



Review

Translating Neuroscience into Architectural Research: A Critical Narrative Review and Translational Framework of the Academy of Neuroscience for Architecture (ANFA)

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Abstract

Recent developments in cognitive neuroscience, neuroimaging, and embodied cognition have stimulated growing interest in neuroscience-informed architecture. However, despite the rapid expansion of the field, neuroarchitectural scholarship remains conceptually fragmented and methodologically diverse, and its institutional evolution, thematic structure, and translational implications have not been comprehensively synthesised. Using a narrative critical synthesis supported by translational qualitative structuring and conceptual synthesis, this study examines foundational publications, institutional documents, conference outputs, and applied studies that have shaped neuroscience-informed architecture since the early 2000s. The review identifies recurring thematic domains, including sensory perception, spatial cognition, emotion, empathy, embodied cognition, environmental behaviour, healthcare design, and evidence-based architectural practice. It indicates that ANFA-related scholarship has played a significant role in legitimising neuroscience as a relevant framework for understanding architectural experience and informing design practices in therapeutic, educational, and behavioural contexts. The review also highlights persistent methodological challenges in translating neuroscientific findings into architectural research, particularly given that architectural experience is multisensory, embodied, socially situated, and temporally dynamic. The study concludes that neuroscience-informed architecture should be understood not as a deterministic explanatory model but as a translational framework that connects neuroscientific knowledge with architectural theory and practice. This expanding evidence base calls for more ecologically valid, interdisciplinary, and methodologically rigorous research, while encouraging architects and practitioners to adopt evidence-based, human-centred design strategies that enhance health, well-being, and user experience across diverse built environments.



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1. Introduction

Architectural environments have played a fundamental role in human existence since the earliest stages of human history, functioning not only as shelters but also as systems that organise social life, regulate behaviour, and shape human–environment interaction. From an evolutionary perspective, built environments have co-developed with human cognition, bodily practices, and socio-cultural structures, influencing perception, memory, and social organisation [1,2]. Rather than passive physical structures, architectural settings actively

mediate sensory, emotional, cognitive, and behavioural processes [2–4], contributing to a shift away from formalist interpretations toward embodied and human-centred approaches to space.

Architectural experience encompasses interrelated material, symbolic, sensory, emotional, and cultural dimensions [5–8]. These dimensions are integrated through bodily engagement, movement, and temporal interaction, producing holistic environmental experiences [9,10]. Consequently, architectural experience emerges through dynamic interactions between the body, mind, and environment, making architecture an important domain for understanding how spatial settings shape cognition, emotion, and behaviour [11–13].

Scientific investigations of human–environment relationships gradually expanded during the nineteenth and twentieth centuries. The emergence of experimental psychology and physiology established the foundations for studying perception and environmental experience [14], while the work of Helmholtz and Wundt introduced measurable approaches to sensory and mental processes [15,16]. During the twentieth century, environmental psychology further shifted attention toward user–environment interactions and the influence of built environments on behaviour and psychological well-being [12,17–21]. These developments provided an important interdisciplinary foundation for later attempts to integrate architecture with neuroscience.

Major scientific and technological developments after the 1960s transformed how cognition and behaviour could be investigated. Increasing design complexity and advances in computational approaches expanded architectural theory beyond traditional representational models [22,23], while neuroscience entered a period of rapid growth following the development of brain-imaging technologies such as positron emission tomography and functional magnetic resonance imaging. These advances enabled direct investigation of the neural mechanisms underlying perception, memory, attention, and emotion [24,25]. At the same time, phenomenology and embodied cognition challenged disembodied models of mind. Through the work of Merleau-Ponty and later developments in enactive theories, cognition came to be understood as emerging through continuous interactions among brain, body, and environment rather than isolated internal computation [3,26,27]. These ideas resonated strongly with architectural concerns regarding spatial experience, movement, materiality, and multisensory engagement.

Within this broader intellectual context, neuroscience-informed architecture emerged as a distinct interdisciplinary field in the early twenty-first century. The establishment of the Academy of Neuroscience for Architecture (ANFA) in 2003 provided an important institutional platform for dialogue between architects and neuroscientists and contributed to the development of what later became known as neuroarchitecture [28]. Since then, scholarship has expanded considerably to encompass theoretical debates, empirical investigations, and applications in healthcare architecture, educational environments, spatial cognition, emotional regulation, multisensory perception, and evidence-based design [9,29–31]. Despite this growth, important methodological and epistemological challenges remain, particularly in translating laboratory-based neuroscientific findings into the multisensory, socially situated realities of architectural experience.

Recent European discussions have further broadened the conceptual foundations of neuroscience-informed architecture by emphasising healthy, evidence-based approaches to the built environment [32–34]. Scholars have increasingly argued that architectural quality should be understood not only in aesthetic or functional terms but also in terms of its capacity to promote physical, psychological, and social well-being. These developments reinforce the view of architecture as a health-related, human-centred practice that integrates environmental psychology, neuroscience, and public health perspectives. Consequently,

contemporary neuroarchitecture should be situated within a broader international context extending beyond North American institutional frameworks.

Recent reviews and scoping studies have further demonstrated the field's conceptual and methodological maturation. Higuera-Trujillo et al. [35] critically examined neuroarchitecture and its precursor traditions, while subsequent reviews highlighted the growing diversity of empirical approaches, including neuroimaging, electrophysiological techniques, virtual reality, and physiological measurements. Other studies emphasised the relevance of neuroscience-informed design to learning environments, cognitive performance, and human well-being [36–38], whereas Abbas [39] synthesised recent evidence concerning the influence of architectural environments on brain function and psychological well-being. Collectively, these studies indicate that neuroarchitecture has reached a greater degree of conceptual and methodological maturity while continuing to face important empirical and epistemological challenges.

Despite this expansion, the field remains theoretically fragmented and methodologically diverse, ranging from phenomenological interpretations to highly experimental neuroimaging-based investigations without a unified analytical framework. Moreover, the broader conceptual structure, thematic organisation, and methodological evolution of scholarship associated with the neuroscience-informed architectural paradigm have not yet been systematically synthesised. In this context, ANFA-related scholarship is understood broadly and is not limited to publications produced by ANFA board members or conference participants. Rather, the review encompasses theoretical, empirical, and applied studies that either emerged directly from ANFA initiatives or developed within the broader neuroscience-informed architectural paradigm that ANFA helped institutionalise. Accordingly, the analysis includes foundational publications, institutional documents, conference outputs, and related neuroarchitectural research concerned with cognition, perception, emotion, embodied experience, healthcare design, and evidence-based architectural practice.

In response to this gap, the present study reviews foundational publications, institutional initiatives, and applied studies that have shaped neuroarchitectural discourse since the early 2000s. The aim is to identify the principal conceptual themes, methodological tendencies, and epistemological links characterising this interdisciplinary field and to evaluate both its contributions and its limitations. By doing so, the study seeks to provide a critical and structured understanding of how neuroscience has been mobilised within architectural discourse and how the brain–body–environment relationship has been conceptualised in relation to architectural experience.

2. Materials and Methods

2.1. Review Design and Analytical Framework

This study adopts a qualitative interpretive review design and a narrative critical synthesis, supported by translational qualitative structuring and conceptual synthesis, to examine how neuroscientific knowledge has been interpreted, adapted, and incorporated into architectural discourse and practice, particularly through the institutional and scholarly contributions of the Academy of Neuroscience for Architecture. The review was informed by interpretive principles proposed by Dixon-Woods et al. [40] and employed an inductive thematic synthesis approach. Given the interdisciplinary and conceptually heterogeneous nature of neuroarchitecture, this approach provides an appropriate framework for evaluating foundational texts, institutional initiatives, conceptual frameworks, and empirical tendencies while preserving their theoretical and contextual complexity. Rather than aiming for exhaustive bibliographic coverage, quantitative meta-analysis, or statistical generalisation, the study focuses on identifying major conceptual themes, method-

ological orientations, and epistemological tensions that have shaped the development of neuroscience-informed architecture.

Table 1 summarises the methodological structure of the review, including the literature sources, search strategy, selection and exclusion criteria, screening procedures, thematic coding and theme refinement process, comparative and historical analyses, and supplementary descriptive publication-trend and conceptual mapping components used to examine the conceptual, institutional, and methodological development of neuroscience-informed architecture.

Table 1. Review design and analytical framework employed in the study.

Component	Procedure	Purpose/Output
Review Design	Qualitative interpretive review	Critical examination of the theoretical, institutional, and empirical development of neuroscience-informed architecture
Research Gap and Aim	Identification of conceptual and methodological fragmentation	Provide a structured synthesis of neuroarchitectural scholarship
Literature Sources	Books, journal articles, conference proceedings, ANFA publications, and institutional documents	Establish the review corpus
Search Strategy	Keywords including neuroarchitecture, architecture and neuroscience, built environment, spatial cognition, embodied cognition, and related terms	Identify relevant literature
Selection Criteria	Conceptual relevance, institutional significance, methodological diversity, and historical importance	Ensure inclusion of influential theoretical and empirical studies
Exclusion Criteria	Removal of duplicate records, sources lacking explicit architecture–neuroscience relevance, purely technical neuroscience studies, editorials, and marginal references	Maintain thematic coherence and analytical focus
Screening Procedure	Iterative title, abstract, and full-text assessment	Identify representative and relevant studies
Analytical Framework	Interpretivist and inductive approach	Examine the translation of neuroscientific knowledge into architectural discourse
Thematic Coding	Identification of recurring concepts, methodological approaches, and application domains	Categorise major themes and patterns in the literature
Theme Refinement	Iterative comparison and cross-checking with historical developments and descriptive publication-trend observations	Enhance analytical consistency between qualitative interpretation and supplementary descriptive observations
Comparative and Historical Analysis	Examination of conceptual evolution and institutional developments	Trace the emergence and expansion of neuroarchitecture

Table 1. Cont.

Component	Procedure	Purpose/Output
Supplementary Descriptive Component	Scopus-based publication-trend overview and researcher-developed conceptual maps	Provide descriptive and conceptual support for historical and thematic interpretation without claiming formal metric-based or citation-based analysis.
Critical Synthesis	Integration of qualitative findings, descriptive publication-trend observations, and conceptual mapping	Evaluate the strengths, limitations, and translational implications of neuroscience-informed architecture

2.2. Literature Selection

The review corpus was developed through purposive selection of foundational and influential sources directly associated with neuroscience-informed architecture and, more specifically, with the development of ANFA-related scholarship. The selected materials include scholarly books, peer-reviewed articles, edited volumes, conference proceedings, institutional documents, ANFA newsletters, and applied studies published primarily after the early 2000s, reflecting the field's formal institutionalisation through ANFA's establishment in 2003.

The selection process prioritised sources that explicitly addressed the relationship between architectural environments and neuroscientific concepts, methods, or findings. Particular emphasis was placed on works that examined how built environments influence perception, cognition, emotion, memory, embodied experience, environmental behaviour, and human well-being. Foundational contributions predating ANFA were also included where necessary to establish the broader scientific and conceptual background of the field, particularly in relation to environmental psychology, embodied cognition, phenomenology, and cognitive neuroscience.

Three principal criteria guided the selection of the literature. First, conceptual relevance was prioritised, meaning that the selected sources needed to engage directly with the architecture–neuroscience relationship rather than merely referencing adjacent disciplinary concerns. Second, institutional significance was considered, particularly regarding ANFA's role in shaping the intellectual infrastructure of neuroarchitecture. Third, methodological diversity was intentionally preserved by including both theoretical and empirical works to capture the field's heterogeneity.

The literature search was conducted primarily through Scopus and was supplemented by scholarly books, conference proceedings, and institutional documents from the Academy of Neuroscience for Architecture (ANFA). Search terms included combinations of “neuroarchitecture”, “architecture and neuroscience”, “neuroscience-informed architecture”, “built environment”, “spatial cognition”, “embodied cognition”, “environmental psychology”, and related concepts. This search strategy was designed to capture both foundational contributions and more recent developments across theoretical, empirical, and applied domains.

Following the initial search, records were screened iteratively based on title, abstract, and full-text assessment. Particular attention was given to studies that addressed the relationship between architecture and neuroscience from conceptual, empirical, institutional, or translational perspectives. Seminal publications and highly cited contributions were retained to ensure historical continuity, while more recent studies were included to reflect current developments in the field.

Sources were excluded if they lacked an explicit connection between architecture and neuroscience, focused exclusively on technical neuroscientific issues without archi-

tectural implications, duplicated previously identified findings, or provided insufficient conceptual or methodological relevance to the aims of the review. Editorial materials, brief commentaries, and publications lacking substantive scholarly content were also excluded.

2.3. Analysis

The analysis followed an inductive thematic review process. Rather than applying predefined analytical categories, the selected literature was examined iteratively to identify recurring conceptual domains, methodological patterns, and interpretive tensions emerging from the literature itself. The initial reading focused on identifying major recurring themes concerning how neuroscience has been mobilised in architectural environments.

The analytical process began with a holistic reading of the selected corpus to gain an overall understanding of the field's conceptual and methodological landscape. Themes emerged through iterative reading but were subsequently organised into broader analytical categories consistent with existing neuroarchitectural literature. Theme development continued until no substantially new conceptual categories emerged. Preliminary codes were refined through repeated comparison across sources, allowing broader analytical domains to develop progressively. Where conflicting interpretations or disciplinary perspectives were encountered, these differences were treated as expressions of the field's conceptual heterogeneity rather than as inconsistencies to be eliminated. Accordingly, competing perspectives were incorporated into the analysis to capture the epistemological diversity characterising neuroarchitectural scholarship.

Through repeated close reading and comparative interpretation, these recurring themes were organised into broader analytical domains. These included perception and sensory processing, cognition and memory, emotion and empathy, embodied cognition, spatial navigation and wayfinding, environmental behaviour, evidence-based design, healthcare architecture, and adaptive environments. These categories emerged inductively from the reviewed material rather than being imposed a priori, allowing the analysis to remain responsive to the field's internal conceptual organisation.

In addition to thematic identification, the analysis also focused on methodological tendencies across the literature. Particular attention was given to how different studies operationalised architectural experience, whether through conceptual argumentation, behavioural observation, neuroimaging methods, electrophysiological measurement, or applied environmental interventions. This allowed the review to identify not only the themes that dominate the literature but also how those themes have been methodologically approached.

The methodological perspective of this review is grounded in an interpretivist epistemological position. Architectural knowledge is understood here as historically situated, socially mediated, and conceptually constructed rather than reducible to purely objective or universal explanatory models. This position is especially important in the context of neuroarchitecture because architectural experience involves multisensory, embodied, social, and temporal dimensions that cannot be fully captured through isolated neuroscientific measurements alone.

This review does not attempt to evaluate neuroscientific findings based on experimental validity or clinical efficacy. Instead, the primary concern is how neuroscientific knowledge has been framed, translated, and legitimised within architectural discourse and how these translations have shaped the conceptual boundaries of neuroarchitecture as an interdisciplinary field. This interpretive orientation allows for critical examination of both the productive contributions and the limitations of neuroscience-informed architectural literature. The scope of the review is, therefore, intentionally selective rather than exhaustive. Its aim is not to catalogue all existing publications in the field but to analyse those that

have played a significant role in establishing, expanding, or critically shaping the dialogue between architecture and neuroscience.

Theme identification followed an inductive and iterative coding process guided by the interpretive framework adopted in this review. The comparative interpretation process was conducted manually, through repeated close reading and matrix-based synthesis, rather than using dedicated qualitative data analysis software. Recurring concepts, methodological approaches, and application domains were grouped into broader thematic categories through repeated comparison across sources. To enhance analytical consistency, the resulting themes were continuously refined and cross-checked against the historical discussion and supplementary descriptive observations.

2.4. Translational Qualitative Structuring and Conceptual Synthesis

To complement the qualitative interpretive review, this section adopts a translational qualitative structuring and conceptual synthesis approach to contextualise the historical, institutional, and thematic development of neuroscience-informed architecture. Scopus-indexed publication records were used only as a contextual source for observing broad publication trends and were not treated as the basis for a formal bibliometric, metric-based, or empirical descriptive analysis. Publication records were retrieved using combinations of the keywords “neuroarchitecture”, “architecture and neuroscience”, “neuroscience-informed architecture”, “built environment”, “spatial cognition”, and “embodied cognition”. The retrieved records were screened for relevance, and duplicate entries were removed. This component was limited to illustrating broad publication trends and supporting the historical interpretation of the field’s development. It was not intended as a formal metric-based or citation-based analysis. Accordingly, no formal performance indicators, citation counts, co-citation analysis, bibliographic coupling, author collaboration metrics, or link-strength calculations were performed.

In addition to these contextual publication-trend observations, visual diagrams of conceptual networks and theoretical affinities were developed to visualise recurrent thematic domains and intellectual relationships identified through the interpretive synthesis. These were produced through the manual thematic interpretation of the reviewed literature rather than through automated citation-based or network-analytic procedures. They should therefore be understood as researcher-developed schematic representations rather than formal keyword co-occurrence, co-authorship, co-citation, or bibliographic linking networks. Their purpose is to support the narrative and thematic interpretation of the literature by illustrating conceptual relationships among major themes and influential scholars. A qualitative translational synthesis matrix was also developed through iterative synthesis of recurrent relationships identified across the reviewed studies, linking neuroscientific concepts, architectural applications, and potential clinical or design relevance. Together, these elements complement the interpretive review by providing descriptive and conceptual support for understanding the development of neuroscience-informed architecture.

3. Results of the Review: Thematic and Historical Development of Neuroarchitecture

3.1. Contextual Publication-Trend Observations and Conceptual Relationships in Neuroscience-Informed Architectural Research

To complement the qualitative review and contextualise the historical development of neuroarchitecture, a supplementary descriptive publication-trend overview and conceptual mapping component was developed. Publication trends and researcher-developed conceptual maps were used to contextualise the Academy of Neuroscience for Architecture’s institutional role within the broader development of neuroscience-informed architectural research.

Figure 1 illustrates the temporal evolution of neuroscience-informed architectural research. Although isolated contributions existed before the early 2000s, publication activity increased considerably after 2003. This trend reflects the progressive consolidation of neuroarchitecture and its growing interdisciplinary character. While this temporal association should not be interpreted as evidence of direct causality, it suggests that the establishment of the Academy of Neuroscience for Architecture (ANFA) coincided with the field’s increasing visibility and institutional maturation.

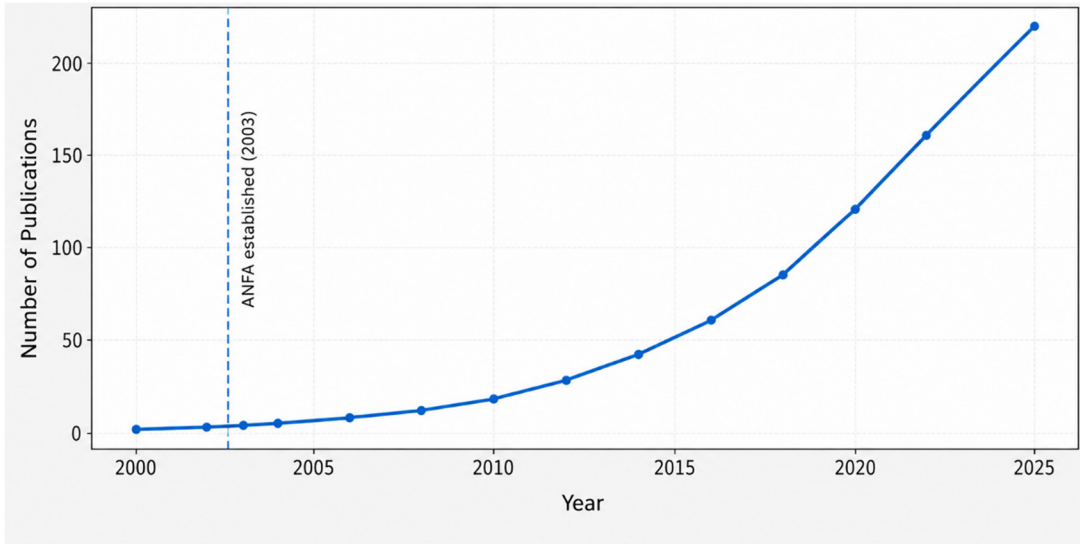


Figure 1. Temporal evolution of publications related to neuroscience-informed architectural research (2000–2025).

Beyond publication growth, understanding the intellectual structure of the field requires examining the relationships among recurrent concepts and thematic domains. Therefore, a visual diagram (see Figure 2) of conceptual networks was developed to illustrate the principal thematic domains derived inductively from the interpretive review, including spatial cognition, embodied cognition, emotion, healthcare design, and evidence-based architecture.

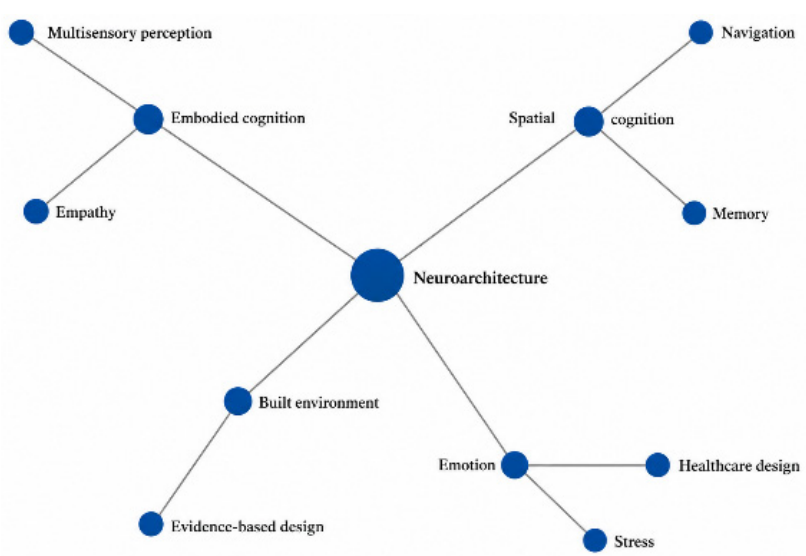


Figure 2. Visual diagram of conceptual networks among major thematic domains derived inductively from the interpretive review.

The diagram illustrates relationships among recurrent concepts identified through the interpretive review, including spatial cognition, embodied cognition, emotion, healthcare design, and evidence-based design. It should be understood as a schematic conceptual representation rather than a formal keyword co-occurrence or network-analytic output. The figure visualises the main thematic domains that recur across the reviewed literature and highlights their conceptual interconnections. These relationships suggest that neuroscience-informed architectural research has developed as an integrative field combining cognitive neuroscience, environmental psychology, architectural theory, and evidence-based design. Rather than presenting statistically generated clusters, the diagram supports the qualitative synthesis by making visible the conceptual diversification of ANFA-related scholarship.

In addition to thematic relationships, a visual diagram of theoretical affinities was developed to illustrate how influential scholars from architecture, neuroscience, cognitive science, and environmental psychology have contributed to the conceptual organisation of the field.

Figure 3 presents a visual diagram of theoretical affinities among influential scholars who have contributed to neuroscience-informed architectural research. The diagram illustrates conceptual affinities and interdisciplinary connections identified through the interpretive review and should not be interpreted as formal co-authorship, co-citation, citation, or network-analytic output. Rather than presenting statistically generated relationships, the figure visualises how key contributors from architecture, neuroscience, cognitive science, and environmental psychology have shaped overlapping areas of discussion within the field. The positioning of scholars in the diagram is therefore interpretive and illustrative, not the result of network centrality calculations or formal link-strength calculations. In this sense, the figure supports the qualitative synthesis by highlighting the interdisciplinary and translational character of neuroarchitecture.

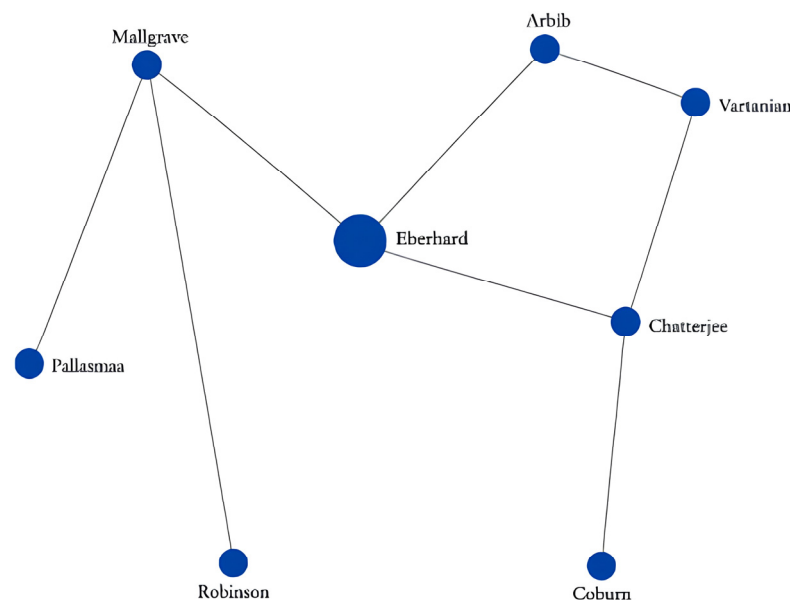


Figure 3. Visual diagram of theoretical affinities among influential scholars derived inductively from the interpretive review.

The descriptive publication trends and conceptual maps support the historical and thematic developments identified in the qualitative review. Rather than indicating a single causal trajectory, these observations suggest that the Academy of Neuroscience for Architecture (ANFA) served as one of the principal institutional platforms that contributed to the visibility, coherence, and translational orientation of neuroscience-informed architectural research. These descriptive and schematic elements complement the interpretive synthesis

and provide contextual support for understanding the evolution of neuroarchitecture as an increasingly interdisciplinary field.

3.2. *The Scientific Foundations of Neuroscience-Informed Architecture*

The emergence of neuroscience-informed architecture cannot be understood independently of the broader transformation of neuroscience after the 1970s. During this period, neuroscience underwent a major epistemological and methodological expansion, shifting from fragmented investigations of isolated neural mechanisms toward an integrated scientific framework capable of explaining cognition, perception, emotion, and behaviour across multiple biological and psychological levels [25,41,42]. This transformation established the scientific conditions necessary for later interdisciplinary applications to architecture.

One of the most significant developments in this period was the rise of Cognitive Neuroscience, which redirected scientific attention from isolated neurological deficits or cellular mechanisms toward understanding higher cognitive functions such as memory, attention, language, emotional processing, and decision-making in relation to brain activity [27,43]. This transition was made possible by major developments in non-invasive neuroimaging technologies. Positron emission tomography and later functional magnetic resonance imaging fundamentally changed neuroscience by enabling direct observation of neural activity in living human subjects during cognitive tasks, allowing researchers to investigate the neural basis of perception, cognition, and emotion more directly than previously possible [24,44].

Electrophysiological techniques such as electroencephalography and magnetoencephalography expanded the temporal precision of neuroscientific investigation, enabling researchers to examine neural dynamics on a millisecond scale and to understand how distributed brain regions coordinate during perceptual and behavioural processes [45,46]. These methodological developments contributed to a broader conceptual shift away from strict localisation models toward network-based understandings of cognition, in which perception and behaviour emerge from dynamic interactions among distributed neural systems rather than isolated modules [47].

The developments in molecular neuroscience, neuroplasticity research, and computational neuroscience expanded the explanatory scope of brain science even further. Studies on synaptic plasticity demonstrated that environmental experience can physically reshape neural organisation, reinforcing the idea that cognition is fundamentally shaped by interactions with environmental conditions [48]. This idea became particularly important for architecture because it provided a biological foundation for understanding how built environments may influence human experience beyond immediate perception.

Neuroarchitecture has increasingly expanded beyond individual buildings toward broader urban, adaptive, and technological environments [28,49–51]. The studies examined how cities, digital environments, and adaptive systems shape emotional regulation, behavioural movement, and cognitive experience. Studies on urban attractors, mobile emotional states, and adaptive environmental systems indicate a growing recognition that architectural experience is not confined to enclosed buildings but extends across broader environmental systems. This expansion reflects a conceptual shift from building-centred architecture toward environment-centred neuroarchitecture [52]. These developments established the scientific infrastructure through which architectural environments could later be examined as active components of cognitive and emotional life rather than merely physical settings.

Table 2 summarises the principal conceptual and methodological stages in the development of neuroarchitecture, illustrating the transition from early conceptual and institutional foundations to contemporary empirical approaches employing neuroimaging, behavioural

mapping, virtual reality, and mobile sensing technologies. Representative studies and dominant methodological orientations are included to highlight the field's increasing complexity and translational orientation.

Table 2. Evolution of Neuroscience-Informed Architectural Research.

Period	Dominant Orientation	Representative Studies	Main Methods
Early 2000s	Conceptual advocacy and institutional formation	Eberhard [53], Jarmusch [54], Tuma [55]	Conceptual and theoretical approaches
Late 2000s	Translation into healthcare and dementia care	Zeisel [56]	Behavioural observation and evidence-based design
Early–mid 2010s	Ecological validity and mobile technologies	Aspinall et al. [57]	Mobile EEG, in-situ physiological monitoring, real-world urban walking
2010–2017	Expansion of neuroimaging and neuroaesthetics	Chatterjee and Vartanian [13], Coburn et al. [28]	fMRI and EEG
2018–2021	Embodied cognition and environmental adaptation	Andreani and Sayegh [58], Safavi et al. [59]	Behavioural mapping and multisensory approaches

3.3. The Institutional Emergence of Neuroarchitecture: The Role of ANFA

The formal institutionalisation of neuroscience-informed architecture began with the establishment of the Academy of Neuroscience for Architecture (ANFA) in 2003 [53,54,60]. Although earlier environment–behaviour studies and environmental psychology had already examined relationships between built environments and human behaviour [17,18], ANFA represented the first systematic institutional effort to establish direct dialogue between architecture and neuroscience.

The institutional significance of ANFA lies in its role as a translational platform through which neuroscientific knowledge became conceptually and professionally accessible to architectural discourse [61]. Established by architects and aligned with the American Institute of Architects, ANFA aimed to introduce neuroscientific perspectives into architectural education, design practice, and theoretical discussion [62]. Through conferences, workshops, seminars, and publications, ANFA created an interdisciplinary infrastructure that legitimised neuroscience as a relevant knowledge base for architecture.

The publication of John Paul Eberhard's *How the Brain Experiences Architecture* in 2003 marked one of the earliest major conceptual interventions in this emerging field. Eberhard argued that architectural space actively shapes cognition, emotion, memory, and behaviour through neural mechanisms, repositioning architecture from a passive physical container to an active environmental system influencing mental life [53]. This perspective provided an important conceptual foundation for subsequent neuroarchitectural discourse.

The early institutional period between 2003 and 2006 was characterised primarily by knowledge dissemination and conceptual legitimisation rather than empirical consolidation [54,55]. ANFA newsletters, educational programmes, and interdisciplinary workshops played a central role in introducing neuroscientific concepts into architectural education and professional practice, thereby establishing a new intellectual vocabulary for discussing spatial experience.

Over time, ANFA-related scholarship expanded beyond conceptual advocacy and helped shape a broader interdisciplinary research agenda. The increasing diversification of themes and methods reflects the gradual maturation of neuroarchitecture from an institutional initiative into a more complex field of theoretical, empirical, and applied inquiry.

The principal thematic domains identified in the reviewed literature are summarised in Table 3, including sensory perception, memory and spatial cognition, emotion and empathy, embodied cognition, healthcare and therapeutic architecture, and adaptive evidence-based design.

Table 3. Structured synthesis of the principal thematic domains identified in neuroscience-informed architectural research.

Theme	Main Focus	Representative Topics	Typical Approaches	Architectural Implications
Sensory perception	Processing of visual and multisensory stimuli	Light, colour, geometry, complexity	Neuroimaging, EEG, behavioural studies	User comfort and environmental experience
Memory and spatial cognition	Navigation and environmental representation	Wayfinding, memory, orientation	Cognitive studies, behavioural observation	Legibility and dementia-friendly environments
Emotion and empathy	Emotional appraisal and affective responses	Neuroaesthetics, empathy, stress regulation	fMRI, EEG, neuroaesthetics	Healing and emotionally supportive spaces
Embodied cognition	Brain–body–environment interaction	Multisensory experience, movement, embodiment	Phenomenological and behavioural approaches	Human-centred and experiential design
Healthcare and therapeutic architecture	Environmental effects on health and well-being	Dementia care, stress reduction, recovery	Evidence-based design and applied studies	Therapeutic and inclusive environments
Adaptive and evidence-based design	Translating neuroscience into practice	Behavioural mapping, environmental adaptation	Multidisciplinary approaches	Responsive and evidence-based design

3.4. Major Themes and Methodological Evolution of ANFA-Related Scholarship

As neuroarchitecture evolved beyond its initial institutional phase, ANFA-related scholarship developed into a diverse body of theoretical, empirical, and applied research. The reviewed literature reveals several recurring thematic domains that collectively shaped the intellectual structure of neuroscience-informed architecture. At the same time, the field underwent a gradual methodological transformation from predominantly conceptual discussions toward increasingly empirical and translational approaches.

One of the most prominent themes concerns sensory perception and environmental cognition. Numerous studies have examined how architectural elements such as light, geometry, scale, materiality, and environmental complexity influence perceptual processing and emotional responses [4,5,13,63]. These studies emphasise that architectural experience is fundamentally multisensory and cannot be reduced to visual perception alone.

Memory and spatial cognition constitute another major domain. Research has prompted us to consider how architectural environments affect cognitive mapping, navigation, orientation, and environmental familiarity [24,48]. These issues are particularly relevant in healthcare settings and dementia-care environments, where spatial legibility and environmental clarity influence behavioural stability and cognitive functioning [56,64].

Embodied cognition and empathy emerged as increasingly important themes as the field developed [65]. Drawing upon phenomenology, enactive cognition, and mirror-neuron theories, researchers argued that architectural experience arises through active bodily engagement with environmental conditions rather than detached visual observation [11,26,27]. This perspective represented an important shift away from earlier cognitive-centred interpretations.

Healthcare architecture and therapeutic environments are among the strongest applied domains within neuroscience-informed design. Research concerning Alzheimer’s care facilities, healing environments, and stress-reducing spatial configurations demonstrates how architectural interventions can influence orientation, emotional regulation, and behavioural well-being [56,64].

The reviewed literature demonstrates that neuroscience-informed architecture encompasses a broad range of conceptual and applied themes, including sensory perception, spatial cognition, embodied experience, and healthcare design. These thematic domains illustrate the growing scope of neuroarchitectural inquiry and its increasing relevance to human-centred and evidence-based design. At the same time, the field has gradually expanded beyond theoretical discussions toward more empirical and translational approaches. Representative experimental developments illustrating this methodological evolution are discussed in the following section.

Illustrative Experimental Findings in Neuroarchitectural Research

Although much of the early neuroarchitectural literature was characterised by conceptual discussions and advocacy-oriented arguments, subsequent studies increasingly incorporated empirical methodologies to investigate the relationship between architectural environments and human cognition, emotion, and behaviour. These developments illustrate how neuroscience-informed architecture has gradually moved beyond purely theoretical debates toward more experimentally grounded approaches.

One important line of research concerns neuroaesthetic responses to architectural environments. Chatterjee and Vartanian [13] argued that aesthetic experiences involve neural systems associated with reward processing, affective appraisal, and cognitive evaluation. Their work demonstrated that architectural preferences are not merely subjective judgments but are associated with measurable neural processes. Similarly, Coburn et al. [28] proposed that architectural experience emerges from interactions among perceptual, emotional, and cognitive systems, providing an empirical framework for understanding how built environments influence human experience.

Experimental approaches employing electrophysiological measurements have also contributed to the field. Studies using electroencephalography (EEG) suggest that environmental variables such as lighting conditions, spatial organisation, and visual complexity can affect attentional states and emotional responses. These findings indicate that architectural stimuli can influence neural activity and support the development of evidence-based design strategies to improve user experience and psychological comfort.

In addition to neuroimaging and electrophysiological methods, behavioural approaches have expanded the methodological repertoire of neuroscience-informed architecture [66]. Safavi et al. [59] demonstrated that integrating neurocognitive indicators with climatic and behavioural variables through architectural behavioural mapping can enhance adaptive and inclusive design practices. Their framework illustrates how neuroscientific knowledge can be translated into practical decision-making for design and user-sensitive environmental interventions.

Recent systematic and methodological reviews further demonstrate the increasing diversity of experimental approaches employed in neuroarchitecture. Studies have documented the growing use of electroencephalography, functional magnetic resonance imaging, virtual reality, physiological monitoring, and multisensory assessment techniques [35,67,68]. More recent syntheses have also highlighted the growing relevance of neuroscience-informed design for learning environments, well-being, and evidence-based architectural practice [36,39].

Collectively, these findings indicate that neuroarchitecture has evolved from predominantly conceptual discussions toward increasingly empirical and translational forms of inquiry. The growing integration of neuroimaging, electrophysiological techniques, virtual reality, physiological monitoring, and behavioural mapping reflects the methodological maturation of neuroscience-informed architectural research. Although challenges concerning ecological validity, causal inference, and experimental standardisation remain, these developments demonstrate the increasing capacity of neuroarchitecture to contribute to

evidence-based architectural practice and to bridge theoretical knowledge with real-world design applications.

4. Discussion

4.1. Critical Evaluation of Neuroscience-Informed Architectural Research

The findings of this review demonstrate that the integration of neuroscience into architecture represents not merely a methodological innovation but a broader epistemological transformation in how architectural experience is conceptualised. Advances in cognitive neuroscience and brain imaging after the 1970s created new opportunities for examining perception, cognition, and emotional processing in relation to environmental experience [24,25,69]. However, the delayed application of these methods to architecture reveals an important disciplinary tension. While neuroscience relies on experimental reduction and variable isolation [70,71], architecture is inherently multisensory, embodied, socially embedded, and temporally extended [1,5,26]. Consequently, the emergence of neuroarchitecture in the early 2000s reflects not simply a technological extension of neuroscience into architecture but a negotiation between fundamentally different epistemological traditions [53,61].

The Academy of Neuroscience for Architecture (ANFA) emerged as one of the principal institutional platforms through which neuroscience-informed architectural research gained visibility, interdisciplinary coherence, and translational orientation. The descriptive publication trends and thematic patterns identified in the present review suggest that ANFA coincided with, and likely facilitated, the consolidation of neuroarchitecture as a distinct interdisciplinary field. However, much of the early literature prioritised conceptual translation and theoretical expansion over methodological interrogation [54,55,62]. As a result, the field initially developed through conceptual legitimacy rather than empirical robustness, creating a tension between translational ambitions and methodological rigour that continues to shape neuroarchitectural discourse.

A major contribution of early neuroarchitectural scholarship was the reconceptualisation of architectural space as an active cognitive and affective environment rather than a passive physical setting. By grounding spatial experience in biological and cognitive processes, foundational scholars challenged long-standing formalist and symbolic paradigms in architectural theory [4,53,72]. However, many early claims remained largely programmatic, and the promise of neuroscience-informed design often preceded the methodological capacity required for empirical validation [29,30,73]. Consequently, neuroarchitecture initially functioned more as a conceptual horizon than as a fully operationalised research framework, explaining why theoretical development advanced more rapidly than methodological consolidation.

The review also reveals a persistent tension between scientific rigour and ecological validity. Experimental studies employing functional magnetic resonance imaging, electroencephalography, and related neuroscientific tools have generated valuable insights into perceptual and affective responses to architectural stimuli [44,46]. Nevertheless, these studies frequently rely on static imagery, simplified visual representations, or virtual simulations [13]. Although such simplifications are necessary for experimental control, they fail to capture the multisensory, dynamic, and socially situated nature of architectural experience [5,9]. Consequently, questions concerning the ecological validity and practical transferability of laboratory findings remain unresolved.

Moreover, the interpretation of architectural experience is influenced by numerous confounding variables that are difficult to isolate experimentally. Factors such as lighting conditions, acoustic environments, user familiarity, cultural background, mobility patterns, clinical status, and social interactions all shape cognitive and emotional responses

to space. Consequently, findings derived from controlled laboratory settings should not be assumed to translate directly into real-world architectural environments. While neuroimaging studies provide valuable insights into neural mechanisms under experimentally controlled conditions, ecologically valid field investigations capture the complexity and contextual variability of lived spatial experience. Distinguishing between laboratory-based evidence and real-world environmental responses, therefore, remains essential for the future development of neuroscience-informed architecture.

The increasing adoption of embodied cognition frameworks represents one of the most important conceptual developments in the field. By understanding architectural experience as emerging through interactions among brain, body, and environment, embodied approaches challenge reductionist models and align more closely with phenomenological conceptions of space [3,27,74]. This perspective has strengthened neuroarchitecture theoretically by incorporating movement, affect, multisensory perception, and environmental engagement into analyses of spatial experience [63,75]. At the same time, embodied approaches introduce methodological difficulties because embodied experience is dynamic, relational, and context-dependent, making experimental standardisation inherently challenging.

Applied domains such as healthcare architecture, dementia care, and inclusive design are among the most practically valuable areas of neuroscience-informed architectural research. Studies demonstrating the effects of spatial clarity, environmental familiarity, sensory cues, and supportive layouts on well-being provide strong support for evidence-based design approaches [56,59,64]. Nevertheless, even in these contexts, the mechanisms linking neural processes to architectural outcomes often remain inferential rather than directly demonstrated. Thus, practical effectiveness should not be conflated with neuroscientific explanatory precision.

Recent developments extending neuroarchitecture beyond individual buildings into urban environments, adaptive systems, and digitally mediated spaces illustrate the field's growing conceptual maturity [58,76]. However, expanding the scale of analysis also increases methodological complexity, since urban environments involve layered social, environmental, and infrastructural systems that complicate causal modelling.

Neuroscience-informed architecture remains a productive but methodologically unresolved interdisciplinary field. Its greatest contribution lies in foregrounding cognition, emotion, embodiment, and environmental interaction as central dimensions of architectural experience [9,75]. At the same time, important challenges concerning empirical validity and ecological realism persist. Future progress depends on improving methodological transparency, developing ecologically grounded experimental designs, and maintaining theoretical precision in interpreting neuroscientific evidence [71,77]. Without such developments, neuroscience risks functioning more as a legitimising discourse for architecture than as a genuinely transformative scientific framework.

As summarised in Table 4, the development of neuroscience-informed architecture emerged through the convergence of multiple intellectual traditions, ranging from early scientific foundations and environmental psychology to embodied cognition, institutional developments, and contemporary methodological debates. Together, these themes provide the conceptual framework underpinning the present review.

One of the most important findings emerging from the present review is the persistent tension between scientific control and ecological validity in neuroscience-informed architectural research. Experimental approaches based on functional magnetic resonance imaging and electroencephalography offer high levels of methodological precision and causal inference but often simplify the multisensory, embodied, socially situated, and temporally dynamic nature of architectural experience. Conversely, recent developments in behavioural mapping, virtual reality, physiological monitoring, and mobile sensing

technologies offer greater ecological realism while sacrificing some experimental control and causal specificity. Rather than representing competing paradigms, these approaches should be regarded as complementary and potentially convergent. Bridging this tension is one of the principal methodological challenges and future research priorities for neuroarchitecture, highlighting the need for ecologically grounded yet scientifically rigorous models that connect laboratory findings with real-world architectural experience.

Table 4. Conceptual evolution, institutional turning points, and methodological challenges in neuroscience-informed architectural research.

Theme	Focus	Key Contribution	Representative References
Architectural environments and human existence	Architecture as an active system shaping human perception, behaviour, memory, and social organisation	Establishes architecture as an active participant in human–environment relations	Ingold [1]; Malafouris [2]
Multidimensional nature of architectural experience	Material, symbolic, sensory, emotional, and cultural dimensions of architectural environments	Defines architecture as a holistic and embodied experiential system	Pallasmaa [5]; Zumthor [8]
Early scientific foundations	Emergence of experimental psychology and physiology in the nineteenth century	Establishes the scientific basis for studying perception and environmental experience	Helmholtz [15]; Wundt [16]
Environmental psychology	User–environment interaction and behavioural responses to built environments	Provides the interdisciplinary foundation for architecture–human interaction studies	Proshansky et al. [17]; Gifford [12]
Neuroscientific developments after the 1970s	Brain-imaging technologies and the expansion of cognitive neuroscience	Enables direct investigation of neural mechanisms underlying spatial perception and emotion	Posner and Raichle [24]; Raichle [25]
Phenomenology and embodied cognition	Body–mind–environment interaction in human experience	Introduces embodied and enactive models of architectural experience	Merleau-Ponty [26]; Varela et al. [27]
Institutional emergence of neuroarchitecture	Establishment of the Academy of Neuroscience for Architecture in 2003	Marks the institutional legitimisation of neuroscience-informed architecture	Eberhard [53]; Jarmusch [54]
Expansion of ANFA-related scholarship	Growth of empirical and theoretical studies in healthcare, education, emotion, empathy, and evidence-based design	Demonstrates the disciplinary expansion of neuroarchitecture	Robinson and Pallasmaa [9]; Sussman and Hollander [31]
Methodological challenges and ecological validity	Translation problems between laboratory findings and real architectural environments	Identifies unresolved challenges in applying neuroscience to architecture	Pallasmaa [5]; Friston [71]

4.2. Translational and Clinical Implications for Neuroscience-Informed Design

One of the most significant contributions of neuroscience-informed architectural research is its potential for practical applications, especially in contexts where environmental conditions directly impact cognitive, emotional, and behavioural outcomes. While early literature on neuroarchitecture primarily focused on conceptual and theoretical frameworks, the gradual inclusion of empirical research has increasingly shown that architectural environments can actively influence human well-being, stress regulation, orientation, and behaviour adaptation.

This practical application is particularly evident in healthcare architecture, where factors such as spatial clarity, sensory cues, lighting conditions, material familiarity, and environmental organisation are linked to measurable improvements in behavioural stability, emotional comfort, and cognitive functioning. For instance, studies on Alzheimer’s care environments have demonstrated that supportive spatial configurations can reduce confusion, agitation, and disorientation while enhancing environmental engagement and behavioural regulation [56,64]. These findings indicate that neuroscience-informed design can enhance clinical settings not just through aesthetic improvements but by creating environmentally supportive structures.

Beyond dementia care, neuroscience-informed design has wider implications for therapeutic and inclusive architectural practices. Regulating environmental stress, promoting emotional recovery, and managing cognitive load are increasingly recognised as essential aspects of architectural performance, particularly in hospitals, rehabilitation centres, educational environments, and adaptive care facilities. Eberhard [29] posited that understanding how neural responses relate to environmental variables provides architects with a more evidence-based approach for designing spaces that foster psychological well-being and behavioural comfort. Safavi et al. [59] showed that incorporating neurocognitive, climatic, and behavioural data into architectural behavioural mapping can enhance decision-making for adaptive, inclusive, and user-sensitive design practices.

To synthesise these diverse applications and clarify their translational relevance, a qualitative translational synthesis matrix was developed linking major neuroscientific domains with architectural interventions and their potential implications for health and well-being (Table 5). Rather than implying deterministic relationships between neural mechanisms and environmental outcomes, the matrix highlights evidence-based associations that support human-centred and therapeutically responsive design strategies.

Table 5. Qualitative translational synthesis matrix linking neuroscientific domains, brain-related processes, architectural applications, and potential clinical or design relevance.

Neuroscientific Domain	Brain-Related Process	Architectural Application	Translational Relevance
Spatial cognition	Hippocampal navigation	Wayfinding and legibility	Dementia care
Emotion and stress	Limbic regulation	Healing environments	Anxiety and stress reduction
Memory	Contextual memory	Familiar settings	Alzheimer's care
Embodied cognition	Sensorimotor integration	Multisensory design	Rehabilitation
Attention	Cognitive load	Educational environments	Learning performance
Circadian regulation	Light-sensitive pathways	Daylight design	Sleep quality
Social cognition	Mirror-neuron systems	Empathic and inclusive spaces	Mental well-being

As summarised conceptually in Table 5 (illustrating the relationships between major neuroscientific domains, brain-related processes, architectural applications, and potential clinical or design relevance), neuroscience-informed architecture extends beyond theoretical discussion and offers practical implications for healthcare environments, rehabilitation settings, educational spaces, and inclusive design.

However, the practical application of neuroscience in architecture still faces methodological and epistemological limitations. Although clinical and therapeutic applications provide strong justification for neuroscience-informed design, the causal relationship between neural mechanisms and environmental outcomes often remains indirect and inferential. Architectural interventions cannot easily be reduced to isolated variables, and real-world clinical settings involve complex social, emotional, and behavioural dynamics that extend beyond laboratory conditions [5,9]. Therefore, the future development of neuroarchitecture relies not only on enhancing empirical rigour but also on creating ecologically valid and context-sensitive research models that connect neuroscientific evidence with the complex realities of architectural environments. The clinical relevance of neuroscience-informed architecture lies not in deterministic predictions but in strengthening evidence-based design as an adaptable and human-centred architectural practice.

5. Conclusions

This review demonstrates that integrating neuroscience into architecture represents a major interdisciplinary transformation in contemporary architectural theory and research. Although the scientific foundations of this integration emerged during the rapid expansion of cognitive neuroscience, neuroimaging, and embodied cognition after the 1970s, its institutional and conceptual consolidation became particularly visible after the early 2000s, with the establishment of the Academy of Neuroscience for Architecture (ANFA). ANFA represented one of the principal institutional platforms contributing to the formalisation of the dialogue between architecture and neuroscience and to the translation of neuroscientific knowledge into architectural education, theory, and professional practice. Through this process, architectural environments increasingly came to be understood not as passive physical settings but as active cognitive, emotional, and behavioural systems.

The reviewed literature demonstrates that neuroscience-informed architecture has substantially expanded architectural inquiry by linking environmental design with neurocognitive processes such as perception, memory, emotional regulation, and behavioural adaptation. These advances have been particularly influential in applied domains including healthcare architecture, therapeutic environments, and dementia care. At the same time, conceptual developments in embodied cognition and multisensory perception have reinforced the view that architectural experience emerges through dynamic interactions among brain, body, and environment. Collectively, these developments have strengthened interdisciplinary connections between architecture, neuroscience, environmental psychology, and phenomenological approaches to human experience and have contributed to the emergence of more human-centred and evidence-based design perspectives.

Neuroscience-informed architecture remains methodologically unresolved. Despite important advances in neuroimaging, electrophysiological measurement, behavioural mapping, virtual reality, and mobile sensing, significant challenges remain concerning ecological validity, empirical generalisability, and translational applicability. Real architectural environments involve multisensory complexity, bodily movement, social interaction, and temporal continuity that remain difficult to reproduce under controlled laboratory conditions. Bridging the tension between scientific control and ecological validity therefore represents one of the field's principal methodological challenges and remains essential for the development of clinically relevant and therapeutically effective design interventions.

The ANFA case demonstrates both the productive potential and the structural limitations of interdisciplinary integration between neuroscience and architecture. Its most important contribution lies in establishing an evidence-based, translational framework for designing architectural environments that support cognitive health, emotional regulation, stress reduction, behavioural comfort, and therapeutic recovery. As neuroscience-informed architecture continues to expand across healthcare systems, rehabilitation environments, adaptive design, and broader environmental settings, its future development will depend not only on strengthening methodological transparency, ecological validity, and interdisciplinary precision but also on fostering closer collaboration between architectural researchers, clinical and cognitive neuroscience communities, and healthcare institutions. In parallel, the field's continued maturation will require educational innovations that integrate foundational knowledge of cognition, perception, and brain–environment interactions into architectural curricula. Rather than functioning as a deterministic explanatory model, neuroarchitecture should be understood as an evolving translational framework that demands stronger institutional, educational, and clinical connections to develop more human-centred, cognitively supportive, and therapeutically responsive architectural environments.

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