Shenyang, 110034, Liaoning, China

[*] Corresponding author, E-mail addresses: xuzhiping@symc.edu.cn ORCID: https://orcid.org/0000-0003-0634-8887

ARTICLE IN PRESS

Abstract

Background: Eaglewood, also known as Aquilaria sinensis in China, is a type of resinous wood of the Aquilaria in the thymelaeaceae family with diversified values. In traditional Chinese medicine, it serves as a precious material for regulating qi and alleviating pain. Its unique aroma makes it a key ingredient in religious ceremonies and high-end incense. Its natural grain and rarity make it a highly collectible carved artwork. With its triple attributes of cultural heritage, medicinal health, and artistic

ARTICLE IN PRESS

investment value, eaglewood continues to release its irreplaceable and rare value. This article will explore the role of eaglewood in regulating sleep quality from the perspectives of medicine and art design. **Methods**: First of all, GC–MS was applied to detect the main chemical components released into the air after eaglewood incense sticks were lit. Then, the open field test, tail suspension test, forced swimming test, and collaborative hypnosis experiment systematically revealed that eaglewood has a calming effect and aids sleep, and pharmacological data were simultaneously converted into product design parameters. Finally through the combination of eaglewood and spatial aesthetic design, the study proposes the positive impact of the five senses on healing spaces, providing a new theoretical framework and practical path for designing sleep environments. **Results and Conclusions**: GC–MS analysis revealed that the volatile components released into the air from burning agarwood incense sticks were mainly phenols (e.g., Phenol, 2-methoxy-、Phenol, 2,6-dimethoxy-) and terpenoids (e.g., Jasmone, E-、*trans*-2-Caren-4-ol、3-Caren-10-al). These compounds possess sedative, hypnotic and anxiolytic effects. On this basis, animal behavioral experiments further verified that the scented eaglewood can alleviate anxiety and fatigue in mice to a certain extent, and exhibits a significant sedative effect, which can significantly improve the sleep disorders of mice with insomnia. In addition, the unique aroma of eaglewood can create a multi-sensory healing experience through the art design of the space, redefining modern people's perception and expectations of sleep spaces.

ARTICLE IN PRESS

ARTICLE IN PRESS

Keywords: Eaglewood; Insomnia; Sleep regulation; Spatial aesthetics; Multi-sensory experience

Abbreviations

EEG, electroencephalography; EMG, electromyography; FST, forced swimming test; GC-MS, gas chromatography-mass spectrometry; OFT, open field test; PCPA, 4-chloro-DL-phenylalanine; SD, standard deviation; SPF, specific pathogen-free; TLC, thin-layer chromatography; TST, tail suspension test.

Introduction

ARTICLE IN PRESS

In today's fast-paced society, sleep disorders have become a widespread issue affecting urban populations. Insomnia, one of the most common sleep disorders worldwide, has emerged as a significant public health concern impacting human health[1]. According to statistics from the World Health Organization, approximately 30% of adults worldwide experience short-term insomnia, with 10–15% progressing to chronic insomnia[2]. Insomnia not only leads to impaired daytime functioning and reduced quality of life but is also significantly associated with significant health risks such as depression, anxiety, and cardiovascular diseases[3-4]. Addressing the prevalent dilemma about treatment among contemporary young adults—who are both troubled by insomnia and resistant to traditional drug therapy, concerned about side effects and the risk of drug dependence—they show their preference for natural therapies and personalize therapies to the needs of individuals. Meanwhile, people's

ARTICLE IN PRESS

demands for a high-quality sleep environment are gradually increasing with the improvement of living standards, and designs of sleep spaces focus on aesthetic considerations toward therapeutic functionality. In this context, eaglewood, with its unique calming properties, has caught the eye of the design community[5].

Chinese eaglewood belongs to the Aquilaria in the thymelaeaceae family, also called Aquilaria sinensis. In Hainan, the bark of healthy eaglewood trees is white, while they produce a dark and aromatic resin as a response to various attack. Resin-infused pieces can not be cut down until the trees get to 7 years old. Considering the burning time and conditions, the present study chose eaglewood incense sticks made by rolling eaglewood powder produced from 10-year-old Aquilaria sinensis trees in Chengmai county, Hainan into sticks. Most of the trees were deliberately wounded to induce resins usually in heartwood , such as drilling, nailing or hewing the heartwood, and a few via insect-infested.

After gas chromatography-mass spectrometry (GC–MS) analysis, most studies on eaglewood have reported that sesquiterpenes and chromones are key contributors its olfactory properties[6], no matter what methods of inducing resin were employed in studies. Among these studies, likewise, Lin et al. using eaglewoods from Dingan county[7], next to Chengmai where samples of the study were purchased, found the volatile constituents for the olfactory property from Hainan eaglewood samples mainly includes sesquiterpense and aromatic constituents, such as baimuxinol and anisylacetone.

ARTICLE IN PRESS

Beyond its chemical composition, eaglewood also exhibits a broad spectrum of pharmacological activities that support its traditional use in calming the mind. Gong et al.[8] showed that eaglewood had a significant anti-anxiety effect, inhibiting spontaneous activity in light-dark exploration tests and the open field tests.

Apart from its medicinal value, the colors of Hainan eaglewood-a mix of dark brown, and lighter, warmer brown tones from tan to light taupe-are also connected to feelings of comfort and sense of security in psychology, which may contribute to a more soothing interior atmosphere. Choosing proper color for sleep space can contribute to healthy circadian rhythm at night[9]. The influence of color on arousal and emotion has been empirically demonstrated. Wilms et al.[10] found that colors have strong effect on arousal proved via emotion ratings and the skin conductance response amplitudes. Saturated and bright colors caused higher arousal. Circadian states between sleep and wakefulness can be seen as different levels of arousal. The study suggests that color may influence arousal-related responses, which could be relevant when considering sleep environments. Another study found that nature room (brown, orange, and green colors; wood furniture and leather coverings) and vivacious room(red, blue, and green elements; soft-textured materials) evoke more positive emotions than basic (white and blue colors; plastic and metal furniture) and modern (white and cold colors with good-quality essential coverings), suggesting a connection between natural colors and emotional well-being[11]. These findings suggest that a bedroom in natural color and materials may have positive effect on

ARTICLE IN PRESS

ARTICLE IN PRESS

sleep quality. Based on previous studies, the present study combining the medicinal and color effects on sleep quality proposed a design of bedroom with eaglewood properties.

In light of the above, this study aims to expand the traditional applications of eaglewood within the wellness industry by proposing an interdisciplinary concept that develops medicinal and aromatic functions of herbs, and then designs ranges of eaglewood-based decorations with calming nerves effect and aesthetic properties. Through open field tests, tail suspension tests, forced swimming tests, and collaborative hypnosis experiments, we will elucidate the calming and sleep-promoting properties of eaglewood, synchronizing the design of eaglewood-containing decorations based on the pharmacological data. The decorations embodying oriental aesthetics will reconstruct consumption scenarios in the wellness industry. The eaglewood-based designs will present cultural aesthetics and both mental and physical care, offering people living with modern insomnia with Eastern health solutions that combine scientific evidence and aesthetic care.

ARTICLE IN PRESS

Method

Reagents

Eaglewood incense sticks were obtained from a single production batch of Chengmai Jiale Eaglewood Cultivation Cooperative in Hainan, China. The samples were pathological resin-impregnated wood derived from Aquilaria sinensis trees.

ARTICLE IN PRESS

Resin formation was induced by drilling and hewing the heartwood of 10-year-old Aquilaria sinensis trees in Chengmai County. The selection features dark brown coloration and visible dark oil veins. The alcohol-soluble extractive yield was 18.5%, exceeding the 10% requirement of the Chinese Pharmacopoeia, and the specific gravity was approximately 1.05 g/cm³, classifying the samples as "sinking" grade eaglewood. GC–MS analysis further confirmed the authentic pathological nature of the resin, identifying high levels of characteristic 2-(2-phenylethyl)chromones. In addition, two typical compounds were identified: 2(1H)-Naphthalenone,3,5,6,7,8,8a-hexahydro-4,8a-dimethyl-6-(1-methylethenyl)- (a sesquiterpene) and 2-phenethyl-4H-chromen-4-one (a chromone) (Supplementary Fig. 1). Sodium pentobarbital was purchased from Merck, USA, and 4-chloro-DL-phenylalanine (PCPA) was purchased from Meir Bio-Chem Technology Co., Ltd., China.

ARTICLE IN PRESS

GC–MS Analysis of Volatile Components Emitted from Burning Eaglewood

GC–MS was used to analyze the major components released into the air from lit eaglewood. First of all, Gases emitted from burning eaglewood incense sticks were collected with gas sampling bags and then transferred into headspace vials for GC–MS analysis. GC conditions: The carrier gas flow rate was 1.0 mL/min. The oven temperature was initially held at 40 °C for 3 min, increased to 100 °C at a rate of 5 °C/min, and then raised to 250 °C at 6 °C/min, with a final holding time of 10 min.

ARTICLE IN PRESS

MS conditions: An HP-5MS capillary column was adopted. The ion source temperature was set at 120 °C, and the quadrupole temperature was 150 °C.

Experimental Animals and Grouping

Kunming mice (specific pathogen-free [SPF] grade, equal sex distribution, weighing 18–22 g) were obtained from Liaoning Changsheng Biotechnology Co., Ltd.. Animal care and research protocols were based on the principles and guidelines adopted by the European Union Directive 2010/63/EU for animal experiments and approved by the Institutional Animal Care and Use Committee of Shenyang Medical College. Animals were assigned to six groups: Control (6 days), Burning eaglewood (6 days; exposure conditions: 0.8 g standardized eaglewood incense sticks [equivalent to 2 sticks] burned in a 0.5 m^3 sealed chamber for 1 h per session, namely an exposure dose of 1.6 $g/m^3/h$, twice daily at 07:00 and 16:00, though volatile component quantification was not performed).Control (12 days), Burning eaglewood (12 days; same exposure protocol as 6 days group), Insomnia model (untreated × 9 days, then daily intraperitoneal injection of PCPA 500 mg/kg × 3 days), and PCPA + Burning eaglewood (daily eaglewood exposure × 12 days with concomitant PCPA 500 mg/kg, i.p. on days 10–12, exposure protocol identical to other eaglewood groups). On quality control, pre-experiment thin-layer chromatography (TLC) analysis confirmed consistent sample content across randomly sampled sticks of eaglewood.

The incense sticks were ignited and burned smolderingly in the chamber. The estimated temperature at the glowing tip of the incense was approximately 500–

ARTICLE IN PRESS

700 °C (measured via infrared thermometry in similar setups), while the smoke-generating volatilization zone behind the tip reached temperatures between 200 °C and 400 °C. Each session lasted 1 h under a controlled airflow environment to ensure complete smoldering.

Study on the Anti-anxiety Effect of Eaglewood

Open field test (OFT): The apparatus consists of a black square arena (70 cm × 70 cm × 70 cm) with black plastic walls and plate (XR-XZ302, Shanghai Xinruan Information Technology Co., Ltd, China). An infrared camera mounted above the arena recorded locomotor activity. Mice were placed in the center and allowed a 2-minute habituation period, followed by 4 minutes of formal recording.

Study on the Anti-fatigue Effect of Eaglewood

Tail suspension test (TST): Mice were suspended vertically by the distal one-third of their tails from a hook extending from the ceiling of the chamber. (XR-XX203, Shanghai Xinruan Information Technology Co., Ltd), with their heads positioned approximately 10 cm above the platform. Observe and record the time of the first occurrence of immobility in mice, denoted as the immobility latency in the TST. Record the total duration of immobility during the last 4 minutes of the 6-minute test, which is recorded as the total immobility time of the TST. Forced swimming test (FST): The FST System (XR-XQ202, Shanghai Xinruan Information Technology Co., Ltd.) consists of a cylindrical glass tank with a diameter of 12 cm and a height of 25 cm. Prior to the experiment, fill the tank with warm water to a depth of 15 cm at a

ARTICLE IN PRESS

temperature of 23 ± 2 °C, and prepare a thermometer and hot water to ensure that the water temperature can be adjusted throughout the test. Place the mouse into the tank. The entire experiment lasts for 6 minutes. Observe and record the time when the mouse first exhibits immobility, which is recorded as the latency period of the FST. Record the total duration of immobility during the last 4 minutes of the 6-minute test, which is recorded as the total immobility time of the FST.

Study on the Effects of Eaglewood through Collaborative Hypnosis Experiments

All mice received an intraperitoneal injection of sodium pentobarbital (40 mg/kg). Immediately after administration, the sleep latency, time from injection to loss of the righting reflex, and sleep duration, time from loss to spontaneous recovery of righting reflex, were recorded.

Aesthetic Design of Space for Therapy by Eaglewood

Therapeutic spaces represent a sought-after lifestyle environment in contemporary society. Healing is a holistic, transformative, physical, and spiritual process of repair and recovery that produces positive change, finds meaning, and moves toward self-fulfilling wholeness, regardless of disease[12]. Manca, et al.[13] noted that physical factors such as furniture, decorations, and lighting, as well as the degree of daylighting, color temperature, and material temperature, can all influence the psychological factors of patients and overall indoor environmental quality. For example, comfortable seating and appropriate lighting can create a relaxed and welcoming healthcare environment, thereby enhancing people's sense

ARTICLE IN PRESS

of belonging and security[14]. However, most research exists within the theme of updating equipment comfort, such as the updating of technologically advanced furniture and safe coatings[15-16]. Little attention has been paid to the psychological effects[17]. Eaglewood furniture carries profound cultural symbolism and emotional significance. As recorded in the book, Superfluous Things from China's Ming Dynasty, the "eaglewood couches" served not merely as furniture but as symbols of the owner's social status and aesthetic taste. Contemporary designers now face the critical challenge of preserving this cultural legacy while adapting it to modern living requirements. This design incorporates the Hainan Li brocade patterns, which are listed in the UNESCO Intangible Cultural Heritage, as the main motifs for all products. These motifs include human figures, animals, plants, and geometric patterns composed of triangles, diamonds, squares, and curves. These patterns embody the Li people's reverence for life and nature, and love of their lives.

These intangible cultural totems feature both aesthetic value and culture-ethical enrichment. Users can choose eaglewood products with different flavors according to their sleep needs, and this interactive process itself becomes a ritualistic preparation for sleep. This design cleverly integrates the collection value, functional use, and spatial narrative of eaglewood.

Design Extraction of the Color Aesthetics of Eaglewood

This study employs an interdisciplinary, comprehensive analysis method to integrate color psychology, environmental behavior, and medical theory in

ARTICLE IN PRESS

examining the sleep-promoting mechanism of the eaglewood color spectrum. Natural eaglewood samples and spatial design with eaglewood-based derivatives cases were collected. The LZL online image color extraction tool was used to extract the original color values, establishing an rgb color model and determining the overall proportion of colors in the space. This analysis encompasses the entire logical chain, from data collection and model construction to verification mechanisms to academic innovation, meeting the rigorous requirements of interdisciplinary research in the social sciences and engineering. It can support subsequent experimental design and results verification.

Data Analysis

Data were analyzed using GraphPad Prism 8 software and are presented as mean ± standard deviation (SD). Statistical differences between the drug treatment groups and the control or model were analyzed by one-way ANOVA. Results were considered significant at $*P < 0.05$, $**P < 0.01$, $***P < 0.001$.

Results

Major Volatile Components of Burning Eaglewood (GC–MS)

GC–MS analysis indicates (Table 1, Supplementary Fig. 2) the volatile components released from lit eaglewood mainly consisted of phenols, terpenes, aromatic chromone and aldehydes, as well as a small amount of alkanes and siloxanes. Among these compounds, phenols showed the highest relative contents,

ARTICLE IN PRESS

including phenol (peak area: 50.26%), Phenol, 2-methoxy- (4.57%) and Phenol, 2,6-dimethoxy- (6.31%). They were the primary contributors to the smoky, woody and caramel-like sweet aroma of burning eaglewood. Terpenes and their oxygenated derivatives identified included 3-caren-10-al (5.41%), carvone oxide (4.15%) and trans-2-caren-4-ol (3.19%). Aromatic compounds were represented by 1-(2,4-dimethylfuran-3-yl)-ethanone (7.08%) and Jasmone, E- (2.28%). In addition, small amount of alkanes (e.g., Tetradecane, 6,9-dimethyl-) and siloxanes (e.g., Cyclotetrasiloxane, octamethyl) were detected. These substances were derived from combustion side reactions or column bleed, rather than native components of eaglewood. Overall, phenols and terpenes dominated the volatile profile in the air after eaglewood combustion.

Table 1 Volatile Components of Burning Eaglewood (GC–MS)

Compound Name	**Molecular Formula**	**Retention Time (min)**	**Peak Area (%)**	**Aroma / Characteristic Description**
Phenol	C_6H_6O	11.196–11.293	50.26	Smoky, phenolic
1-(2,4-Dimethyl-furan-3-yl)-etha none	$C_8H_{10}O_2$	17.625–17.721	7.08	Caramel, sweet
Phenol, 2,6-dimethoxy-	$C_8H_{10}O_3$	21.615–21.698	6.31	Woody, herbal
Phenol, 2-methyl-	C_7H_8O	13.512–13.589	7.01	Smoky, phenolic
Phenol, 3-methyl-	C_7H_8O	14.147–14.244	6.11	Smoky, phenolic

ARTICLE IN PRESS

3-Caren-10-al	$C_{10}H_{14}O$	16.066–16.188	5.41	Smoky, rosin & herbal
Phenol, 2-methoxy-	$C_7H_8O_2$	14.603–14.667	4.57	Smoky, sweet
Carvone oxide	$C_{10}H_{14}O_2$	17.419–17.554	4.15	Camphoraceous, minty
trans-2-Caren-4-ol	$C_{10}H_{16}O$	19.472–19.613	3.19	Pine, herbal
Jasmone,E-	$C_{11}H_{16}O$	22.930–22.988	2.28	Floral, jasmine-like
1,5-Cyclooctadien-4-one	$C_8H_{10}O$	9.977–10.080	1.72	Fatty, fruity
Cyclohexasiloxane, dodecamethyl-	$C_{12}H_{36}O_6Si_6$	21.089–21.172	2.56	Non-native component (possible column bleed)
1-Piperidinecarbonitrile	$C_6H_{10}N_2$	10.151–10.215	0.82	Trace pyrolysis product
3-Pyrazolidinone, 1,4-dimethyl	$C_5H_{10}N_2O$	19.113–19.177	0.76	Trace pyrolysis product
Tetradecane, 6,9-dimethyl-	$C_{16}H_{34}$	24.823–24.880	0.81	Alkane (combustion product)
Cyclotetrasiloxane, octamethyl-	$C_8H_{24}O_4Si_4$	11.793–11.844	0.43	Non-native component (possible column bleed)

ARTICLE IN PRESS

An Inhibitory Effect of Eaglewood on Anxiety in Insomnia Model Mice

The results of the eaglewood anti-anxiety experiment (**Fig.1**) showed that compared with the control group and the PCPA model group, eaglewood had no significant effect on the total distance of spontaneous activity in mice (**Figs.1C** and **1D**). Compared with the control group, lighted eaglewood for 6 days did not significantly affect the activity of spontaneously active mice (**Fig.1E**), while lighted

ARTICLE IN PRESS

eaglewood for 12 days significantly inhibited mouse activity (**Fig.1F**). Compared with the model group, lighted eaglewood for 12 days also significantly inhibited mouse activity (**Fig.1F)**, demonstrating a clear anti-anxiety effect. Compared with the control group, lighted eaglewood for 6 and 12 days significantly prolonged the time and distance spent in the central area by mice with spontaneous activity (**Fig.1G-J**). For the model group mice, the findings showed significantly shorter time and distance in the central area, indicating that the insomnia model mice exhibited apparent restlessness and agitation. However, 12 days of lighting eaglewood significantly prolonged the time spent and distance travelled in the central area by mice with spontaneous activity. (**Fig.1H** and **1J**), demonstrating a significant anti-anxiety effect.

Anti-fatigue Potential of Eaglewoods

As shown in **Fig.2A-D**, the TST results demonstrated that neither 6-day nor 12-day lighted eaglewood significantly affected the latency period or total immobility time of mice, compared to the control and PCPA groups. In contrast, the FST (**Fig.2E-H**) revealed the 12-day eaglewood treatment group showed statistically significant improvements in both latency and total immobility time relative. It is important to note, however, that while the FST is widely employed as a screening tool for antidepressant-like activity, it may also reflect alterations in fatigue resistance or general motivational states. Given that the TST - another established behavioral despair paradigm-did not yield significant effects, the differential outcomes between these two tests suggest that the observed FST results are

ARTICLE IN PRESS

test-specific and do not provide unequivocal evidence of classic antidepressant-like activity. Rather, these findings may be more indicative of potential anti-fatigue properties, though this interpretation warrants further validation.

Hypnotic Effect of Eaglewood in Insomnia Model Mice

The results of collaborative hypnosis experiments demonstrated differential effects based on treatment duration (**Fig.3**). While experiments of 6-day lighted eaglewood showed no significant effects on sleep latency or duration compared to the control group **(Figs.3A, 3C**), the 12-day treatment group exhibited statistically significant improvements in both parameters-reducing sleep latency and extending sleep duration (P<0.01 versus control). These duration-dependent effects suggest that sustained exposure to eaglewood is required to achieve sleep improvements in this experimental model.

Design and Proposal for Color Analysis

The careful selection of colors can evoke emotions, set moods, and influence the perception of space[18-19], and effective therapeutic space design principles should include proximity to nature[20]. Therefore, this study is based on the natural colors of eaglewood, employing precise color extraction techniques to construct a color scheme for the space. As shown in **Fig.4**, the color scheme consists of five primary hues, with their rgb values and spatial proportions as follows: dark brown (rgb(58, 35, 20), 20.9%), reddish-brown (rgb(113, 78, 52), 30.14%), light brown (rgb(160, 123, 93), 29.44%), beige (rgb(202, 175, 150), 13.16%), and warm white

ARTICLE IN PRESS

(rgb(247, 241, 234), 6.36%). This color strategy establishes a warm and calm ambiance. To enhance the healing atmosphere, a color scheme is systematically applied to the design of key elements within the space, including custom tea sets, textiles, and other matching furnishings. The design of warm-toned light sources (~2700 – 3000 K) further amplifies the overall warmth and comfort of the space, and the light interacts with the eaglewood-colored surfaces to create a unique aesthetic atmosphere. Additionally, patterns and motifs with regional cultural characteristics are incorporated as decorative elements to evoke a sense of cultural recognition and reflect the specific ethnic spirit and cultural connotations.

Based on ergonomic principles, beds and bedding serve as the core elements of a rest space, and their design is crucial to the comfort and therapeutic experience of users. This proposal (**Fig.5**) focuses on bedroom sets, prioritizing natural materials with excellent skin-friendliness, such as high-count cotton, linen, or silk blends for bedding. The color scheme strictly follows the hues of eaglewood for the overall healing space, consisting of dark brown (rgb(62, 36, 20), 21.32%), reddish brown (rgb (109, 76, 54), 25.40%), light brown (rgb (152, 120, 98), 20.99%), beige (rgb(192, 177, 165), 19.11%), and warm white (rgb(227, 219, 212), 13.18%), maintaining the space's warm and serene ambiance. Meanwhile, patterns and totems with regional cultural characteristics are incorporated into the design of bedding through knitting techniques, and traditional rattan-weaving techniques are used in the decoration of the background to enhance the cultural recognition and local expression of the space.

ARTICLE IN PRESS

Functionally, bedroom sets establish natural connections through eaglewood. Its core innovation lies in an integrated warm light device serving as the base for the eaglewood ornament, providing soft ambient lighting (~2700 – 3000 K color temperature) to create a cozy atmosphere and having a controllable heating function, which gently heats the eaglewood to continuously and controllably release its natural fragrance. The synergy of the above materials, colors, cultural elements, and functional design is intended to provide users with not only the physical comfort of ergonomic support when resting in bed, but also a deep multi-sensory healing experience through sight (eaglewood hues and cultural patterns), touch (skin-friendly materials and natural wood), and actively induced olfactory stimulation (the aroma of eaglewood released by heating).

As a key auxiliary piece of furniture in the sleeping space, the design of the bedside table is crucial for integrating ergonomic dimensions with multi-sensory healing functions. This design strictly adheres to ergonomic principles and incorporates multiple healing functions. It provides a space with soft lighting (color temperature ~2700 – 3000K), soothing background sounds, and optional and controllable fragrance as its key functions. In terms of material, local materials are prioritized, with regionally distinctive vegetation, such as rattan, bamboo, or particular herbal plants, used for weaving or inlay. The color scheme (**Fig.6**) harmonizes with the overall therapeutic space, featuring dark brown (rgb (38, 21, 9), 26.15%), reddish brown (rgb (103, 70, 44), 25.55%), light brown (rgb (160, 123, 90),

ARTICLE IN PRESS

17.76%), and warm white (rgb (240, 239, 237), 16.47%), and beige (rgb (205, 189, 171), 14.08%), maintaining a warm and calm ambiance. The use of warm white helps to brighten specific areas, avoiding a sense of oppression. The special features of natural materials, such as veins of woven rattan and the warm, smooth texture of bamboo combined with this color scheme not only creates a visually harmonious and unified atmosphere but also enhances tactile comfort through the skin-friendly feel of natural textures, such as the skin-friendly texture of natural materials and the subtle tactile feel of woven patterns. This synergy between materials and colors, complemented by other sensory experiences, including olfactory and auditory, aims to effectively alleviate users' tension from both psychological and physiological perspectives, promoting relaxation and improved sleep quality. The function of aroma regulation creates the innovative concept of bedroom sets, utilizing integrated warm lights and a controllable heating base to gently heat eaglewood ornaments and release its unique natural aroma. In this way, uses can achieve active and controllable olfactory healing experience.

Lighting plays a dual role in healing spaces, providing both functionality and atmosphere. With eaglewood as the core material, the surface of the lighting fixtures is decorated with delicate totem patterns that have specific regional cultural significance. The design not only reflects the ethnic spirit and cultural recognition but also reinforces the cultural narrative within the space through visual artistic language, helping to evoke resonance and a sense of cultural belonging in users and enhancing

ARTICLE IN PRESS

the spiritual healing dimension of the space. Building on this study's innovative concept, these lighting fixtures integrate a precision temperature-controlled heating device (< 80 °C) that promotes the release of the unique natural fragrance of eaglewood rich in calming and relaxing ingredients, like agarospirol. This aromatic diffusion synergizes with the warm, low-intensity lighting of the fixtures (~2700–3000K) to create a visual-olfactory stimulation that amplifies relaxation and promotes sleep improvement. To match the characteristics of eaglewood, the solemnity of cultural totems, and the need to create a quiet atmosphere, the color scheme (**Fig.7**) is dominated by deep warm brown tones: reddish brown (rgb(128, 102, 76), 28.90%), dark brown (rgb(90, 67, 44), 26.87%), and black-brown (rgb (39, 24, 12), 23.07%), accounting for a total of 78.84%. These are complemented by light brown (rgb (173, 145, 113), 14.76%) and off-white (rgb (218, 200, 181), 6.41%), respectively, for harmonization and brightening. This color scheme effectively creates a calm, understated, and restful lighting environment, avoiding the potential disruption of sleep rhythms caused by high brightness or cool light, while also making the lighting fixtures themselves a quiet yet culturally rich visual focal point within the space.

ARTICLE IN PRESS

Discussion

Insomnia and related psychological disorders are one of the most common health problems in modern society. Eaglewood, when used as an adjunctive therapy,

ARTICLE IN PRESS

can help reduce over-reliance on medical resources. In this study, GC–MS was applied to determine the main components released into the air from burning eaglewood incense sticks. The results revealed that the volatile substances were mainly phenols and terpenoids. Among them, Jasmone, E -, trans-2-caren-4-ol, 3-caren-10-al, carvone oxide and Phenol, 2-methoxy- have been documented to exert sedative, anxiolytic and neuroprotective effects. These compounds produce soothing and sleep-promoting effects via olfactory pathways or central nervous system mechanisms. Certain phenols and terpenoids also possess auxiliary effects such as anti-inflammation, antioxidation and expectorant act. To this end, the present work utilized OFT, TST, FST, and collaborative hypnosis experiments to assess the anti-anxiety, anti-fatigue, and hypnotic effects of lighted eaglewood.

In the OFT, total distance (unchanged at 6 days) ruled out sedation. Center time and distance—key anxiety indices—were significantly increased by 12-day eaglewood, reversing the reduced center exploration seen in PCPA model mice (indicating restlessness), thus demonstrating an anti-anxiety effect. PCPA shortened latency and increased total immobility time in the FST, indicating aggravated fatigue/despair, and 12-day eaglewood treatment reversed both parameters. The TST showed no significant eaglewood effects, whereas the FST showed improvements after 12-day treatment. Given the discrepant outcomes across these two common antidepressant screens, the FST findings more likely reflect anti-fatigue rather than antidepressant-like properties.

ARTICLE IN PRESS

Returning to the insomnia model, PCPA is a selective and irreversible inhibitor of tryptophan hydroxylase that depletes central serotonin[21]. In our collaborative hypnosis experiments (pentobarbital-induced sleep test), the behavioral endpoints—sleep latency (time from injection to loss of the righting reflex) and sleep duration (time from loss to spontaneous recovery of the righting reflex)—were used to evaluate insomnia severity. These measures have been consistently employed in PCPA-based sleep research (Li et al.[22], Tang et al.[23]). We acknowledge the absence of polysomnographic validation (e.g., electroencephalography [EEG] and electromyography [EMG]), which is a methodological limitation; however, the present behavioral results that the model group had prolonged sleep latency and reduced sleep duration, consistent with previous relevant research findings of insomnia[24]. Lighted eaglewood for 12 days significantly shortened sleep latency and extended sleep duration, indicating a hypnotic-like effect. It is important to note that pentobarbital is a positive allosteric modulator of $GABA_a$ receptors; therefore, these results may reflect altered sensitivity to GABAergic agents rather than a direct sleep promoting effect. Supporting this hypothesis, GC–MS analysis identified Jasmone, E- as a major volatile component in burning eaglewood, which has been reported to possess anxiolytic and sedative properties by modulating neurotransmitter levels, particularly enhancing GABAergic transmission[25]. Other detected compounds, such as *trans*-2-Caren-4-ol and 3-Caren-10-al, have also been associated with neuroprotective and calming effects. Thus, at a mechanistic level,

ARTICLE IN PRESS

olfactory stimuli from lighted eaglewood could interact with endogenous sleep-regulatory systems via neural pathways linking the olfactory bulb to hypothalamic sleep centers, potentially enhancing $GABA_a$ receptor function or GABAergic transmission. This proposed mechanism requires further validation using neurochemical, electrophysiological, and pharmacological approaches. Taken together, the combined findings support that sustained (12-day) exposure to lighted eaglewood alleviates anxiety, reduces fatigue-related immobility in the FST, and improves sleep parameters in a PCPA-induced insomnia model.

Tao, et al.[26] investigated the influence of classroom color environments on college students' emotions during campus lockdowns. It found that warm colors were perceived as more effective in creating pleasure, relaxation, and mental attention compared to cool and neutral colors. Warm colors were associated with a more pleasant experience, while cool colors were noted to enhance attention. Küller also concluded in "The impact of light and color on psychological mood: a cross-cultural study of indoor work environments" that using highly saturated colors has a negative impact on mood[27]. Likewise, Ru et al.[28] find that the exposure to low illuminance, when compared with high illuminance, generates positive effects on participants' moods, thereby indicating that low saturation is more effective in stabilizing mood. For visual experience, sleeping areas are filled with the color of eaglewood, and the main colors are warm neutral tones, which are used on the walls and ceiling throughout the space to balance the warm colors and create a calm

ARTICLE IN PRESS

meditative atmosphere. Psychology has confirmed that low saturated colors cause low excitementand reduce anxiety[29]. This study systematically extracted the natural color characteristics of eaglewood to develop a spatial color scheme centered on warm and calm brown tones. The scheme strictly adheres to color harmony theory and psychological principles, creating a cross-sensory synergy with the aroma of eaglewood to promote emotional stability and deep relaxation.

Through artistic design, eaglewood, an ancient material, continues to deliver its healing value in modern life, creating a scientific and therapeutic sleeping experience. This attempt not only expands the functional dimensions of aesthetic design of healing space, but also provides a cultural solution to the sleep crisis in contemporary society. When night falls and the fragrance of eaglewood slowly flows through the designed space, perhaps we can rediscover the lost art of sleep in this olfactory nocturne.

ARTICLE IN PRESS

Limitations of this study

Although standardized incense sticks were used, the inherent chemical variability of eaglewood, including diverse geographical origins and induction methods, may affect the external validity and generalizability of our findings to other eaglewood types. Additionally, further research is needed to clarify how eaglewood affects sleep mechanisms.

ARTICLE IN PRESS

Funding

This work was supported by the Department of Science & Technology of Liaoning province (No.2023-BSBA-294); Hainan Provincial Natural Science Foundation of China (No.725QN305); Hainan Federation of Social Science Associations, Hainan Academy of Social Science (No.HNSK(QN)23-97); Hainan Provincial Educational Reform Program of China from the Education Department of Hainan Province (No.Hnjg2025ZC-44). The funding sources had no involvement in study design, collection, analysis, and interpretation of data in the report's writing or deciding to submit the article for publication.

Declaration of interest statement

We confirm that the manuscript has been read and approved by all named authors and that there are no other persons who satisfied the criteria for authorship but are not listed. We further confirm that all have approved the order of authors listed in our manuscript.

Data Availability Statement

The authors confirm that the data supporting the findings of this study are available within the article.

ARTICLE IN PRESS

References

1. Morin CM, Buysse DJ (2024) Management of insomnia. N Engl J Med 391(3):247–258.

2. Wang M, Fan S, Wang Z, et al. (2025) A systematic review and meta-analysis of acoustic stimulation in the treatment of insomnia. Front Neurosci 19:1572086.

3. Kyle SD, Siriwardena AN, Espie CA, et al. (2023) Clinical and cost-effectiveness of nurse-delivered sleep restriction therapy for insomnia in primary care (HABIT): a pragmatic, superiority, open-label, randomised controlled trial. Lancet 402(10406):975–987.

4. Khan MS, Aouad R (2022) The effects of insomnia and sleep loss on cardiovascular disease. Sleep Med Clin 17(2):193–203.

5. Shivanand P, Arbie NF, Krishnamoorthy S, et al. (2022) Agarwood—the fragrant molecules of a wounded tree. Molecules 27(11):3386.

6. Sundaraj Y, Mediani A, Rodrigues KF, et al. (2023) GC–MS olfactometry reveals sesquiterpenes α-Humulene and δ-Cadinene significantly influence the aroma of treated Aquilaria malaccensis essential oil. Aust J Crop Sci 17(12):893–901.

ARTICLE IN PRESS

ARTICLE IN PRESS

7. Lin F, Mei WL, Wu J, et al. (2010) GC–MS analysis of volatile constituents from Chinese eaglewood produced by artificial methods. J Chin Med Mater 33(2):222–225.
8. Gong B, Wang CH, Wu YL, et al. (2023) Anxiolytic and antidepressant effects of agarwood inhalation and its mechanism. China J Chin Mater Med 48(4):1023–1031.
9. Jalali MS, Gibbons RB, Jones JR (2025) Psychology or physiology? Choosing the right color for interior spaces to support occupants' healthy circadian rhythm at night. Buildings 15:2665.
10. Wilms L, Oberfeld D (2018) Color and emotion: effects of hue, saturation, and brightness. Psychol Res 82(5):896–914.
11. Rapuano M, Sarno M, Ruotolo F, et al. (2023) Emotional reactions to different indoor solutions: the role of age. Buildings 13(7):1737.
12. Yan X, Geng T (2024) Healing spaces improve the well-being of older adults: a systematic analysis. Buildings 14(9):2701.
13. Manca S, Bonaiuto M, Fornara F (2022) Perceived hospital environment quality indicators: the case of healthcare places for terminal patients. Buildings 13(1):57.
14. Applebaum D, Fowler S, Fiedler N, et al. (2010) The impact of environmental factors on nursing stress, job satisfaction, and turnover intention. J Nurs Adm 40:323–328.

ARTICLE IN PRESS

ARTICLE IN PRESS

15. Saltik B (2025) The evolution and impact of furniture design in contemporary society. BioResources 20(4):8841–8847.

16. Zhuan S (2023) Research on aging-friendly home space design based on humanization. Acad J Archit Geotech Eng 5:46–50.

17. Huisman ERCM, Morales E, Van Hoof J, et al. (2012) Healing environment: a review of the impact of physical environmental factors on users. Build Environ 58:70–80.

18. Tomassoni R, Galetta G, Treglia E (2015) Psychology of light: how light influences the health and psyche. PSYCH 6:1216–1222.

19. Manav B (2017) Color-emotion associations, designing color schemes for urban environment-architectural settings. Color Res Appl 42:631–640.

20. Sabar DP, Djimantoro MI (2020) The application of healing space concept in holistic care facilities: a brief guideline for design. IOP Conf Ser Earth and Environ Sci 426:012068.

21. Lai Y, Hua L, Yang J, et al. (2023) The effect of Chinese agarwood essential oil with cyclodextrin inclusion against PCPA-induced insomnia rats. Molecules 28(2):635.

22. Li YM, Shen CY, Jiang JG (2024) Sedative and hypnotic effects of the saponins from a traditional edible plant Liriope spicata Lour. in PCPA-induced insomnia mice. J Ethnopharmacol 327:118049.

23. Tang N, Wu C, Chen M, et al. (2017) Therapeutic effects of Jiaotai pill on rat insomnia via regulation of GABA signal pathway. Trop J Pharm Res 16:2135.

ARTICLE IN PRESS

ARTICLE IN PRESS

24. Du F, Cao S, Guo S, et al. (2025) Effects of electroacupuncture on p-chlorophenylalanine-induced insomnia mice. Innot Acupunct Med 18(1):25.

25. Bezerra FMDH, Vieira-Neto AE, Benevides SC, et al. (2023) Pharmacological potential of cis-jasmone in adult zebrafish (*Danio rerio*). Planta Med 89:539–550.

26. Tao W, Wu Y, Li W, et al. (2022) Influence of classroom colour environment on college students' emotions during campus lockdown in the COVID-19 post-pandemic era—a case study in Harbin, China. Buildings 12(11):1873.

27. Küller R, Ballal S, Laike T, et al. (2006) The impact of light and colour on psychological mood: a cross-cultural study of indoor work environments. Ergonomics 49:1496–1507.

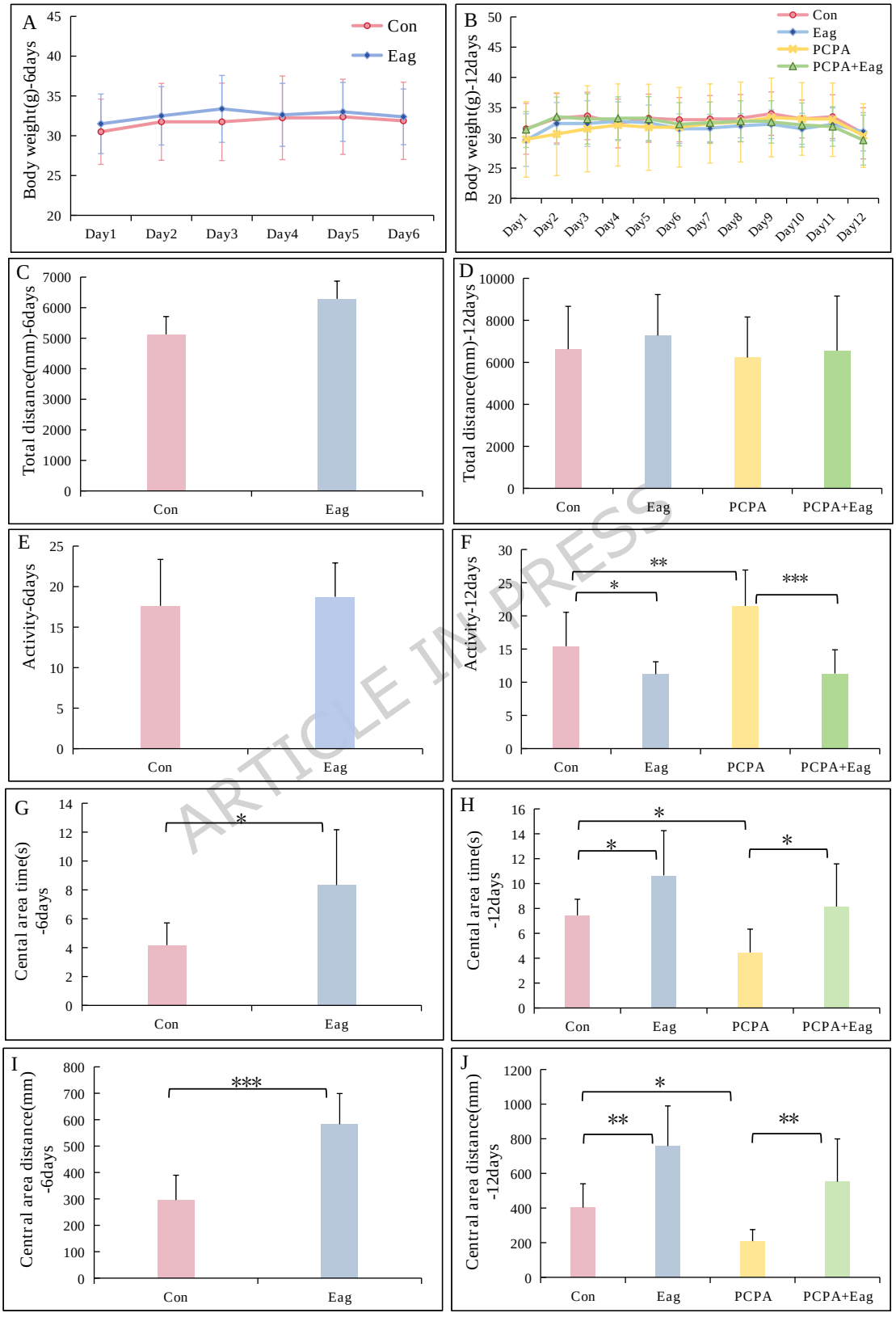
28. Ru T, de Kort YAW, Smolders KCHJ, et al. (2019) Non-image forming effects of illuminance and correlated color temperature of office light on alertness, mood, and performance across cognitive domains. Build Environ 149:253–263.

29. West B, Silberman J (2020) A colorful impact: the psychological impact of colors. J Student Res 8(2).

ARTICLE IN PRESS

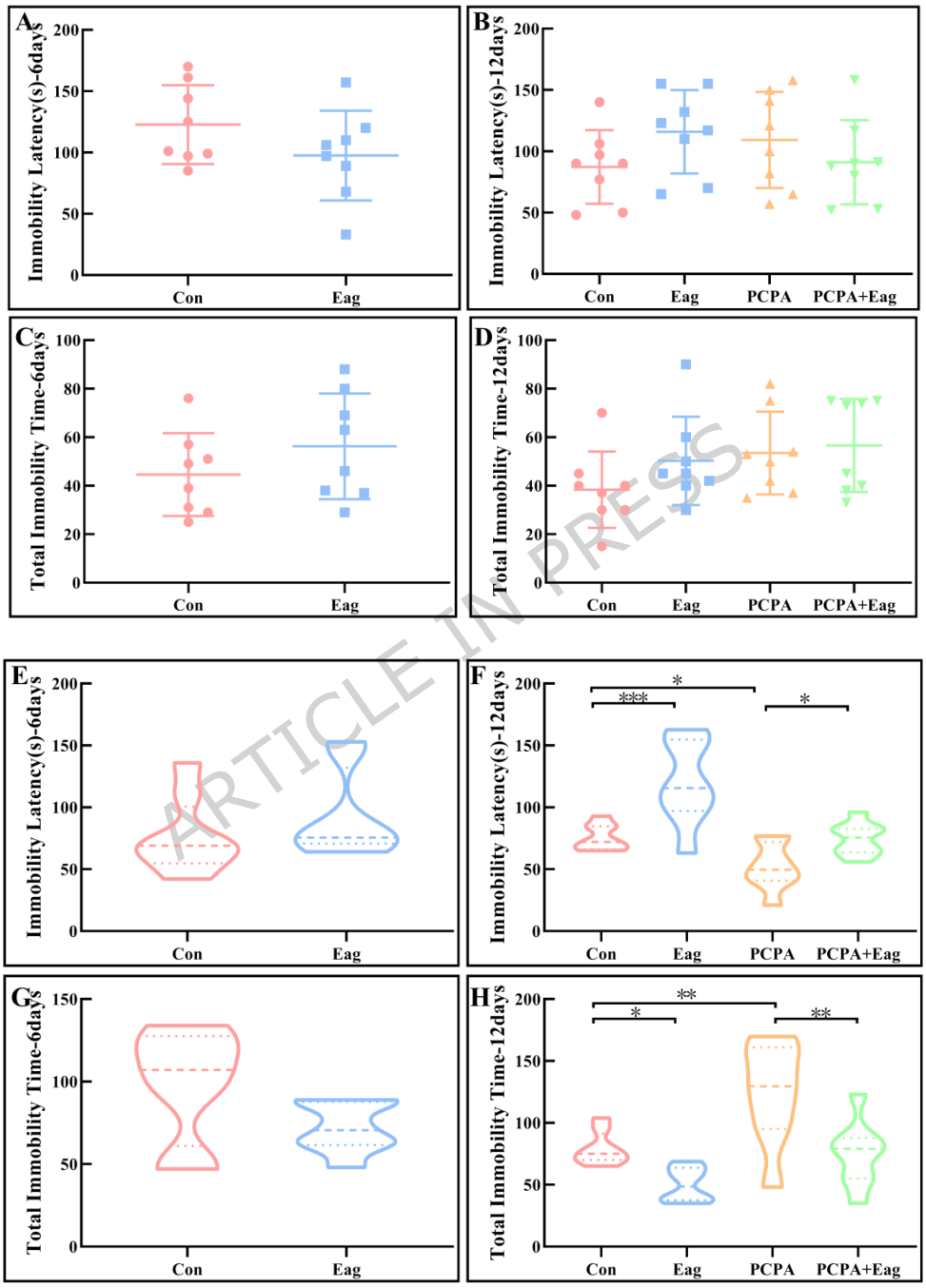
ARTICLE IN PRESS

Figure Captions



ARTICLE IN PRESS

Fig.1 Results of anti-anxiety effect of eaglerwood (n=8) $^{*}P$<0.05, $^{**}P$<0.01, $^{***}P$<0.001, Con: Control, Eag: Eaglewood, PCPA: 4-chloro-DL-phenylalanine.



ARTICLE IN PRESS

Fig.2 Experimental results of anti-fatigue effect of eaglewood (*n*=8) Fig. 2A-D results of TST, Fig. 2E-H results of FST. $^{*}P<0.05$，$^{**}P < 0.01$，$^{***}P < 0.001$, Con: Control, Eag: Eaglewood, PCPA: 4-chloro-DL-phenylalanine.

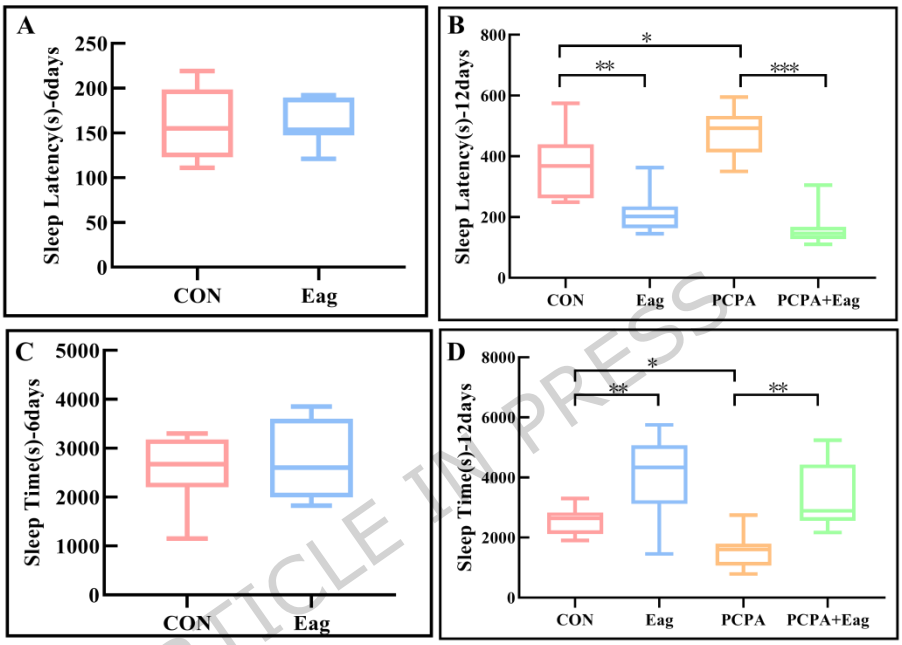


Fig 3 Experimental results of calming nerves and aiding sleep effects of eaglewood (*n*=8) $^{*}P<0.05$, $^{**}P<0.01$, $^{***}P<0.001$, Con: Control, Eag: Eaglewood, PCPA: 4-chloro-DL-phenylalanine.



Fig.4 Design Proposal for Furniture in the Healing Space



Fig.5 Design Proposal for Beds and Bedding in the Healing Space

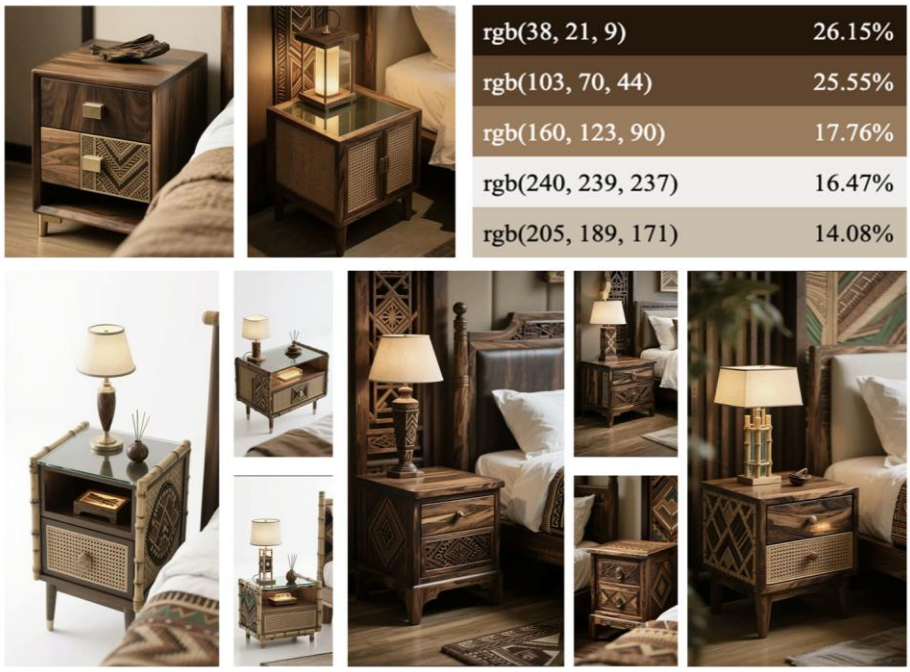


Fig.6 Design Proposal for Bedside Table in the Healing Space



Fig.7 Design Proposal for Lighting Fixtures in the Healing Space