

Virtual Reality Simulation as a Tool for Salutogenic and Multisensory Interior Design: A Human-Centric Well-Being Approach

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ABSTRACT

Contemporary interior architecture increasingly shifts from function-oriented design toward approaches that prioritise users' wellbeing and spatial experience. However, despite growing recognition of the role of multisensory spatial atmosphere in shaping emotional responses and environmental comfort, designers still lack methodological tools enabling systematic evaluation of these factors at early design stages. This paper proposes a conceptual framework integrating immersive virtual reality (VR) simulation with multisensory perception theory and the salutogenic model of sense of coherence (SOC) as a methodological basis for analysing atmospheric spatial parameters in interior environments. The framework organises relationships between spatial design variables, perceptual mechanisms, and simulation-based evaluation procedures within a three-level structure enabling controlled investigation of users' responses to colour, lighting conditions, material tactility, spatial proportions, and environmental legibility. By positioning immersive virtual environments as perceptual laboratories rather than visualisation tools, the proposed model supports evidence-based assessment of spatial atmosphere prior to implementation and contributes to the development of wellbeing-oriented interior design strategies grounded in measurable environmental parameters.

Keywords: Virtual reality simulation, Salutogenic design, Multisensory perception, Spatial atmosphere, Interior architecture, Human-centred design

INTRODUCTION

Contemporary interior architecture is increasingly shifting from function-oriented design toward approaches that prioritise users' wellbeing and spatial experience. Within this transformation, architectural environments are no longer understood solely as physical settings for activity but as active factors influencing perception, emotional responses, and cognitive functioning.

One of the most important conceptual frameworks supporting this shift is salutogenic design, derived from Aaron Antonovsky's theory of salutogenesis. Unlike pathogenic approaches focused on reducing negative environmental impacts, the salutogenic perspective emphasises spatial qualities that strengthen users' sense of coherence through orientation, perceived control, and meaningful engagement with place.

At the same time, research in environmental psychology and multisensory perception demonstrates that architectural experience emerges through the interaction of multiple sensory stimuli rather than through visual perception alone. Colour atmosphere, lighting spectrum, spatial proportions, acoustic conditions, and material tactility jointly influence users' emotional responses and perceived environmental comfort.

Despite the growing recognition of these relationships, designers still face methodological limitations when evaluating the perceptual impact of spatial solutions prior to implementation. Conventional visualisation techniques capture experiential qualities of space only partially and rarely allow systematic investigation of users' responses to atmospheric spatial parameters.

Immersive virtual reality (VR) simulations provide new opportunities for analysing spatial atmosphere at early design stages by enabling controlled manipulation of environmental variables and observation of users' perceptual reactions in simulated architectural environments.

This paper proposes a conceptual framework integrating immersive virtual reality simulation with multisensory perception theory and the sense-of-coherence model as a methodological foundation for analysing atmospheric spatial parameters in interior architecture.

SALUTOGENIC APPROACH IN INTERIOR ENVIRONMENTS

Salutogenesis, introduced by Antonovsky (1979, 1987), shifts attention from disease-oriented interpretations of health toward factors supporting wellbeing and resilience. Within this framework, the key mechanism regulating human interaction with the environment is the sense of coherence (SOC), defined through three interrelated components: comprehensibility, manageability, and meaningfulness.

Table 1: Relationships between salutogenic spatial factors and sense of coherence components in interior environments.

Salutogenic Factor	SOC Component	Spatial Meaning	Example in Interior Architecture
Access to daylight	Comprehensibility / Manageability	improves orientation, regulates circadian rhythm, increases environmental predictability	windows, skylights, adaptive daylight systems
Spatial legibility	Comprehensibility	supports cognitive mapping and reduces stress related to navigation	clear circulation layout, visual axes, wayfinding systems
Possibility of choice and control	Manageability	increases users' sense of agency and environmental control	adjustable lighting, movable furniture, zoning of privacy levels
Contact with nature	Meaningfulness	strengthens emotional engagement with space and supports stress recovery	indoor plants, natural views, biophilic materials
Sensory qualities of materials	Meaningfulness / Manageability	supports multisensory grounding and emotional comfort	wood, natural textiles, tactile finishes, warm surfaces

In architectural environments, comprehensibility refers to spatial legibility and predictability, manageability relates to perceived environmental control, and meaningfulness corresponds to emotional engagement with place. Together, these components describe how users interpret spatial structures and respond to environmental conditions.

Interior environments designed according to salutogenic principles support orientation, reduce stress, and strengthen users' ability to interact confidently with their surroundings. Spatial hierarchy, access to daylight, opportunities for choice and control, and multisensory material qualities contribute to environments perceived as understandable, supportive, and emotionally significant.

Consequently, the architectural environment can be interpreted not only as a physical container of activity but as a health-supporting resource regulating psychological comfort and spatial experience.

MULTISENSORY PERCEPTION OF ARCHITECTURAL SPACE

Architectural space is increasingly understood as a multisensory environment shaped through the interaction of visual, auditory, tactile, thermal, proprioceptive, and olfactory stimuli. Research in environmental psychology demonstrates that spatial atmosphere emerges through relationships between sensory modalities rather than through isolated perceptual inputs.

Crossmodal perception theory indicates that visual stimuli activate expectations related to touch, temperature, sound, and movement, influencing orientation processes and emotional interpretation of spatial environments. As a result, spatial experience depends not only on geometric configuration but also on sensory correspondences between colour, light, materiality, and spatial scale.

Table 2: Crossmodal correspondences in interior architectural environments and their impact on spatial perception.

Visual Parameter	Crossmodal Association	Perceptual Effect	Example in Interior Environments
Warm colours (red, orange)	warmth, proximity, acoustic intensity	stimulation, activation, reduced perceived distance	social spaces, cafés, collaborative zones
Cool colours (blue, green)	coolness, calmness, acoustic softness	relaxation, cognitive clarity, perceived spaciousness	healthcare interiors, resting areas
High brightness	openness, safety, alertness	improved orientation and perceived control	circulation zones, educational interiors
Low brightness	intimacy, quietness	emotional focus, reduced stimulation	contemplative spaces, relaxation zones
Natural materials (wood, stone)	warmth, softness, authenticity	psychological comfort, stress reduction	residential interiors, therapeutic environments
Smooth surfaces	acoustic reflection, visual clarity	formality, precision, spatial order	office interiors, institutional buildings

(Continued)

Table 2: Continued.

Visual Parameter	Crossmodal Association	Perceptual Effect	Example in Interior Environments
Textured materials	tactile richness, acoustic absorption	sensory grounding, spatial depth	multisensory environments
Large-scale spaces	reverberation, visual distance	monumentality, reduced intimacy	atria, public halls
Enclosed spaces	acoustic damping, tactile proximity	safety, privacy	healthcare rooms, learning environments
Daylight	temporal rhythm, natural variability	circadian regulation, wellbeing	workspaces, schools, housing
Artificial coloured lighting	emotional tone modulation	atmosphere control	exhibition interiors, immersive spaces

Colour and lighting conditions play a particularly important role in shaping spatial atmosphere. Variations in spectral composition and intensity influence perceived temperature, emotional activation, and spatial readability. Similarly, material properties contribute to environmental interpretation by activating tactile expectations related to surface warmth, softness, and authenticity.

Even when direct physical contact is not possible, visual representations of texture and reflectivity evoke haptic associations influencing perceived comfort and safety. In immersive virtual environments, such processes can be simulated through physically based rendering (PBR), enabling analysis of material atmosphere prior to implementation.

Understanding architectural space as a multisensory system therefore allows designers to interpret spatial atmosphere as an operational environmental parameter influencing users' wellbeing and sense of coherence.

Table 3: Multisensory spatial parameters and methods of perception analysis in VR environments.

Spatial Parameter	Possible VR Manipulation	Type of User Response	Measurement Methods
Colour atmosphere	hue, saturation, contrast	emotional response, arousal level	questionnaires (SAM, Likert scale), HR/HRV
Lighting conditions	intensity, direction, colour temperature	visual comfort, alertness, orientation	eye-tracking, cognitive tasks, surveys
Daylight simulation	window size, time-of-day scenarios	circadian perception, spatial realism	subjective comfort scales
Material textures	surface reflectance, roughness simulation	tactile expectation, perceived warmth	semantic differential scales
Spatial proportions	ceiling height, width, depth	perceived safety, openness, control	spatial preference tests
Acoustic atmosphere	reverberation, background sound	stress level, concentration	physiological response, surveys
Wayfinding clarity	visibility of paths, landmarks	orientation efficiency	navigation time measurement

(Continued)

Table 3: Continued.

Spatial Parameter	Possible VR Manipulation	Type of User Response	Measurement Methods
Biophilic elements	greenery, natural views	stress recovery, wellbeing	mood scales, HRV
Privacy gradients	openness vs enclosure	perceived control, security	behavioural observation
Multisensory integration	colour–light–material combinations	atmosphere evaluation	comparative scenario testing

VIRTUAL REALITY AS A TOOL IN INTERIOR ARCHITECTURE RESEARCH

Immersive virtual reality environments enable controlled manipulation of spatial parameters such as colour atmosphere, lighting conditions, material textures, and spatial proportions while allowing users to experience architectural scenarios at a 1:1 scale prior to construction.

Experimental comparisons between physical environments and their virtual representations demonstrate a high level of correspondence in behavioural and cognitive responses, confirming the validity of VR as a research tool in human–environment interaction studies. Unlike conventional visualisation methods, immersive simulations allow systematic evaluation of perceptual and emotional reactions to spatial conditions already at early design stages.

VR technologies also support participatory design workflows and improve communication between designers and users by enabling shared spatial understanding of proposed environments. In educational contexts, immersive simulations strengthen spatial reasoning and support the development of future-oriented design competencies related to evidence-based architectural practice.

Importantly, immersive environments enable integration of subjective evaluation methods with physiological indicators such as heart-rate variability and electrodermal activity, creating new possibilities for analysing emotional responses to architectural space. As a result, VR functions as a methodological bridge connecting spatial parameters with users' perceptual and affective reactions.

Table 4: Spatial factors and their evaluation methods in immersive VR-based interior environment research.

Spatial Factor	Scope of Analysis in VR Environments	Methods Used in VR Research	Example Indicators	Representative Literature
Colour	Evaluation of surface colour and chromatic lighting effects on spatial atmosphere and emotional response	controlled colour manipulation in immersive 1:1 models; scenario comparison; PAD-based assessment	affective response, perceived warmth/coolness, spatial preference, visual comfort	Lee & Lee (2025); Li et al. (2026); Spence (2020); Jonauskaitė & Mohr (2025)

(Continued)

Table 4: Continued.

Spatial Factor	Scope of Analysis in VR Environments	Methods Used in VR Research	Example Indicators	Representative Literature
Lighting	Analysis of spectral composition, intensity, contrast, and dynamic lighting conditions	dynamic lighting simulations; immersive exposure experiments; lighting scenario testing	perceived calmness, alertness, safety, spatial legibility, mood	Lee & Lee (2025); Boubekri (2021); Chamilothoni et al. (2019)
Materials	Evaluation of texture, reflectivity, surface character, and perceived material authenticity	physically based rendering (PBR); multisensory simulation; integration with thermal and haptic cues	perceived quality, naturalness, tactile comfort, atmospheric character	Malnar & Vodvarka (2004); Pallasmaa (2012); Helfenstein-Didier et al. (2023)
Proportions	Assessment of spatial scale, enclosure, and dimensional relationships	immersive walkthroughs in full-scale models; comparative spatial variants	perceived spaciousness, enclosure ratio, spatial balance, usability	Kuliga et al. (2015); Stabryła & Grudzińska (2025)
Orientation (legibility)	Analysis of spatial navigation, wayfinding performance, and functional clarity	user tracking; navigation tasks; behavioural mapping	navigation time, error frequency, cognitive load, spatial legibility	Kuliga et al. (2015); Yu et al. (2022); Hölscher et al. (2006)
Comfort	Evaluation of visual, thermal, and perceptual environmental comfort	multisensory simulation (visual, auditory, thermal cues); immersive exposure protocols	perceived environmental comfort, immersion level, thermal perception, stress reduction	Helfenstein-Didier et al. (2023); Chamilothoni et al. (2019); Antonovsky (1996)
User emotions	Measurement of affective and atmospheric responses to architectural environments	PAD model; SAM scales; questionnaires; physiological indicators; behavioural observation	arousal, pleasure, sense of control, relaxation, stress level	Mehrabian & Russell (1974); Lee & Lee (2025); Li et al. (2026); Kuliga et al. (2015)

OPERATIONALISATION OF ATMOSPHERIC SPATIAL PARAMETERS

Within the proposed framework, atmospheric spatial parameters are understood as measurable environmental variables influencing users' perception of interior environments. These include spectral lighting conditions, chromatic composition, material tactility, spatial enclosure ratios, and spatial legibility.

Spectral lighting conditions regulate mood, circadian perception, and spatial readability. Chromatic composition influences emotional interpretation and spatial orientation. Material tactility supports sensory grounding through expectations related to texture and temperature. Spatial enclosure ratios affect perceived safety and openness, while spatial legibility supports orientation and predictability.

Together, these parameters define the multisensory structure of spatial atmosphere and can be analysed systematically in immersive virtual environments.

By translating atmospheric qualities into operational variables, the proposed model enables integration of multisensory perception research with salutogenic design strategies.

Atmospheric Parameter	Comprehensibility	Manageability	Meaningfulness
Spectral lighting conditions	improves spatial readability and visual hierarchy	supports circadian comfort and reduces cognitive fatigue	shapes mood and experiential atmosphere
Chromatic composition	supports orientation through colour coding and spatial differentiation	stabilises emotional responses and reduces overstimulation	contributes to identity and symbolic interpretation of space
Material tactility	increases perceptual clarity of surfaces and boundaries	enhances physical comfort and perceived safety	strengthens sensory attachment and authenticity
Spatial enclosure ratios	supports understanding of spatial structure and scale	regulates perceived control and exposure levels	influences intimacy and spatial experience
Spatial legibility	improves predictability of movement and navigation	reduces stress and cognitive load	strengthens sense of belonging and environmental coherence

MAPPING ATMOSPHERIC SPATIAL PARAMETERS TO SENSE-OF-COHERENCE COMPONENTS

Atmospheric spatial parameters contribute to users' perception of interior environments through mechanisms corresponding to the three components of sense of coherence.

Lighting conditions and spatial legibility primarily support comprehensibility by improving orientation and spatial hierarchy. Opportunities for environmental control and enclosure ratios strengthen manageability by increasing perceived agency within space. Material qualities and chromatic atmosphere contribute to meaningfulness by supporting emotional attachment and experiential depth.

Within immersive virtual environments, these relationships can be systematically investigated through comparative scenario testing, enabling evaluation of how multisensory spatial variables regulate psychological comfort and environmental coherence.

Table 5: Salutogenic mapping of atmospheric spatial parameters in VR-supported interior design.

Atmospheric Spatial Parameter	Sensory Mechanism	Sense of Coherence Component	Wellbeing-Related Outcome	VR-based Evaluation Method
Spectral lighting conditions	visual adaptation, circadian regulation, affective modulation	Comprehensibility / Manageability	visual comfort, reduced fatigue, spatial clarity	dynamic lighting scenarios, spectral variation testing, PAD-scale assessment
Chromatic composition	colour-based orientation, emotional regulation, perceptual temperature	Meaningfulness / Comprehensibility	mood stabilisation, identity of space, spatial differentiation	colour scenario comparison, affective response surveys, immersive walkthrough testing
Material tactility	tactile expectation, thermal perception, surface authenticity	Manageability / Meaningfulness	perceived safety, sensory comfort, attachment to place	PBR rendering variants, thermal cue simulation, multisensory immersion testing
Spatial enclosure ratios	perception of openness vs. protection, scale calibration	Manageability	perceived control, psychological comfort, reduced stress	full-scale spatial proportion simulations, enclosure scenario comparison
Spatial legibility	navigation predictability, cognitive mapping, spatial hierarchy recognition	Comprehensibility	orientation efficiency, reduced cognitive load, environmental coherence	navigation tracking, wayfinding tasks, behavioural path analysis

PROPOSED MODEL OF VR APPLICATION IN SALUTOGENIC INTERIOR DESIGN

Conceptual Assumptions of the Model

The proposed model positions immersive virtual reality as an evidence-based evaluation environment supporting the design of salutogenic interiors by enabling controlled analysis of spatial parameters influencing users' perception, orientation processes, emotional responses, and environmental comfort prior to construction.

Within this framework, immersive virtual environments function as perceptual laboratories for investigating how atmospheric spatial parameters shape users' sense of coherence. Spatial comprehensibility is supported

through environmental legibility and lighting structure, manageability through enclosure ratios and material comfort, and meaningfulness through chromatic identity and multisensory spatial atmosphere.

The framework is organised as a three-level structure in order to ensure conceptual clarity, methodological coherence, and empirical testability. It distinguishes between spatial design parameters, perceptual mechanisms of environmental experience, and VR-based evaluation procedures, reflecting the causal logic of user–environment interaction within immersive simulation contexts.

Rather than claiming universal applicability, the model is presented as a structured methodological proposal designed to support systematic investigation of user experience in immersive environments and to facilitate the development of interior spaces that promote psychological comfort, orientation, and environmental coherence.

Three-Level Structure of the Proposed Model

The proposed framework integrates spatial design variables, perceptual mechanisms, and simulation-based evaluation processes into a coherent analytical structure.

Level 1 — Spatial Stimuli (Design Variables)

The first level includes atmospheric spatial parameters treated as controllable architectural variables:

- colour,
- spectral lighting conditions,
- material tactility,
- spatial proportions,
- spatial legibility,
- and overall sensory atmosphere.

These parameters define the environmental structure of interior space and form the basis for analysing users' multisensory experience.

Level 2 — Perceptual Mechanisms (User Experience Processes)

The second level describes perceptual mechanisms through which spatial stimuli influence users' experience of architectural environments. Within the salutogenic framework proposed by Antonovsky, these mechanisms correspond to the three components of sense of coherence:

- comprehensibility,
- manageability,
- meaningfulness.

In architectural environments, these dimensions are expressed through spatial orientation, emotional regulation, sensory comfort, perceived control, and environmental coherence.

This level constitutes the central interpretative layer linking physical spatial parameters with users' psychological responses.

Level 3 — VR as an Evaluation Interface

The third level positions immersive virtual reality as a methodological interface enabling measurement and analysis of perceptual responses to spatial environments.

Within this framework, VR enables:

- scenario comparison between alternative design solutions,
- multisensory simulation of spatial atmosphere,
- behavioural tracking in navigational tasks,
- affective assessment using psychometric models,
- spatial legibility testing,
- and pre-occupancy evaluation of architectural environments.

Through these functions, immersive simulations support evidence-based optimisation of interior environments prior to implementation.

Flow Structure of the Model

The relationships between spatial variables and wellbeing outcomes may be described as a sequential perceptual process:

spatial parameters → sensory perception → emotional response → sense of coherence

More specifically:

colour / light / materials / proportions / legibility

→ spatial atmosphere

→ affective state

→ wellbeing support

Within this structure, virtual reality shifts from a representational medium reproducing spatial form toward a simulation platform capable of modelling environmental atmosphere as a regulator of psychological wellbeing.

Atmospheric parameters such as spectral lighting conditions, chromatic composition, material tactility, enclosure ratios, and spatial legibility can therefore be systematically modified and evaluated in relation to users' emotional states and perceptual coherence. This enables analysis not only of how architectural environments appear, but also of how they are experienced and how they support wellbeing-oriented design strategies.

PILOT EXPERIMENTAL APPLICATION IN AN ACADEMIC VR ENVIRONMENT

To support empirical validation of the proposed framework, a pilot experimental study is planned within an academic interior architecture environment using immersive virtual reality simulation tools.

The study will investigate how selected atmospheric spatial parameters, including chromatic composition, lighting spectrum, spatial enclosure ratios, and material tactility, influence perceived comprehensibility, manageability, and meaningfulness within simulated interior environments.

Participants will evaluate multiple spatial scenarios presented in immersive virtual environments at a 1:1 scale using structured questionnaires derived from sense-of-coherence components and semantic differential scales describing perceived spatial atmosphere.

The availability of immersive visualisation laboratories and a representative group of interior architecture students provides a realistic research setting for testing relationships between multisensory spatial perception and sense-of-coherence mechanisms in simulated architectural environments.

DISCUSSION AND LIMITATIONS

Despite its conceptual contribution, the proposed framework has not yet been validated through empirical studies conducted in immersive environments. Differences between simulated and physical sensory experience, particularly in relation to tactile, thermal, and olfactory perception, may influence users' responses to spatial atmosphere.

At the same time, immersive simulation technologies provide sufficient perceptual realism to support early-stage evaluation of environmental variables regulating spatial orientation and emotional interpretation of architectural space.

Future research should therefore combine behavioural observation, psychometric assessment, and physiological measurements in order to strengthen the empirical applicability of the proposed model within salutogenic interior design methodologies.

CONCLUSION

This paper proposes a conceptual framework integrating immersive virtual reality simulation with multisensory perception theory and the sense-of-coherence model as a methodological foundation for analysing atmospheric spatial parameters in interior architecture.

By operationalising spatial atmosphere as a structured set of perceptual variables related to orientation, environmental control, and emotional engagement with place, the proposed model supports the development of evidence-based design strategies addressing users' wellbeing.

The integration of immersive simulation technologies into architectural research enables systematic evaluation of spatial scenarios prior to implementation and contributes to emerging future-oriented competencies in human-centred interior architecture.

Future empirical studies conducted in immersive environments will further verify the relationships between multisensory spatial perception and sense-of-coherence mechanisms, supporting the development of research-informed salutogenic design methodologies.

ACKNOWLEDGMENT

The author would like to express sincere gratitude to the authorities of the Faculty of Architecture at the West Pomeranian University of Technology in Szczecin for supporting the development of research activities related to immersive virtual reality applications in interior architectural design.

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