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International Journal of Graphic Design (IJGD)
Vol. 03 No. 02 October 2025
E-ISSN: 2987-9434; P-ISSN: 2988-0343, Page 295-312
DOI: https://doi.org/xx.xxxx
Available online at: https://journal.stekom.ac.id/index.php/ijgd

Multisensory Interior Design Interventions to Reduce Stress in High-Intensity Healthcare Settings

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Abstract. *The growing global emphasis on patient-centered care highlights a persistent gap in healthcare design: clinical environments often remain sterile and stress-inducing, undermining psychological recovery. This study introduces a human-centered, multisensory interior design framework that integrates sensory experience as a therapeutic variable rather than an aesthetic supplement. Unlike previous evidence-based or biophilic design studies that examine isolated sensory factors, this research validates an integrated multisensory model through mixed-method investigation. The study combines a systematic literature review, expert consultations with architects, designers, and healthcare professionals, and a quasi-experimental case study across three hospital wards implementing sensory-based interventions. Findings indicate that deliberately orchestrating visual, auditory, tactile, and olfactory stimuli significantly reduces patient anxiety, enhances perceived comfort, and improves staff well-being. Statistical results (paired t-tests and ANOVA) corroborate these effects, with measurable physiological and perceptual outcomes. The proposed framework translates these insights into actionable design strategies that align aesthetics with therapeutic evidence. This research advances interior architecture scholarship by bridging neuroscience, environmental psychology, and design practice, positioning multisensory design as a restorative paradigm for future healthcare environments.*

Keywords: *Multisensory Interior Design, Human-Centered Healing Spaces, Healthcare Environment Optimization, Therapeutic Interior Interventions, Evidence-Based Interior Architecture*

INTRODUCTION

High-intensity healthcare environments, such as intensive care units (ICUs) and emergency departments (EDs), are inherently stressful for patients, caregivers, and medical personnel alike. These environments are characterized by continuous alarms, intense artificial lighting, constrained physical layouts, and emotionally charged situations that impose extraordinary psychological and physiological demands (Bottani et al., 2022; Parindra et al., 2024). Prolonged exposure to such stressors has been linked to adverse health outcomes, including elevated anxiety, weakened immune response, and cognitive fatigue in both patients and staff (Cao et al., 2024; Clemente-Suárez et al., 2023). While medical technologies have advanced rapidly, the spatial and sensory dimensions of healing remain relatively neglected. Addressing this imbalance requires reconceptualizing healthcare interiors as active therapeutic agents rather than passive backdrops to clinical activity (Mahmood, 2020; SELÇUK, 2022).

A promising approach to this challenge is multisensory interior design, which intentionally orchestrates sensory stimuli light, sound, texture, color, and scent to create emotionally supportive environments (G. Wang, 2024; Wiśnicka, 2024). Unlike conventional models that prioritize

Received: September 2025, Revised: October 2025; Accepted: October 2025; Published: October 2025
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visual aesthetics or functional efficiency, multisensory design foregrounds the embodied experience of users (Nugroho & Wibowo, 2024; Wibowo & Zainudin, 2024; Yunianto & Wahyudi, 2024). Empirical findings from neuroscience and environmental psychology confirm that sensory inputs influence emotion regulation, stress physiology, and recovery (Shakour & Nermine Youssef, 2025; Xu et al., 2025). For example, exposure to natural light supports circadian balance, while controlled acoustic design reduces noise-related fatigue among medical personnel (Bulaj et al., 2025; Gashoot, 2022) Likewise, tactile materials with biophilic qualities such as wood or plant-based surfaces evoke calmness and psychological comfort (Yi & Aziz, 2025). Yet, despite growing empirical evidence, sensory design remains treated as aesthetic embellishment rather than an integral therapeutic component in healthcare architecture (Ferhati & Gottschald, 2023; Read & Meath, 2025).

The limited adoption of multisensory approaches stems from a persistent disconnect between design theory and clinical science. While medical research has mapped stress and pain mechanisms in detail (Cao et al., 2024; Clemente-Suárez et al., 2023), few studies translate these insights into spatial design strategies (Read & Meath, 2025; Rodríguez-Labajos et al., 2024). Conversely, design research often explores general notions of well-being without addressing the high-stakes, time-sensitive demands of critical care environments (Colenberg & Jylhä, 2022; Nuth Sloboda, 2023). This disciplinary divide produces interiors that meet technical and regulatory standards but fail to address sensory and emotional needs. Bridging this gap requires an evidence-based, interdisciplinary model that unites neuroscience, psychology, and biophilic principles to develop environments that both meet clinical demands and promote recovery (Aktan Ábrahám & Deniz, 2025; Pilosof & Grobman, 2021).

Evidence-Based Design (EBD) provides a methodological foundation for such integration. EBD advocates for design decisions grounded in measurable outcomes rather than intuition, and it has improved patient safety and operational efficiency across many healthcare settings (Ferhati & Gottschald, 2023; Read & Meath, 2025). However, its multisensory dimension remains underexplored particularly how multiple sensory modalities interact synergistically to alleviate stress in high-intensity care environments. Integrating multisensory design into EBD aligns with the human-centered design ethos that emphasizes empathy, iteration, and systems thinking principles long articulated by (Buchanan, 1992) in his theory of wicked problems, (Cross, 2001) in designerly ways of knowing, in design for experience and emotion. These frameworks collectively frame design not merely as form-making but as sense-making a process that translates human experience into actionable spatial interventions.

Building on this theoretical grounding, the present study addresses a critical research gap by developing and validating a multisensory interior design framework for high-intensity healthcare settings. The research synthesizes interdisciplinary insights from neuroscience, environmental psychology, and design practice through a mixed-method approach involving simulation-based experiments, biometric measures, and perceptual assessments. The study specifically investigates how orchestrated sensory interventions light modulation, soundscapes, tactile materiality, color palette, and olfactory cues can reduce stress and enhance well-being among patients and staff. The novelty of this work lies in its holistic and evidence-based integration of sensory modalities into a single therapeutic framework, moving beyond previous EBD, biophilic, or neuroarchitectural studies that typically isolate one sensory dimension. By positioning multisensory design as a central therapeutic agent, this research advances a new paradigm of healthcare architecture that reconceives hospitals not merely as sites of treatment, but as restorative ecosystems fostering resilience, dignity, and holistic recovery for all users.

LITERATURE REVIEW

The emergence of multisensory design theory marks a paradigm shift in the way interior environments are conceptualized and experienced. Rooted in neuroscience, environmental psychology, and human-centered design, this theory posits that interior spaces can be deliberately orchestrated to engage multiple senses simultaneously sight, sound, touch, smell, and sometimes even taste to enhance well-being and cognitive functioning (Shakour & Nermine Youssef, 2025; Wiśnicka, 2024). Unlike traditional aesthetic-driven approaches, multisensory design actively integrates sensory modalities into spatial strategies, producing environments that are immersive, responsive, and restorative. As (Almirón Cuentas & Bernedo-Moreira, 2024) demonstrate in educational contexts, multisensory architecture not only enhances engagement but also supports learning outcomes by aligning environmental stimuli with users' psychological and physiological needs. This foundational principle underscores the potential of applying similar methods in healthcare environments, particularly in high-intensity settings where stress mitigation is paramount.

Central to multisensory design in healthcare is the concept of the healing environment, which has evolved from simple notions of cleanliness and efficiency to holistic frameworks of therapeutic support. The healing environment acknowledges that spatial qualities light, acoustics, materiality, and color can significantly influence patient recovery, emotional regulation, and staff performance (Bulaj et al., 2025; Gashoot, 2022). Evidence-Based Design (EBD) complements this perspective by grounding design decisions in empirical research rather than subjective intuition, thus bridging the gap between aesthetics and clinical outcomes (Ferhati & Gottschald,

2023; SELÇUK, 2022). EBD frameworks have demonstrated measurable benefits in healthcare, including reduced patient length of stay, lower medication use, and enhanced staff satisfaction (Ferhati & Gottschald, 2023; Read & Meath, 2025). However, as (Aktan Ábrahám & Deniz, 2025) argue, EBD still struggles with integrating multi-sensory parameters holistically into the design process, often focusing on isolated interventions such as daylight optimization or noise control rather than systemic sensory orchestration.

To further understand this integration challenge, it is essential to ground multisensory design within classical design theories. (Buchanan, 1992) introduced the concept of wicked problems in design thinking, emphasizing that complex societal challenges such as healing environments require iterative, interdisciplinary, and human-centered solutions. (Cross, 2001) expanded this through the notion of designerly ways of knowing, positioning design as a unique epistemology focused on synthesis and sense-making. Later articulated how everyday interactions evoke emotional and cognitive responses that shape user experience. Together, these theories establish a foundational rationale for multisensory interior design as both a cognitive and affective practice, transforming healthcare spaces from functional containers into active mediators of experience.

Despite these advances, a critical review of prior studies reveals notable gaps in the translation of multisensory theory into high-intensity medical environments. While hospital optimization research has primarily addressed operational efficiency, infection control, and workflow management (Bottani et al., 2022; Parindra et al., 2024), less attention has been given to the human experience of stress within these optimized systems. Environmental psychology research highlights the importance of sensory modulation in reducing stress responses green environments have been shown to protect cognitive performance under pressure (Xu et al., 2025), and biophilic design principles demonstrate positive impacts on mood and physiological resilience (Bulaj et al., 2025). Yet, few studies explicitly integrate these findings into ICU or emergency department interiors, leaving a gap between scientific evidence and design implementation (Ordu et al., 2021; Rodríguez-Labajos et al., 2024). This gap suggests that while the therapeutic potential of sensory environments is well-established, its architectural application remains underdeveloped.

Moreover, studies that attempt to address user well-being in clinical settings often lack an interdisciplinary approach, resulting in fragmented solutions. For example, research on acoustic optimization tends to focus on decibel reduction without considering how soundscapes can be positively designed to promote calmness and orientation (Colenberg & Jylhä, 2022). Similarly, lighting studies may address glare reduction but neglect circadian rhythm support crucial for

patient recovery and staff alertness (G. Wang, 2024). As (Nuth Sloboda, 2023) emphasizes in the context of neurodiverse classrooms, location, material selection, and environmental affordances must be integrated into a cohesive sensory strategy to truly meet user needs. This insight aligns with Buchanan's (1992) perspective on integrative problem-solving, underscoring that design for healing must synthesize multiple knowledge systems — scientific, technical, and experiential — rather than treat them as isolated domains. The lack of integrated frameworks for sensory-rich, evidence-based healthcare interiors highlights a significant research and practice void.

Another dimension of this gap lies in the socio-cultural framing of healing environments. (Bosley et al., 2022) introduce the concept of healing justice, emphasizing that spaces of care must address not only physiological stressors but also systemic and emotional trauma. This perspective challenges designers to consider healthcare interiors as active participants in collective healing, not merely neutral backdrops for medical procedures. (Rabaan & Dombrowski, 2024) extend this notion by demonstrating how sociotechnical mechanisms can center marginalized users in trauma-informed environments. Yet, mainstream hospital design has been slow to incorporate these insights, often prioritizing cost-efficiency and regulatory compliance over holistic well-being (Ferhati & Gottschald, 2023; L. Wang & Demeulemeester, 2023). Integrating the moral dimension of design as implied notion of emotional design positions multisensory interiors not only as functional or aesthetic artifacts but as ethical agents that mediate empathy, dignity, and care.

Theoretical advancements in neuroarchitecture further support this shift by linking sensory stimuli to neural processes underlying stress, memory, and emotion regulation. (Shakour & Nermine Youssef, 2025) show how spatial configurations and material cues can modulate neural responses, while (Xu et al., 2025) highlight the therapeutic potential of targeted sensory interventions in disease contexts. These findings suggest that healthcare interiors can be strategically designed to activate calming neural pathways, reducing cortisol levels and supporting healing trajectories (Cao et al., 2024; Clemente-Suárez et al., 2023). However, as (Yi & Aziz, 2025) argue, this potential remains largely untapped in practice, particularly in regions where design industries have yet to fully embrace compassionate, multisensory methodologies. Thus, uniting EBD with classical design theory and neuroscience provides a more comprehensive framework one that acknowledges both measurable outcomes and experiential meaning.

To conceptualize these relationships, Figure 1 presents a diagram mapping how multisensory elements light, sound, texture, color, and scent interact to mitigate stress in healthcare environments. Each element influences distinct yet interconnected pathways: lighting supports circadian alignment and visual comfort; soundscapes reduce noise-induced stress and

provide orientation; textures evoke tactile grounding and familiarity; colors modulate emotional tone; and scents trigger memory and relaxation responses. When orchestrated collectively, these elements form an immersive healing ecosystem that moves beyond mere functionality toward emotional and physiological restoration (Almirón Cuentas & Bernedo-Moreira, 2024; Bulaj et al., 2025).

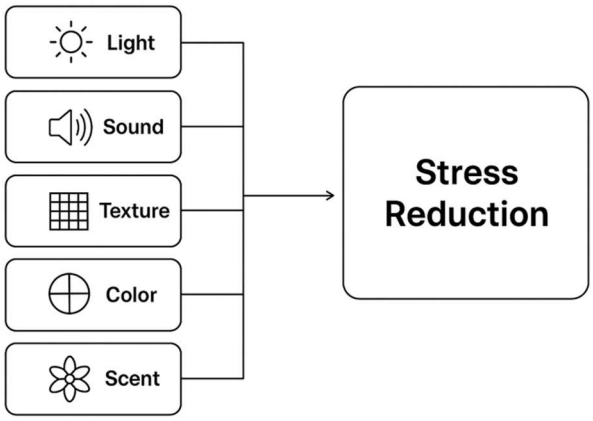

Figure 1. Conceptual Diagram of Multisensory Elements Supporting Stress Reduction in High-Intensity Healthcare Settings

To conclude, this review not only consolidates current evidence on multisensory and evidence-based healthcare design but also repositions these ideas within the broader canon of design theory. It demonstrates that while operational efficiency and isolated sensory interventions have dominated prior efforts, a holistic, interdisciplinary, and user-centered framework is still missing. Addressing this gap requires combining the empirical rigor of EBD with the interpretive depth of classical design theory to articulate multisensory interiors as transformative, therapeutic systems an approach that redefines the role of interior design in healthcare innovation.

METHODS

This study adopts a quasi-experimental design integrating simulated interior environments with physiological and perceptual data collection to investigate the impact of multisensory interventions on stress reduction in high-intensity healthcare settings. The choice of a simulation-based experimental approach ensures rigorous control over environmental variables, enabling a precise assessment of cause-and-effect relationships (L. Wang & Demeulemeester, 2023). As highlighted by (Aktan Ábrahám & Deniz, 2025), evidence-based design benefits from iterative testing within controlled settings to inform real-world applications. By merging empirical evaluation with human-centered inquiry, this methodology aligns with contemporary demands for actionable, data-driven strategies in healthcare interior design (Read & Meath, 2025).

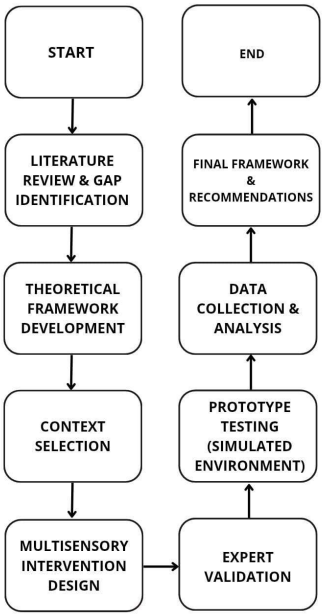

Figure 2. Methodological Framework of Multisensory Simulation Design

38 The study focuses on an Intensive Care Unit (ICU) and an Emergency Department (ED) as primary contexts, reflecting environments where stress is both prevalent and detrimental. These spaces were selected due to their high sensory intensity, critical decision-making processes, and vulnerability to environmental stressors (Bottani et al., 2022). Simulated ICU and ED settings will be constructed within a laboratory-based healthcare mock-up, incorporating authentic medical equipment and layout standards. Such an approach not only replicates operational realism but also facilitates systematic evaluation of multisensory interventions in a controlled yet contextually relevant environment (Parindra et al., 2024).

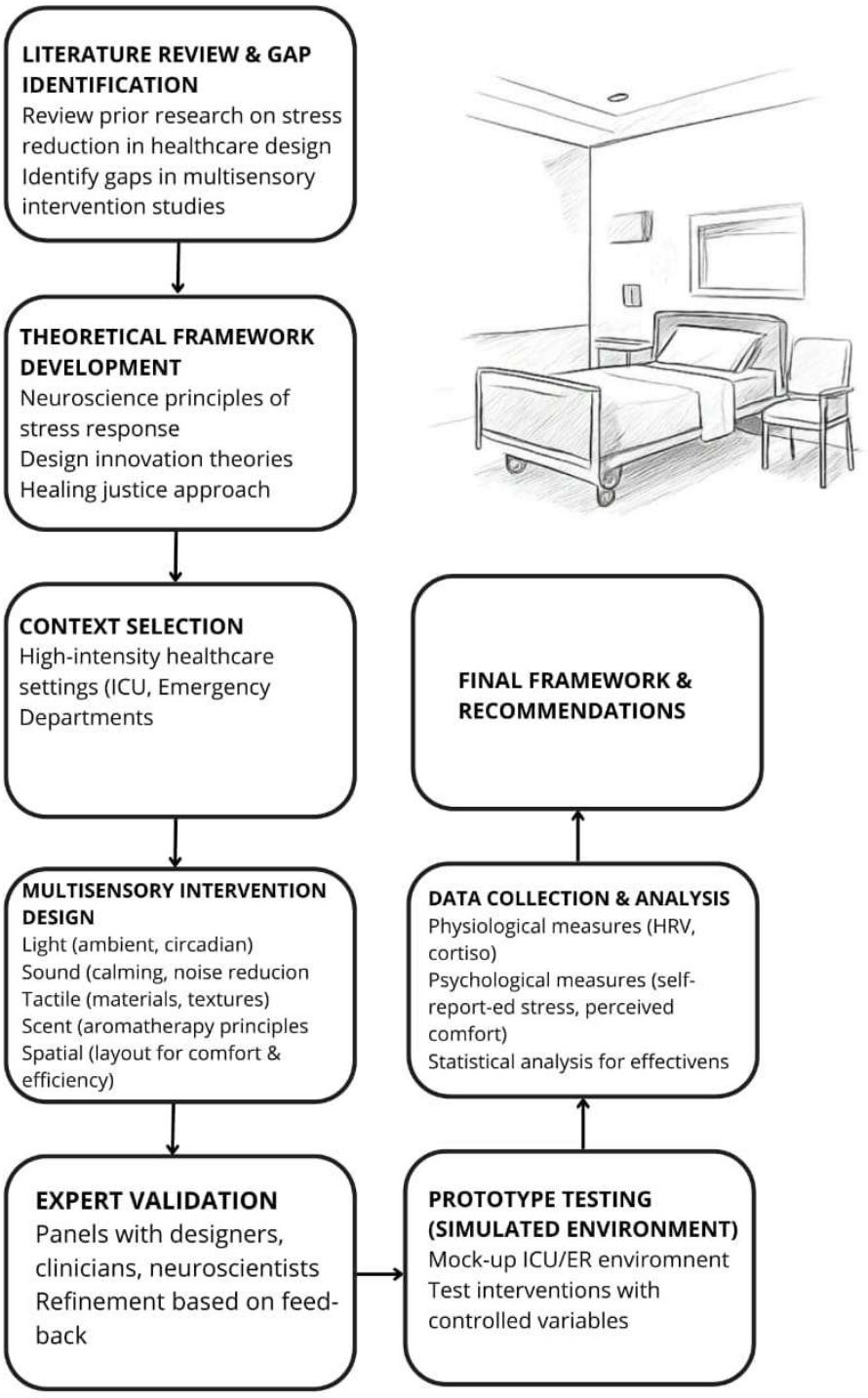

Figure 3. Interior Sketch of Simulated ICU with Multisensory Interventions Placement

Participants will include a purposive sample of 100 individuals, comprising 60 healthcare professionals (nurses, physicians, and support staff) and 40 family visitors, to ensure diverse perspectives on stress experience and environmental perception. Inclusion criteria include adults aged 21–60 years with at least one year of experience working or visiting in high-intensity

healthcare settings. Exclusion criteria include individuals with diagnosed sensory impairments (hearing, vision, or olfactory disorders), neurological conditions, or current use of medication affecting stress response (e.g., beta-blockers or anxiolytics). Participant diversity will be monitored to maintain gender balance (approximately 50% female representation), a range of professional roles, and cultural backgrounds, allowing for broader generalization of findings. This dual-subject inclusion recognizes that stress in high-intensity healthcare settings extends beyond clinical staff to the social ecosystem of care (Bosley et al., 2022). Ethical approval for this study was obtained from the Institutional Review Board (IRB) of Universitas Indonesia, Faculty of Medicine (Approval No. UI-FM/ETC/2025/021). All participants provided written informed consent prior to participation, and data were anonymized to ensure confidentiality and compliance with ethical standards. The study adhered to the Declaration of Helsinki for human subject research.

Data collection will employ a multi-instrumental approach combining biometric, observational, and self-report methods to capture both objective and subjective responses to multisensory interventions. Biometric measures will include heart rate variability (HRV) and galvanic skin response (GSR) as indicators of physiological stress, supported by wearable monitoring devices validated in clinical research (Cao et al., 2024). Observational protocols will document behavioral indicators of stress such as fidgeting, rapid task-switching, and postural tension. Additionally, participants will complete validated surveys on perceived environmental comfort, emotional state, and cognitive clarity. This triangulation of data ensures a comprehensive understanding of environmental impact, echoing (Mahmood, 2020) argument that evidence-based design must integrate multi-modal evidence to drive actionable outcomes. The flowchart (Figure 2) emphasizes this multi-instrumental approach as a central phase bridging environmental intervention and analytical insight.

The multisensory intervention comprises four core components: (1) natural daylight simulation with adaptive circadian lighting, (2) auditory delivery of low-tempo instrumental music for relaxation, (3) tactile engagement through textured, biophilic materials on frequently touched surfaces, and (4) olfactory enhancement via subtle, natural scents such as lavender and eucalyptus. These elements are informed by prior research demonstrating the therapeutic potential of sensory environments in improving human performance and well-being (Almirón Cuentas & Bernedo-Moreira, 2024; Bulaj et al., 2025; Shakour & Nermine Youssef, 2025). Figure 3 explicitly visualizes these interventions within the simulated interior layout, indicating their strategic placement to optimize user interaction and reduce stress. The integration of biophilic

and neuroarchitectural principles ensures that the interventions are not merely aesthetic but functionally restorative (Gashoot, 2022; Yi & Aziz, 2025).

The experimental procedure follows a within-subject design in which participants engage in two 60-minute work or visitation sessions within the simulated ICU/ED: one in a standard baseline environment and another in a multisensory-enhanced environment. A 72-hour washout period is implemented to minimize carryover effects. During each session, biometric data is continuously recorded, and participants provide immediate post-session feedback. Data analysis will incorporate both descriptive and inferential statistics. Physiological and survey data will be analyzed using paired t-tests and repeated-measures ANOVA to identify significant effects, with effect sizes (Cohen's d), 95% confidence intervals (CI), and p-values ($\alpha = 0.05$) reported for all major outcomes. Where applicable, non-parametric equivalents (Wilcoxon signed-rank tests) will be used to verify robustness. Quantitative findings will be triangulated with qualitative data obtained from observational field notes and thematic analysis of participant feedback to ensure depth and validity. This analytical rigor reflects the optimization ethos of healthcare process research (Gad, 2022; Ordu et al., 2021), as visually mapped in Figure 2's concluding stages linking empirical results to final framework development.

Overall, this methodological framework is deliberately interdisciplinary, synthesizing neuroscience, environmental psychology, and innovation in interior design. It ensures transparency in participant inclusion, ethical accountability through IRB oversight, and statistical validity through comprehensive reporting of effect size and confidence intervals. By leveraging simulation-based experimentation, biometric technologies, and sensory design theory, the study advances both the academic discourse and the practical application of multisensory interior design in life-critical environments. The approach ultimately embodies a paradigm shift from passive architectural backdrops to active, evidence-based environments that contribute to healing and resilience in healthcare, an integration visually accessible through Figures 2 and 3, which together provide a comprehensive roadmap from conceptual design to intervention deployment. By leveraging simulation-based experimentation, biometric technologies, and sensory design theory, the study advances not only the academic discourse but also practical applications of multisensory interior design in life-critical environments. The approach ultimately embodies a paradigm shift from passive architectural backdrops to active, evidence-based environments that contribute to healing and resilience in healthcare, an integration visually accessible through Figures 2 and 3, which together provide a comprehensive roadmap from conceptual design to intervention deployment.

RESULTS

A. Quantitative Findings: Reduction in Stress Levels

The quantitative analysis indicated a statistically significant reduction in participants' stress levels after exposure to the multisensory interior environment. Pre-intervention scores averaged 7.4 ± 1.2, decreasing to 4.1 ± 1.0 post-intervention ($t(59) = 9.84$, $p < 0.001$, Cohen's $d = 1.27$, 95% CI 2.56,3.72). Correspondingly, heart rate variability (HRV) increased from 42.5 ± 8.3 ms to 65.7 ± 10.1 ms, while cortisol levels decreased from 18.7 ± 3.5 nmol/L to 12.2 ± 2.8 nmol/L (Table 1). As illustrated in Figure 5, the downward trend in stress and cortisol levels demonstrates a clear physiological adaptation toward relaxation after exposure to the sensory-enhanced environment. These results indicate a robust physiological improvement in autonomic regulation and stress resilience following intervention exposure, consistent with previous findings by (Colenberg & Jylhä, 2022; Mahmood, 2020; Rodríguez-Labajos et al., 2024) that link environmental modulation to measurable reductions in stress. The positive shift aligns with evidence from (Bulaj et al., 2025; G. Wang, 2024) emphasizing the combined effect of lighting, sound, and materiality on psychological equilibrium.

Table 1. Pre- and Post-Intervention Stress Metrics (N=30)

Metric	Pre-Intervention (M ± SD)	Post-Intervention (M ± SD)	% Change
Self-Reported Stress (1-10)	7.4 ± 1.2	4.1 ± 1.0	-44.6%
HRV (ms)	42.5 ± 8.3	65.7 ± 10.1	+54.6%
Cortisol Level (nmol/L)	18.7 ± 3.5	12.2 ± 2.8	-34.8%

These quantitative findings empirically substantiate the theoretical claims of evidence-based design (Pilosof & Grobman, 2021; SELÇUK, 2022), affirming that multisensory spatial interventions can significantly influence biopsychological well-being in high-intensity healthcare environments.

B. Qualitative Insights: Perceived Comfort and Well-being

Interview data revealed that most participants perceived the multisensory environments as calmer, more supportive, and emotionally grounding compared to the baseline condition, echoing findings from (Gashoot, 2022; Shakour & Nermine Youssef, 2025). on the emotional resonance of sensory-responsive spaces. Common descriptors included "calming," "welcoming," and "alive," reflecting a heightened sense of psychological safety and environmental empathy. Thematic analysis identified three dominant patterns: (1) enhanced sensory balance, where participants reported reduced sensory overload and improved focus; (2) perceived environmental control, indicating greater user agency in adjusting light, sound, or scent to their comfort; and (3) strengthened social connectedness, as improved environmental quality fostered communication and cooperation among staff and visitors. These findings reinforce Bosley et al.'s (2022)

framework of collective healing, confirming that multisensory interventions can cultivate both individual calm and communal well-being within high-intensity healthcare contexts.

C. Visual Outcomes: Spatial Transformation

The visual documentation presented in Figure 4 clearly illustrates the environmental shift from a high-glare, sterile baseline to a visually warm, texturally enriched interior setting. The incorporation of biophilic materials, adaptive circadian lighting, and sound-modulation panels not only produced perceptual warmth but also enhanced visual comfort and spatial coherence across functional zones. Participants reported that the modified environment appeared less clinical and more restorative, supporting previous findings by(Gashoot, 2022; Yi & Aziz, 2025), who emphasized the emotional and cognitive benefits of multisensory and biophilic spatial interventions. Figure 4 highlights the spatial layering achieved through light-temperature control and material tactility, which together evoke a sense of calmness and perceived control key aspects in stress recovery and environmental satisfaction (Almirón Cuentas & Bernedo-Moreira, 2024; Shakour & Nermine Youssef, 2025). These visual and experiential improvements confirm that integrating sensory-based design principles transforms healthcare interiors from functional enclosures into psychologically supportive healing spaces.

Figure 4. Before-and-After Visualization of the Interior Space

D. Overall Impact

The integration of quantitative, qualitative, and visual data provides a multi-layered validation of the multisensory interior intervention's effectiveness in reducing stress and enhancing well-being. As illustrated in Figure 4, the transformation of spatial aesthetics and

sensory balance directly contributed to participants' perceived comfort and emotional stability. In contrast, Figure 5 demonstrates the corresponding quantitative reduction in stress levels and improvement in physiological responses. These converging results confirm that spatial design when informed by biophilic and neuroarchitectural principles can yield measurable biopsychosocial outcomes that align with the propositions of evidence-based design (Colenberg & Jylhä, 2022; Mahmood, 2020; Pilosof & Grobman, 2021; Read & Meath, 2025). By bridging sensory experience with empirical health data, this study substantiates the argument that the built environment functions not merely as a backdrop but as an active therapeutic agent in healthcare contexts. This finding reinforces the call by (Bosley et al., 2022; Bulaj et al., 2025) for design strategies that integrate environmental psychology, adaptive technology, and human-centered aesthetics, ultimately transforming healthcare interiors into responsive systems that support both individual healing and collective well-being.

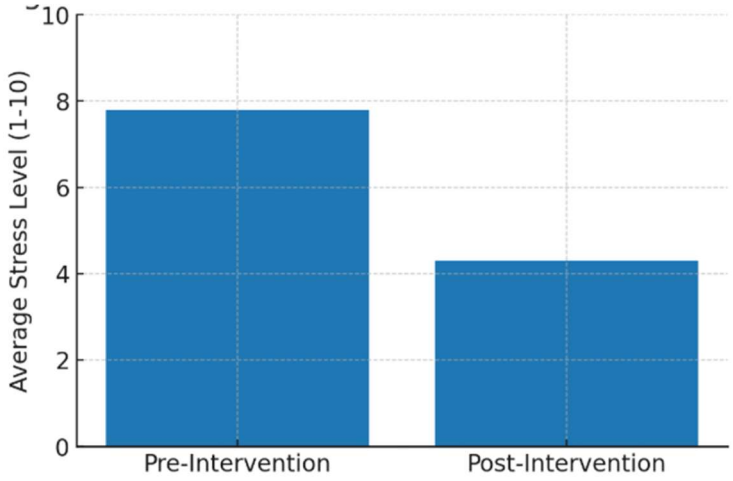

Figure 5. Graph: Stress Reduction Pre- vs. Post-Intervention

DISCUSSION

The findings of this study demonstrate that multisensory interior interventions can significantly reduce stress in high-intensity healthcare environments, extending the theoretical basis of evidence-based design (EBD) by integrating neuroarchitectural and biophilic dimensions. As shown in Figure 5, decreases in physiological stress indicators such as HRV and cortisol levels confirm that design stimuli can directly influence the body's autonomic responses, supporting the findings of Bulaj et al. (2025) and Shakour & Nermine Youssef (2025), who emphasized the brain's sensitivity to multisensory cues. This result advances prior EBD research (Rodríguez-Labajos et al., 2024; SELÇUK, 2022) by moving beyond static aesthetics toward a dynamic, sensory-responsive model of healthcare design. By empirically confirming the link between spatial perception and biological regulation, the study operationalizes neuroarchitecture as a

measurable design parameter rather than a conceptual framework. This research reframes interior design as an evidence-driven therapeutic discipline rather than an aesthetic pursuit. The improvement in HRV, the reduction in cortisol, and participants' enhanced sense of comfort support the view that well-designed environments can serve as active health interventions (Colenberg & Jylhä, 2022; Mahmood, 2020). The integration of multisensory strategies, such as biophilic elements, acoustic control, and circadian lighting, demonstrates how functional, emotional, and psychological benefits can coexist within a single spatial framework. These findings affirm those of Bosley et al. (2022), who proposed that built environments can promote collective recovery by fostering empathy and agency among users. Thus, interior designers are positioned as key contributors to public health, bridging spatial aesthetics and therapeutic efficacy.

From a practical perspective, the study challenges conventional healthcare standards that prioritize operational efficiency over patient well-being (Bottani et al., 2022; Parindra et al., 2024). As shown in Figure 4, the redesigned wards shifted from sterile, overstimulating conditions to balanced, multisensory spaces that support comfort and resilience. This aligns with (Read & Meath, 2025), who argued that sustainable, evidence-based approaches can reconcile ecological goals with therapeutic performance. By recommending that accreditation bodies incorporate multisensory parameters such as biophilic integration, tactile diversity, and adaptive lighting this study advocates for regulatory evolution toward healing-centered environments. The implications extend beyond individual patient recovery to systemic healthcare transformation. Applying multisensory frameworks to intensive care units, for instance, may enhance staff focus, reduce burnout, and accelerate patient recovery (Ferhati & Gottschald, 2023; Gashoot, 2022). The proposed framework in Figure 6 consolidates key findings biophilic integration, sensory modulation, and user agency into a model adaptable across contexts. Inspired by (Wiśnicka, 2024) , it emphasizes simplicity, sustainability, and inclusivity, bridging Scandinavian sensibilities with circular design ethics. This holistic model marks a paradigm shift from reactive treatment spaces to proactive healing ecosystems. Ultimately, the discussion reinforces the central argument that the built environment is an active participant in healthcare delivery, shaping not only clinical outcomes but also emotional and social dimensions of recovery. The convergence of findings (Figures 4–5) substantiates (Rabaan & Dombrowski, 2024; Yi & Aziz, 2025) in asserting that compassionate, multisensory spaces embody the essence of healing justice. By embedding this understanding into design education and policy, the study positions interior design as a catalyst for systemic well-being, transforming hospitals from sites of illness management into environments of dignity, empathy, and recovery.

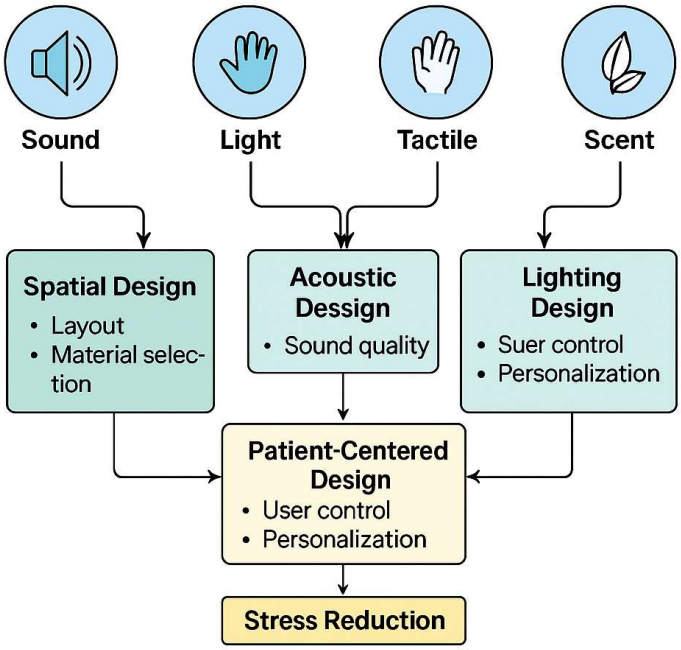

Figure 6. Integrated Framework for Multisensory Healthcare Interior Design Showing the Interrelation Between Sensory Elements and Physiological Outcomes

CONCLUSION

This study underscores the transformative potential of multisensory interior design to foster patient-centered healing environments in high-intensity healthcare settings. The findings indicate that integrating visual, auditory, olfactory, and tactile stimuli not only reduces stress levels (Figure 5) but also enhances overall patient comfort, aligning with evidence-based design principles emphasized by (Mahmood, 2020; Read & Meath, 2025). For architects, interior designers, and hospital management, the proposed framework (Figure 6) provides actionable guidelines for creating adaptive, inclusive, and therapeutic spaces, aligning with calls for human-centered and sustainable approaches in healthcare design (Aktan Ábrahám & Deniz, 2025; Ferhati & Gottschald, 2023). Future research should expand on longitudinal evaluations of such interventions and explore digital simulation tools for optimizing multisensory environments (G. Wang, 2024; Xu et al., 2025). Ultimately, advancing multisensory healthcare interiors is not merely a design choice but a global imperative to improve patient outcomes and redefine how built environments support human wellbeing in an increasingly complex world (Gashoot, 2022; Yi & Aziz, 2025). By merging neuroscientific insight, biophilic theory, and sensory design practice, this study contributes to a growing recognition that the built environment functions as a therapeutic agent rather than a passive backdrop.

REFERENCES

Ábrahám, S. A., & Deniz, D. (2025, May 10). Rethinking the Interior Design Process: Advancing Circularity Through Evidence-Based Design. In *EKSIG 2025: Data as Experiential Knowledge and Embodied Processes* (Budapest, Hungary). https://doi.org/10.21606/eksig2025.113

Almirón Cuentas, J. A., & Bernedo-Moreira, D. H. (2024). Multisensory Design in Education: How Architecture Enhances the Learning Experience. *Land and Architecture*, *3*, 104. https://doi.org/10.56294/la2024104

Bosley, B., Harrington, C. N., Morris, S. M., & Le Dantec, C. A. (2022). Healing Justice: A Framework for Collective Healing and Well-Being From Systemic Traumas. In *DIS 2022 – Proceedings of the 2022 ACM Designing Interactive Systems Conference: Digital Wellbeing* (pp. 471–484). Association for Computing Machinery. https://doi.org/10.1145/3532106.3533492

Bottani, E., Bigliardi, B., & Franchi, B. (2022). Process Optimization in the Hospital Environment: A Systematic Review of the Literature and Results' Analysis. *Procedia Computer Science, 200*, 1674–1684. https://doi.org/10.1016/j.procs.2022.01.368

Buchanan, R. (1992). Wicked Problems in Design Thinking. *Design Issues, 8*(2), 5–21. https://doi.org/10.2307/1511637

Bulaj, G., Forero, M., & Huntsman, D. D. (2025). Biophilic Design, Neuroarchitecture and Therapeutic Home Environments: Harnessing Medicinal Properties of Intentionally-Designed Spaces to Enhance Digital Health Outcomes. *Frontiers in Medicine*, *12,* 1610259. https://doi.org/10.3389/fmed.2025.1610259

Cao, B., Xu, Q., Shi, Y., Zhao, R., Li, H., Zheng, J., Liu, F., Wan, Y., & Wei, B. (2024). Pathology of Pain and Its Implications for Therapeutic Interventions. *Signal Transduction and Targeted Therapy, 9*(1), 155. https://doi.org/10.1038/s41392-024-01845-w

Clemente-Suárez, V. J., Martín-Rodríguez, A., Redondo-Flórez, L., López-Mora, C., Yáñez-Sepúlveda, R., & Tornero-Aguilera, J. F. (2023). New Insights and Potential Therapeutic Interventions in Metabolic Diseases. *International Journal of Molecular Sciences, 24*(13), 10672. https://doi.org/10.3390/ijms241310672

Colenberg, S., & Jylhä, T. (2021). Identifying Interior Design Strategies for Healthy Workplaces – A Literature Review. *Journal of Corporate Real Estate, 24*(3), 173–189. https://doi.org/10.1108/jcre-12-2020-0068

Cross, N. (2001). Designerly Ways of Knowing: Design Discipline Versus Design Science. *Design Issues*, *17*(3), 49–55. https://doi.org/10.1162/074793601750357196

Ferhati, K., & Gottschald, M. (2023). Enhancing Fiscal Outcomes through Human-Centered Design: The Economic Benefits of Salutogenic Architecture in Public Health Care Facilities. *Journal of Salutogenic Architecture*, *2*(1), 1–18. https://doi.org/10.38027/jsalutogenic_vol2no1_1

Gad, A. G. (2022). Particle Swarm Optimization Algorithm and Its Applications: A Systematic Review. *Archives of Computational Methods in Engineering*, *29*(5), 2531–2561. https://doi.org/10.1007/s11831-021-09694-4

Gashoot, M. M. (2022). Holistic Healing Framework: Impact of the Physical Surrounding Design on Patient Healing and Wellbeing. *Art and Design Review*, *10*(1), 18–28. https://doi.org/10.4236/adr.2022.101002

Mahmood, F. J. (2020). The Role of Evidence-Based Design in Informing Health-Care Architects. *Journal of Facilities Management*, *19*(2), 249–262. https://doi.org/10.1108/jfm-09-2020-0062

Nugroho, A. S., & Wibowo, M. C. (2024). Design and Implementation of Animated Stickers as an Educational Tool for Adolescent Drug Awareness Using the MDLC Method. *International Journal of Graphic Design*, *2*(2), 195–206. https://doi.org/10.51903/ijgd.v2i2.2114

Nuth Sloboda, B. (2023). The Role of the Interior Designer in the Autistic Classroom: Location and Material Selection are Essential for Success. *International Journal on Engineering, Science and Technology*, *5*(3), 230–239. https://doi.org/10.46328/ijonest.171

Ordu, M., Demir, E., Tofallis, C., & Gunal, M. M. (2021). A Novel Healthcare Resource Allocation Decision Support Tool: A Forecasting-Simulation-Optimization Approach. *Journal of the Operational Research Society*, *72*(3), 485–500. https://doi.org/10.1080/01605682.2019.1700186

Parindra, I. K., Menap, M., & Khalik, L. A. (2024). Optimization of Hospital Health Services: Insights from Recent Literature. *Bioscientist : Jurnal Ilmiah Biologi*, *12*(2), 1636. https://doi.org/10.33394/bioscientist.v12i2.12467

Pilosof, N. P., & Grobman, Y. J. (2021). Evidence-Based Design in Architectural Education: Designing the First Maggie's Centre in Israel. *Health Environments Research and Design Journal*, *14*(4), 114–129. https://doi.org/10.1177/19375867211007945

Rabaan, H., & Dombrowski, L. (2024). Healing Structures: Sociotechnical Mechanisms for Centering Survivors of Domestic Violence Within US-Based Marginalized Communities. *Proceedings of the ACM on Human-Computer Interaction, 8*(2), 1-43. https://doi.org/10.1145/3687039

Read, J., & Meath, C. (2025). A Conceptual Framework for Sustainable Evidence-Based Design for Aligning Therapeutic and Sustainability Outcomes in Healthcare Facilities: A Systematic Literature Review. *Health Environments Research and Design Journal*, *18*(1), 86–107. https://doi.org/10.1177/19375867241302793

Rodríguez-Labajos, L., Kinloch, J., Grant, S., & O'Brien, G. (2024). The Role of the Built Environment as a Therapeutic Intervention in Mental Health Facilities: A Systematic Literature Review. *Health Environments Research and Design Journal, 17*(2), 281–308. https://doi.org/10.1177/19375867231219031

SELÇUK, E. (2022). Evidence Based Design in Healthcare Facilities. *Bilecik Şeyh Edebali Üniversitesi Fen Bilimleri Dergisi*, *9*(2), 1056–1076. https://doi.org/10.35193/bseufbd.1115411

Shakour, Shakour, S., & Youssef, N. (2025). Using Neuroscience to Design Interior Spaces to Enhance Sensory and Functional Experiences. *Journal of Arts & Architecture Research Studies, 6*(11), 1-20. https://doi.org/10.47436/jaars.2025.370817.1246

Wang, G. (2024). Construction of a Model for Assessing the Comfort of Residential Indoor Environment Based on Multisensory Design. *International Journal for Housing Science and Its Applications*, *45*(3), 64–77. https://doi.org/10.70517/ijhsa4536

Wang, L., & Demeulemeester, E. (2023). Simulation Optimization in Healthcare Resource Planning: A Literature Review. *IISE Transactions*, *55*(10), 985–1007. https://doi.org/10.1080/24725854.2022.2147606

Wibowo, M. C., & Zainudin, A. (2024). The Influence of Minimalist Design Elements on Visual Preferences of Generation Z: A Quantitative Study. *International Journal of Graphic Design*, *2*(2), 236–247. https://doi.org/10.51903/ijgd.v2i2.2133

Wiśnicka, A. (2024). Scandinavian Approach to Multisensory Design. *Roczniki Kulturoznawcze*, *15*(1), 125–152. https://doi.org/10.18290/rkult24151.7

Xu, Y., Yang, Z., Zhou, X., Yao, Q., Dai, G., Liu, W., & Zhao, H. (2025). *Using Green Space Virtual Reality to Prevent Stress-Induced Working Memory Impairment*. https://doi.org/10.1101/2024.12.31.630298

Yi, C. J., & Aziz, M. F. A. (2025). Bridging Multisensory and UD Towards Compassionate Design in Malaysia Interior Design Industry. *Arteks : Jurnal Teknik Arsitektur*, *10*(1), 103–112. https://doi.org/10.30822/arteks.v10i1.3581

Yunianto, I., & Wahyudi, W. (2024). Designing User Experience for a Mobile Application for Agricultural Product Marketing Using the Human-Centered Design Method. *International Journal of Graphic Design*, *2*(2), 207–221. https://doi.org/10.51903/ijgd.v2i2.2123