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The Role Of Olfaction In Restorative Learning Environments

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Abstract

This paper examines olfaction as an emerging dimension of multisensory architecture, with particular attention to learning environments. Primarily, architectural discourse often overlooks the role of olfaction in shaping human experiences within spaces. Anchored in evidence from interdisciplinary subject matters covering environmental psychology, cognitive neuroscience and biophilic design, the paper reviews research examining how natural olfactory stimuli influence physiological and cognitive responses. The review finds that pleasant natural aromas, particularly those associated with vegetation and natural materials, may contribute to improved psychological wellbeing and learning experiences. These effects are considered within the broader relationship between sensory perception and the physical environment, highlighting how olfaction can interact with other sensory modalities to shape occupants' responses to architectural space, suggesting that restorative experiences may depend on the coordination of multiple sensory inputs rather than a single environmental variable.Therefore, the paper argues for a more deliberate consideration of olfaction within architectural design. Rather than treating smell as an incidental environmental condition. Strategies including olfactory zoning, sensory refuge spaces, natural materials, vegetation, and carefully controlled plant-based scents may complement existing visual, auditory, tactile and thermal design approaches. Integrating olfaction into learning environments therefore offers a broader approach to multisensory architecture and provides a basis for designing learning spaces that support comfort and contribute to more holistic wellbeing-oriented approaches to multisensory architectural design of learning environments.

Keywords: Multisensory Design, Olfaction, Tactile Stimuli, Cognitive Load, Restorative Learning Environments, Neuroarchitecture

1. INTRODUCTION

Restorative learning environments are spaces that are characterised by their ability to improve wellbeing by reducing stress and enhancing psychological and cognitive outcomes. In the corporate and health industries, restorative environments have been shown to reduce patient anxiety and enhance perceived staff comfort and overall wellbeing (Kamel & Sellaoui, 2026; Yildirim et al., 2024). However, beyond the corporate and health industries, learning environments stand out. In today's world, a significant portion of humans spend a substantial amount of their lives within the boundaries of the learning environment, and it is a fact that the environment where a student learns can either promote overall growth or significantly hinder it (Thomson & Kucirkova, 2025). Consequently, studies have shown that restorative learning spaces have the potential to mitigate added stress, stimulate creativity, induce concentration, and improve cognitive performance, therefore enhancing learning outcomes (Almirón Cuentas & Bernedo-Moreira, 2024; Thomson & Kucirkova, 2025).

This then places the physical learning environment in a unique position within the educational context since research has shown that architectural decisions, from spatial configuration to material selection, shape the cognitive and affective states of learners in ways that are neither incidental nor superficial (Barrett et al 2015). However, despite the important role the physical learning environment plays in a student's learning, prevailing architectural practice and research continue to prioritise two major sensory modalities, which are visual and auditory, while the Olfactory dimensions are often treated as secondary considerations.

This sensory asymmetry carries tangible consequences for educational environments where learning takes place, especially in Nigeria where research has shown that many schools still suffer from poor conditions such as overcrowding, poor lighting and ventilation, inadequate furniture, excessive noise, weak maintenance and limited learning resources which invariably hinder both the learning outcomes of these students and their overall wellbeing (Adeyemo, 2026; Obetta & Shaibu, 2025; Obi et al., 2022)

Furthermore, Sørensen & Kristensen (2024) found that the air quality in crowded classrooms shows higher levels of Volatile Organic Compounds (VOCs) linked to skin, sweat, breath, personal care products and cleaning-related terpenes such as limonene, causing such spaces to smell stale or chemically intense, affecting the performance of the users of the space. This is significant because Carton et al., (2023) had found that Total Volatile Organic Compounds (TVOC) levels significantly correlated to students study engagement in university classrooms and Zhao et al., (2025) noted that "exposure to a medium–high level of TVOC (2000 µg/m3) significantly reduces task accuracy by 4.9% compared to the low level (100 µg/m3)". Choi et al. (2022) note that pleasant aroma improved mood and memory, as shown in the case of lemon, even though overall, learning effects were not shown to be significant.

This paper therefore posits that olfactory design parameters represent an underutilised resource in the field of restorative learning in the educational architecture landscape. Through a thematic synthesis of recent empirical literature, the paper examines the mechanisms through which scent influences cognition, emotion and physiological arousal in educational settings. The paper is guided by two major questions: 1) How do olfactory stimuli influence learners' cognitive and emotional states; 2) What are the design characteristics associated with restorative outcomes?

2. METHODOLOGY

This paper employs a narrative literature review approach to synthesise the evidence available on the role of olfactory stimuli in physical learning environments. Given the multidisciplinary nature of the research, a narrative review was selected as the most appropriate approach since the subject matter spans across neuroarchitecture, environmental psychology, cognitive science, educational research and building sciences. White et al. (2020) and Cuentas & Bernedo-Moreira (2023) both explicitly adopted a narrative review methodology to highlight and synthesise key issues across multiple dimensions. Furthermore, Ezzat Ahmed et al. (2021) and Duhoki & Gülten, (2025) used qualitative approaches, including narrative analysis for neuroarchitecture research, showing that this methodological pattern is consistent and recognised as appropriate for synthesising evidence across interconnected disciplines where integration of diverse perspectives is essential.

2.1 Search Strategy and Source Selection

Relevant literature was identified through structured searches of Google Scholar using combinations of keywords related to multisensory design, olfaction, learning environments and neuroarchitecture. Backwards and forward citation tracking was also employed to identify additional relevant studies. The review included peer-reviewed journal articles published in English that examined olfactory or multisensory aspects of educational environments. Studies using objective physiological measures such as electroencephalography (EEG), heart-rate variability, galvanic skin response and cortisol levels were prioritised where available.

3. RESULTS

3.1 Neuroanatomical Basis of Olfactory Influence.

The strong psychological influence of smell is due to its unique neural pathway. Unlike visual, auditory, tactile and gustatory information, which typically reaches the cortex through an early thalamic relay, olfactory signals initially project from the olfactory bulb to primary olfactory regions, especially the piriform cortex, and to closely connect limbic related structures such as the amygdala and entorhinal cortex as shown in Figure 1: Neural Connections of the olfactory system source: (BrainKart, 2017)This relatively direct access to emotion- and memory-related circuits may explain why odours can strongly affect cognition and behaviour (Soudry et al., 2011). This is especially important within educational settings as the hippocampus plays an important role in the formation of memory and spatial learning (Jeffery, 2018; Soudry et al., 2011)

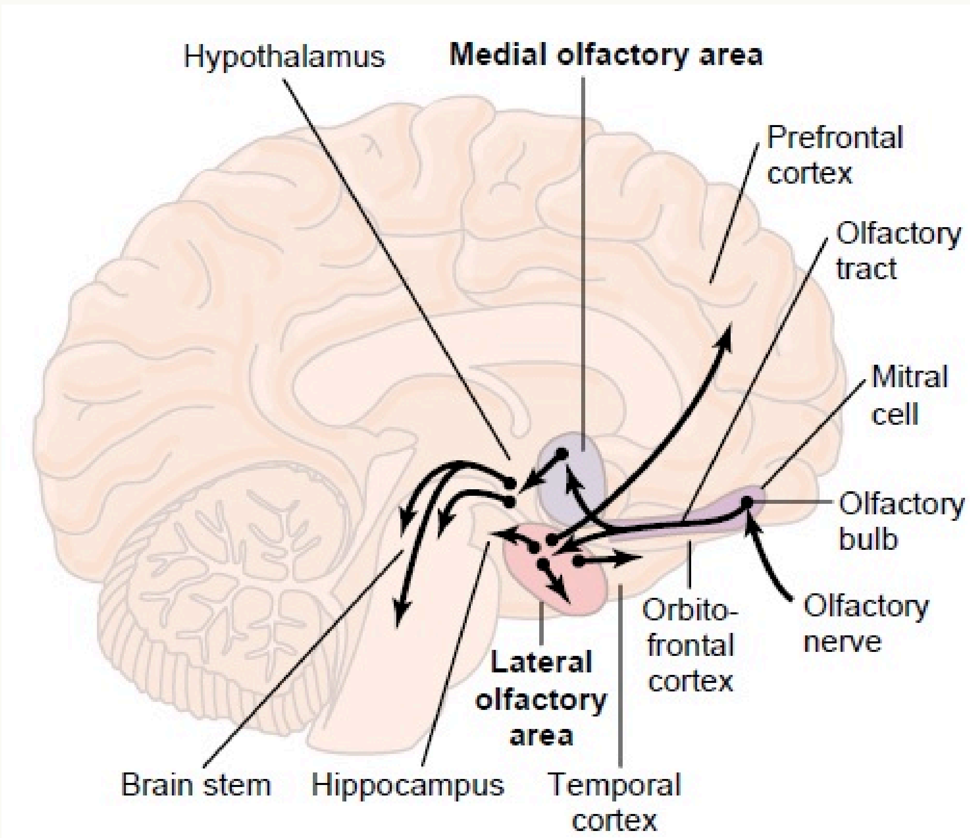

Figure 1: Neural Connections of the olfactory system source: (BrainKart, 2017)

3.2 Plant-based Scents and Cognitive Performance

In a study of primary school students on Batam Island attending coastal campuses, Aguspriyanti et al., (2026) found that physical environmental elements have a major influence on students' psychological and cognitive readiness for learning (Aguspriyanti et al., 2026). When primary school children rated the environmental factors that most strongly enhanced their intrinsic motivation to learn, pleasant or familiar scents emerged as the single influential driver, achieving the highest mean score of 4.19 out of 5.00 (Aguspriyanti et al., 2026). Scent outperformed traditional considerations, such as the visual cleanliness of the school and the spatial availability of an outdoor playground (Aguspriyanti et al., 2026). Students expressed a strong preference for artificial fragrances that replicate sweet, familiar aromas and natural plant-based scents, followed by food aromas, with unfamiliar scents receiving almost no support. These sweet and fresh olfactory cues foster emotional security, visual focus and curiosity, directly supporting academic readiness (Aguspriyanti et al., 2026). Likewise, a study of 44 university students revealed lemon aroma was associated with more positive mood and greater task accuracy, although motor responses were slower (Smith & Nicholson-Lord, 2024). Although these findings largely originate from cross-sectional studies, they provide a neurophysiological basis for applying olfactory design principles in educational environments.

3.3 Plant-based Scents and Physiological Responses

The empirical data show that VOCs derived from plants can directly influence the autonomic nervous system positively by promoting relaxation. Living plants release volatile organic compounds known as phytoncides, including terpenes such as α-pinene and β-pinene (Antonelli et al., 2020). Human studies suggest that prolonged exposure to tree-derived phytoncides may reduce physiological markers of stress and enhance aspects of immune function, as noted by Li et al., (2009), where overnight exposure to vapourised Hinoki cypress oil increased natural killer cell activity and reduced urinary adrenaline and noradrenaline in healthy adults. Similarly, Lavender is associated with reduced anxiety and blood cortisol levels in patients awaiting heart surgery, while transdermal α-santalol produced physiological changes interpreted as consistent with relaxation in healthy adults (Hosseini et al., 2016).

Xu et al., (2026) found that exposure to rosemary leaf aroma (which is high in concentration of the active compound 1,8-cineole) caused a reduction in students' systolic blood pressure (SBP), Diastolic blood pressure (DBP) and heart rate reduction all within a range of ($p < 0.01$) allowing students to complete the cognitive task assigned in a shorter amount of time when attention tests were conducted using the Schulte Grid. Furthermore, factorial measurements by Xu et al., (2026) of Skin Conductance Level (SCL) values were lowest under the high GVI condition compared to the low and medium. That is to say, although the high GVI + no scent condition exhibited the lowest SCL levels (indicating physical relaxation), its subjective landscape preference rating was remarkably low. In contrast, the medium GVI + rosemary leaf scent condition received the highest subjective landscape score. This significant dissociation indicates that a visually saturated environment devoid of matching olfactory cues induces perceptual monotony and boredom rather than restoration.

3.4 Architectural strategies for restorative olfactory environments.

Two major strategies highlighted in the reviewed literature are often related to zoning and materiality considerations. In terms of spatial zoning, studies show that sensory zoning models, transition zones, spatial airlocks, horizontal vestibules, or vertical mezzanines between high-stimulation zones (such as cafeterias and active play areas) and learning areas can serve as buffers to isolate strong odour sources. (Abdou & Younis, 2026; Kim & Park, 2026; Spence, 2020; Torriani et al., 2026), 2020). Whereas, when it comes to the use of natural materials, wood stands out as the most prominent material used in interior spaces, making up approximately 67% of materials smellscapes (Ma et al., 2026). In corridors or common areas, wood panelling serves as a natural humidity regulator, absorbing moisture and gradually releasing light, relaxing and clean resinous aromas, while raw, unfired rammed earth or terracotta clay bricks absorb environmental humidity and, during rainy periods or localised misting, release petrichor, the characteristic scent of wet earth that evokes a deep, restorative connection with nature (Torriani et al., 2026)

4. DISCUSSION

The findings suggest that olfaction should be seen as an active component of restorative architecture. Its relatively direct connections with the amygdala, hippocampus and other limbic structures provide a basis through which environmental odours can influence perception of space (Jeffery, 2018; Soudry et al., 2011). This is particularly relevant in learning environments, where sustained attention and memory formation are fundamental to learning.

The findings show that olfactory cues can generate relatively immediate affective and physiological responses. However, this does not mean that olfaction operates independently of cognition; rather, its close relationship with emotion and memory allows it to influence the affective conditions within which cognitive processes occur. Olfaction may therefore act as an anchor within restorative learning environments.

Furthermore, the findings from Xu et al. (2026) suggest that combining visual greenery with plant aromas may produce a more restorative experience than visual exposure alone. Olfaction may therefore function as a sensory buffer, complementing rather than competing with visual information. This has particular implications for biophilic learning environments, wherein simply increasing the amount of greenery within a space, it should not automatically be assumed to produce greater restoration. The finding that different combinations of greenery and rosemary aroma produced different physiological and subjective responses (Xu et al., 2026) suggests that the quality and coordination of sensory stimuli may be more important than their quantity. As a result, the design objective should shift from maximising individual sensory variables towards achieving an appropriate multi-sensory balance.

At the spatial level, small, enclosed or semi-enclosed refuge spaces with reduced sensory complexity can provide opportunities for students to withdraw from environments characterised by high visual stimulation. Simultaneously, sensory zoning can be used to control the movement of undesirable odours from high odour zones such as cafeterias, kitchens, toilets, waste storage areas. The spaces should be separated from classrooms and studios through transition zones and appropriate ventilation planning, acting as olfactory filters within the building. (Abdou & Younis, 2026; Kim & Park, 2026; Torriani et al., 2026).

Last but not least, Materiality provides a further opportunity for architectural integration with olfaction. Timber, rammed earth and terracotta can contribute naturally occurring olfactory cues while simultaneously shaping other aspects of a space (Ma et al., 2026; Torriani et al., 2026). This suggests that material selection can be considered in terms of its smellscape contribution rather than being evaluated solely through appearance or performance. However, such strategies must remain closely integrated with ventilation and indoor air quality management systems since materials and maintenance products can also generate undesirable emissions.

As a whole, the findings show a shift from treating smell primarily as an environmental problem to recognising it as a designable sensory layer of architecture.

5. CONCLUSION

This paper has synthesised empirical evidence mapping the physiological and cognitive pathways of olfactory perception; the review demonstrated that olfaction is a critical determinant of student attention and learning motivations. However, the implementation of olfactory design in educational settings requires careful consideration. It is also noteworthy that human responses to scent are highly individual, shaped by genetic differences, cultural background, personal experiences, and learned associations. While some scents may promote relaxation and motivation, others may be perceived as unpleasant or trigger adverse reactions in individuals with asthma, fragrance allergies or chemical sensitivities. Hence, using olfaction as an active design resource requires a shift from intuitive design to design grounded in neuro-inclusive practices with a vivid understanding of the cultural context surrounding the building. Architects must design schools that establish an odour-neutral baseline, using passive zones to nurture the minds of all learners.

Future research should focus on four key priorities. First, objective physiological measures, such as EEG, heart-rate variability, galvanic skin response, and cortisol levels, should be used to validate the effects of multisensory design interventions. Second, longitudinal studies are needed to examine their long-term impact on student wellbeing and academic performance. Third, context-specific research should investigate the effectiveness of indigenous Nigerian plant species and locally sourced materials in restorative learning environments. Finally, multisensory design principles should be incorporated into national educational design standards, including the TETFUND infrastructure guidelines, to promote equitable access to healthy and restorative learning environments across Nigerian educational institutions.

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