link to SP2026 IDNE 702 game plan: https://mbolding.github.io/built_environment/IDNE702_SP2026.html

Plan for the JC
Before each class, review the assigned reading and be prepared to engage in an discussion during our next class meetin...

I. Introduction to Neuroarchitecture
A. Defining the Field · Neuroarchitecture is an interdisciplinary field at the juncture of neuroscience, architecture, and ps...

II. Foundational Concepts and Seminal Works (Precursors and Early Formulations)
The intellectual foundations of neuroarchitecture were laid long before the term itself was coined, drawing from early psy...

III. Core Theoretical Frameworks in Neuroarchitecture
Neuroarchitecture draws upon several key theoretical frameworks that provide conceptual lenses for understanding the i...

IV. Key Thought Leaders and Their Definitive Contributions
The field of neuroarchitecture has been shaped by a diverse group of thinkers and researchers from neuroscience, archit...

V. Comprehensive Reviews and Syntheses of the Field
Review articles, systematic reviews, and meta-analyses play a crucial role in any scientific discipline, particularly in an e...

VI. Examining Rigor, Critiques, and Future Directions
A hallmark of a maturing scientific field is its capacity for self-reflection, critical assessment of its methodologies and cla...

VII. Key Organizations and Journals
The development and dissemination of knowledge in neuroarchitecture are significantly supported by dedicated organiz...

VIII. Conclusion
A. Recap of the Essential Literature Landscape · This exploration of essential readings in neuroarchitecture has charted a...

IX. Annotated Bibliography
This annotated bibliography provides a curated list of essential readings in neuroarchitecture, categorized to reflect the...

Works cited
Neuroarchitecture: How the Perception of Our Surroundings Impacts the Brain - PMC · The Science of Design: How Neur...

Additional material

Limitations and Gaps
This bibliography is being written by someone from outside the field and likely has large gaps and misconceptions. It is c...

Wayfinding
Arthur, P.and Passini, R. (1992), Wayfinding: People, Signs, and Architecture McGraw-Hill. Reissued as a collector's editi...

Environmental Psychology
Environmental psychology is an established interdisciplinary field that investigates the complex and reciprocal relationshi...

↑ An Annotated Bibliography of Neuroarchitecture: Foundational Works, Key Theories, Leading Thinkers, and Critical Perspectives

Before each class, review the assigned reading and be prepared to engage in an discussion during our next class meeting. Readings are marked with 📖 emojis. **Specifics about the readings are in the associated comment.**

Some readings are linked, also see a google drive folder with readings that may be hard to find online: https://drive.google.com/drive/folders/1Z5zPwn3Swwr5L2C0rKqfv574A83IOdq9

The discussion will be structured as followed:

Individual

1. **Summary of the Reading**: Provide a concise summary of the key points and themes presented in the reading material.
2. **Analysis of Theoretical Framework**: Examine and discuss the theoretical framework that the reading either presents or is embedded within. Consider its foundational concepts and how it relates to the broader field of neuroarchitecture.

Group

3. **Formulation of a Hypothesis**: Based on the theoretical framework discussed, develop a testable hypothesis. Ensure that it is clear, specific, and capable of empirical investigation.
4. **Design of an Experiment**: Propose an experimental design that could effectively test the formulated hypothesis. Describe the methodology, including variables, controls, and procedures, to ensure the experiment is robust.

5. **Prediction and Interpretation of Outcomes**: Anticipate possible outcomes of the experiment and discuss how these outcomes might be interpreted in the context of the underlying theory. Consider whether certain expected results would provide strong or weak evidence supporting or refuting the hypothesis. And **Consideration of Alternative Outcomes**: Discuss possible alternative outcomes and their implications. Reflect on how these might challenge or refine the theoretical framework or suggest new directions for research.

Your thorough preparation and active participation will contribute to a rich and insightful discussion. I will randomly call on students to lead each of the discussion stages above.

Note

Critically examining the theory of neuroarchitecture is useful for neuroengineers, as it provides a foundational understanding necessary for designing spaces and technologies that optimize cognitive and emotional well-being. This theory, which investigates the interaction between the brain and physical environments, informs the design of spaces as diverse as hospitals and virtual reality settings. By scrutinizing this theory, neuroengineers can innovate by challenging traditional assumptions, ultimately developing more effective technologies such as neuroprosthetics and brain-computer interfaces. Additionally, understanding how environments affect neural function helps in creating intuitive technologies that alleviate cognitive load, enhancing user experiences.

Moreover, critically examining neuroarchitecture ensures that interventions are evidence-based and ethically sound, respecting human neural diversity and avoiding adverse psychological or neurological impacts. Since neuroarchitecture intersects with disciplines like neuroscience, psychology, and architecture, a thorough understanding facilitates collaboration across these fields, leading to more comprehensive and effective solutions.

Examining theories in adjacent fields is beneficial. It fosters interdisciplinary innovation by introducing new ideas and approaches that enrich a practitioner’s problem-solving toolkit and enhances their capacity for contextual understanding. This exploration not only grounds practices in a broader scientific base, ensuring outcomes are reliable and effective, but also highlights ethical and social considerations that might otherwise be overlooked. It promotes better communication and collaboration among professionals from various disciplines and supports continual professional development by encouraging lifelong learning and adaptability.

It is also easier to criticize someone else's work and then you can reflect on the fact that your own work likely has similar flaws.

A. Defining the Field

Neuroarchitecture is an interdisciplinary field at the juncture of neuroscience, architecture, and psychology. Its primary objective is to investigate and understand how the built environment influences human behavior, shapes emotional states, and impacts cognitive processes.[1] The discipline transcends the traditional architectural concerns of mere functionality and aesthetics, aspiring to create spaces that are also inherently supportive of cognitive functions and emotional well-being.[5] At its core, neuroarchitecture operates on the hypothesis that architectural design choices—ranging from spatial layout and configuration to the use of natural light and color schemes—exert a direct and measurable influence on human neurological and psychological processes. These influences can manifest in enhanced cognitive performance, emotional stability, and the efficiency of spatial navigation. The establishment of a clear and comprehensive definition is particularly vital for neuroarchitecture, given its status as an emerging field. Its inherently interdisciplinary nature means that its boundaries, core tenets, and methodologies require careful articulation to foster coherent research and application. This foundational understanding paves the way for a more nuanced exploration of a diverse and evolving body of literature.

B. Brief Historical Context and Evolution

While the formal discipline of neuroarchitecture has witnessed significant growth and articulation, primarily since the early 2000s, its foundations can be traced to much earlier periods. Architectural theorists and thinkers throughout history have recognized and mused upon the psychological and emotional impact of designed space.[1] A frequently cited historical precedent is the collaborative design of the Salk Institute in the 1960s by Jonas Salk and architect Louis Kahn. Their explicit aim was to create an environment that would be conducive to scientific creativity and profound thought, thereby acknowledging the deep connection between space and cognition.[7] and see section C. Timeline

Salk Institute

The term *neuroarchitecture* itself was notably introduced and popularized by neuroscientist Fred Gage during his address at the American Institute of Architects (AIA) National Convention in 2003. This event, coupled with the establishment of the Academy of Neuroscience for Architecture (ANFA) in the same year, marked a pivotal moment in the formalization and consolidation of the field.[9] This historical trajectory reveals a fascinating "formalization lag": while the intuitive understanding and philosophical exploration of architecture's impact on the mind have a long lineage, the development of a structured, scientifically-oriented discipline is a relatively recent phenomenon. This lag suggests that earlier insights were often more experiential or theoretical, lacking the empirical methodologies that characterize contemporary neuroarchitecture. Understanding this development is crucial for contextualizing the seminal works discussed herein and appreciating the shifting paradigms within the field. Furthermore, the emergence of neuroarchitecture appears to be propelled by dual drivers: significant advancements in neuroscience, such as the advent of functional magnetic resonance imaging (fMRI) in the 1990s which provided tools to study brain responses to architectural stimuli [13], and a pressing practical need to design environments that are healthier, more effective, and conducive to human well-being.[4] This duality is reflected in the literature, which spans from fundamental neuroscience research to applied architectural case studies and evidence-based design principles.

C. The Need for an Essential Reading List

Given neuroarchitecture's interdisciplinary nature, its rapid evolution, and the diverse body of knowledge it draws upon, a curated and contextualized bibliography is a useful roadmap. Such a resource can serve as a critical guide for researchers, students, and practitioners seeking to navigate the complex literary landscape. It helps in identifying foundational contributions, understanding current theoretical debates, recognizing influential figures, and pinpointing areas that warrant further investigation. This bibliography endeavors to provide such an essential reading list, offering a structured pathway into the core literature of neuroarchitecture and facilitating a deeper, more critical engagement with its principles and applications.

The intellectual foundations of neuroarchitecture were laid long before the term itself was coined, drawing from early psychological theories and pioneering research that demonstrated the profound impact of the physical environment on brain and behavior.

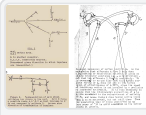
A. Early Perceptual and Environmental Psychology

Early psychological theories, particularly Gestalt psychology as formulated by Max Wertheimer, Kurt Koffka, and Wolfgang Köhler, provided crucial groundwork for understanding how humans perceive and mentally organize visual information within their environment. Principles such as figure-ground relationships, proximity, similarity, and closure, which explain how individuals interpret complex scenes as unified wholes, are fundamental to comprehending the architectural experience.15 These theories, while not "neuroarchitecture" in the modern sense, are foundational to understanding the "neuro" component—specifically, how the brain processes and makes sense of architectural stimuli. They offered initial frameworks for analyzing the perceptual impact of form, space, and composition.

B. The Concept of Enriched Environments

The concept of "enriched environments" (EE) and its impact on brain development and plasticity is a cornerstone in the history of neuroarchitecture, providing early empirical evidence for the environment-brain link.

Donald O. Hebb's work was pivotal in this domain. His early observations and subsequent theoretical formulations highlighted the influence of environmental complexity on cognitive development.

- Hebb, D. O. (1947). “The Effects of Early Experience on Problem-Solving at Maturity.” American Psychologist, 2, 306–307. This brief but highly significant report documented Hebb's serendipitous finding that rats raised as pets in his home—an environment considerably more complex and stimulating than standard laboratory cages—demonstrated superior problem-solving abilities compared to their lab-reared counterparts. This observation is widely considered the genesis of EE research.
- 📖 Hebb, D. O. (1949). The Organization of Behavior: A Neuropsychological Theory. New York: Wiley. This landmark book provided a comprehensive theoretical framework explaining how environmental experiences could lead to lasting changes in neural organization and synaptic efficacy (the "Hebbian synapse"). It laid the groundwork for understanding the mechanisms by which enriched environments could influence brain structure and, consequently, behavior.
    - 
      Donald O. Hebb and the Organization of Behavior: 17 years in the writing - Molecular Br...
      The Organization of Behavior has played a significant part in the development of behavioural neurosc...
      Author **Brown, Richard E.**

An "enriched" environment for rodents

Building upon Hebb's insights, Marian Diamond's research provided compelling anatomical evidence for brain plasticity in response to environmental enrichment. Her work challenged the prevailing dogma of a static, unchangeable adult brain.

- 📖 Bennett, E. L., Diamond, M. C., Krech, D., & Rosenzweig, M. R. (1964). "Chemical and anatomical plasticity of the brain." Science, 146(3644), 610–619. This seminal paper is a cornerstone of neuroplasticity research. Diamond and her colleagues demonstrated tangible neuroanatomical changes, such as increased cortical thickness and altered neurochemistry, in the brains of rats exposed to enriched environments compared to those in impoverished conditions. These findings provided concrete evidence that the physical environment could sculpt the brain.
- Diamond, M. C. (1988). Enriching Heredity: The Impact of the Environment on the Anatomy of the Brain. New York: The Free Press. This influential book summarized Diamond's extensive research on enriched environments, detailing the structural changes observed in the brain and discussing their implications for development and learning. It popularized the idea that an engaging environment is crucial for optimal brain development.

The work on enriched environments, primarily conducted using animal models, was fundamental in scientifically demonstrating that the physical environment is not a passive backdrop but an active agent capable of altering brain structure and function.[16] This principle is central to the very premise of neuroarchitecture. The reliance on animal models in this foundational research, however, underscores a translational challenge that neuroarchitecture continues to grapple with: how to ethically and effectively extrapolate findings from controlled animal experiments to the complexities of human experience in diverse and dynamic built environments. This challenge is often highlighted in critiques of the field.[16] Nevertheless, Marian Diamond's work, in particular, helped to popularize the concept of "use it or lose it" in relation to brain plasticity, emphasizing that mental stimulation and an engaging environment are vital for maintaining brain health throughout life.[20] This accessible principle likely contributed to a broader acceptance of neuroplasticity and, by extension, the notion that architecture could actively shape the brain.

C. Early Calls for Integrating Neuroscience and Architecture

Even before the formal emergence of neuroarchitecture, some visionary architects recognized the potential for a deeper engagement with the biological sciences to inform design. Richard Neutra's influential book Survival through Design (1954) stands out as a prescient call for such integration.

- 📖 Neutra, R. (1954). Survival through Design. Oxford University Press. In this work, Neutra explicitly advocated for the incorporation of physiological and neurological knowledge into the architectural design process. He argued that buildings should be designed to support the biological and neurological needs of their occupants, promoting health and well-being.

Neutra's call in 1954 is significant as it represents a direct appeal from a prominent architect to bridge the gap with the life sciences, decades before neuroarchitecture became a formally recognized field. The considerable time lag between such early calls and the eventual formalized effort in the early 2000s (with figures like Fred Gage and the establishment of ANFA) suggests the existence of substantial historical barriers to interdisciplinary collaboration. These barriers may have included differing methodologies, distinct disciplinary languages, or institutional structures that did not readily support such cross-pollination of ideas. Understanding these historical impediments can offer valuable lessons for contemporary efforts aimed at strengthening the vital interdisciplinary connections that underpin neuroarchitecture.

↑ An Annotated Bibliography of Neuroarchitecture: Foundational Works, Key Theories, Leading Thinkers, and Critical Perspectives

Neuroarchitecture draws upon several key theoretical frameworks that provide conceptual lenses for understanding the intricate relationship between humans and their built surroundings. These theories often bridge evolutionary perspectives with phenomenological and empirical observations.

A. The Biophilia Hypothesis

Proposed by the renowned biologist Edward O. Wilson, the Biophilia Hypothesis posits an innate human tendency to connect with nature and other living systems. This affiliation is thought to be a product of human evolution, deeply rooted in our ancestral past where survival was intricately linked to understanding and interacting with the natural world.

- 📖 Wilson, E. O. (1984). Biophilia. Harvard University Press. This is the seminal text where Wilson articulates the Biophilia Hypothesis, exploring its evolutionary origins and its profound implications for human well-being and conservation.

Gardens at the Bay, Singapore

For neuroarchitecture, the Biophilia Hypothesis provides a robust theoretical basis for biophilic design—an approach that emphasizes the integration of natural elements, patterns, and processes into the built environment. This includes the incorporation of natural light, views of nature, vegetation, water features, and natural materials, all aimed at enhancing psychological well-being, reducing stress, and improving cognitive function.

B. Prospect-Refuge Theory

Developed by the geographer Jay Appleton, Prospect-Refuge Theory suggests that human aesthetic preferences for landscapes are influenced by an innate desire for environments that simultaneously offer opportunities for unimpeded views (prospect) and places of safety or concealment (refuge).[13]

- Appleton, J. (1975). The Experience of Landscape. London: John Wiley. This is the original and comprehensive publication outlining the theory, drawing on observations of landscapes and art. An earlier, concise version appeared as: Appleton, J. (1975). The experience of Landscape. Landscape Research, 1(10), 15–16.28


The theory posits that this preference is rooted in evolutionary survival needs: the ability to see without being seen conferred a significant advantage in terms of detecting prey and avoiding predators.[13] In architectural terms, Prospect-Refuge Theory influences the design of spaces that provide a sense of security, control, and comfort by balancing open vistas with sheltered areas. Examples include elevated viewpoints, protected balconies, or interior spaces with large windows overlooking an expanse, combined with more enclosed, intimate zones.

C. Stress Reduction Theory (SRT)

Pioneered by environmental psychologist Roger S. Ulrich, Stress Reduction Theory (SRT) proposes that exposure to natural environments, or even views of nature, can lead to significant reductions in stress and promote physiological and psychological restoration.[13] SRT builds upon evolutionary concepts, suggesting that humans are genetically predisposed to respond positively to non-threatening natural settings.

- Ulrich, R. S. (1983). Aesthetic and affective response to natural environment. In I. Altman & J. Wohlwill (Eds.), Human behavior and environment, Vol. 6: Behavior and natural environment (pp. 85-125). New York: Plenum. This chapter provides a foundational theoretical exposition for SRT, linking aesthetic responses to nature with affective changes.
- 📖 Ulrich, R. S. (1984). "View through a window may influence recovery from surgery." Science, 224(4647), 420-421.15 This highly influential and frequently cited empirical study demonstrated that post-surgical patients with window views of trees recovered faster, required less pain medication, and had fewer negative comments from nurses compared to patients with views of a brick wall. This paper provided strong early evidence for the therapeutic effects of nature in healthcare settings.
  General Comprehension: · What was the main purpose of this study? · What were the two main groups of patients compar...
- Ulrich, R. S., Simons, R. F., Losito, B. D., Fiorito, E., Miles, M. A., & Zelson, M. (1991). "Stress recovery during exposure to natural and urban environments." Journal of Environmental Psychology, 11(3), 201-230. This key paper used psychophysiological measures (e.g., heart rate, muscle tension, skin conductance) to compare stress recovery rates in individuals exposed to slides of natural versus urban environments, finding significantly faster and more complete recovery with nature scenes.

who installs those AC units??

SRT provides robust empirical support for the principles of biophilic design and has been particularly influential in the field of evidence-based design for healthcare facilities. It underscores the measurable physiological and psychological benefits of incorporating nature and nature views into built environments.

D. Embodied Cognition and Architectural Experience

The framework of embodied cognition posits that human thought and perception are not solely products of an abstract mind but are deeply shaped by the body's physical interactions with the environment.[15] Within neuroarchitecture, this means that architectural spaces are not just passively observed visual stimuli but are actively experienced through our entire sensory-motor system. Our understanding and feeling of a space are constructed through movement, touch, and the overall felt sense of our bodies within that space.[8]

A key concept within this framework is the role of mirror neurons. These neurons, which fire both when an individual performs an action and when they observe another performing that same action, are thought to be crucial for empathy, imitation, and understanding the intentions of others. In an architectural context, it is hypothesized that mirror neuron systems contribute to our empathetic responses to spaces, allowing us to "feel" the qualities of a room or building as if they were extensions of our own bodily states.[1]

Leading thinkers who have significantly contributed to the understanding of embodied cognition in architecture include:

- Juhani Pallasmaa: A Finnish architect and theorist, Pallasmaa has consistently emphasized the multi-sensory nature of architectural experience and the profound role of the body in perception. He critiques the dominance of vision in modern architecture, advocating for designs that engage all senses and acknowledge our embodied existence. His influential book, The Eyes of the Skin: Architecture and the Senses, articulates these ideas, though its full bibliographic details are not consistently provided across all source materials, his extensive authorship of over thirty books is noted.[31] A significant collaborative work is:
    - Robinson, S., & Pallasmaa, J. (Eds.). (2015). Mind in Architecture: Neuroscience, Embodiment, and the Future of Design. MIT Press this edited volume brings together leading voices to explore the intersections of neuroscience, embodiment, and architecture.
- Harry Francis Mallgrave: An architectural historian and theorist, Mallgrave has extensively researched and written about the biological and neurological underpinnings of architectural experience, with a strong focus on embodiment and emotion.
    - Mallgrave, H. F. (2013). Architecture and Embodiment: The Implications of the New Sciences and Humanities for Design. Routledge. Here, Mallgrave argues for a shift away from object-focused design towards an architecture centered on the embodied experience of its inhabitants, drawing on insights from neuroscience, psychology, and biology.
    - Mallgrave, H. F. (2010). The Architect's Brain: Neuroscience, Creativity, and Architecture. John Wiley & Sons. This book delves into the relationship between neuroscience and architectural thought, exploring how brain processes relate to creativity and the experience of designed environments.
- Sarah Williams Goldhagen: An architecture critic and scholar, Goldhagen champions the importance of embodied cognition and evidence from cognitive psychology and neuroscience in understanding how the built environment shapes our feelings, memories, and well-being. Her analysis of Louis Kahn's Salk Institute through the lens of embodied cognition is particularly noteworthy.[8]
    - Goldhagen, S. W. (2001). Louis Kahn's Situated Modernism. Yale University Press. While focused on Kahn, this work lays groundwork for her later explorations of experiential aspects of architecture.
    - Goldhagen, S. W. (2017). Welcome to Your World: How the Built Environment Shapes Our Lives. HarperCollins. This book makes a strong case for a new, experience-focused approach to architecture and urbanism, grounded in contemporary cognitive science.

The embodied cognition framework offers a powerful lens for understanding that architecture is far more than a visual art; it is a holistic experience that deeply engages our entire being. This has profound implications for designing spaces that consider movement, haptic sensations, and the overall "felt" quality of the environment.

E. The Role of Place and Healing Environments (Esther Sternberg)

Esther Sternberg, a physician and researcher specializing in neuroimmunology, has made significant contributions to understanding the science of how physical places can impact stress, healing, and overall well-being. Her work effectively bridges immunology, neuroscience, and environmental psychology, providing a scientific basis for the concept of "healing environments". 9 Sternberg's research explores how sensory experiences within a place—sights, sounds, smells, and spatial qualities—can trigger physiological responses that affect the brain and the immune system, essentially tapping into the "brain's internal pharmacies" to promote health. 40

- Sternberg, E. M. (2000). The Balance Within: The Science Connecting Health and Emotions. W.H. Freeman. This book explores the intricate connections between the brain, emotions, and the immune system, laying the groundwork for understanding how external environments can influence these internal states.
- Sternberg, E. M. (2009). Healing Spaces: The Science of Place and Well-Being. Harvard University Press. This seminal work is arguably her most direct contribution to the discourse relevant to neuroarchitecture. It details the scientific evidence demonstrating how various aspects of the physical environment—from views of nature in hospitals to the design of cities and contemplative gardens—can reduce stress, enhance immune function, and promote healing.
- 📖 Altaf Engineer, Esther M. Sternberg, Aletheia Ida. Healing Spaces: Designing Physical Environments to Optimize Health, Wellbeing and Performance (2020) This is a reprint of articles from the special issue published online in the open access journal *International Journal of Environmental Research and Public Health* a real mix of quality.
    -  **article summary**
      Significance · This framework represents an innovative approach to dementia care that goes beyond traditional...
- Sternberg, E. M. (2023). Well at Work: Creating Wellbeing in Any Workspace. Little, Brown Spark. This more recent work extends her insights into the design of workplaces to foster well-being and productivity.

Sternberg's research provides a compelling scientific rationale for designing environments that actively support healing and reduce stress, with particular relevance for healthcare architecture but also extending to workplaces, homes, and urban settings. Her work has been highly influential in the evidence-based design movement.

The convergence of evolutionary psychology (evident in Biophilia and Prospect-Refuge) and phenomenological/experiential aspects (central to Embodied Cognition and Sternberg's work on the felt sense of place) is a notable characteristic of these core theories. This suggests that neuroarchitecture strives to bridge deep-seated biological predispositions with immediate, subjective human experience. A significant number of these foundational theories—Biophilia, SRT, and elements within Prospect-Refuge and Healing Spaces—place a strong emphasis on the positive impact of natural elements or views of nature.[13] While this "nature dominance" has provided a wealth of actionable design principles, particularly in biophilic design, it also highlights a potential area for further development within neuroarchitecture: exploring a broader range of architectural strategies for well-being in purely urban or artificial contexts that may lack direct connections to nature. Furthermore, there's a discernible trajectory from more conceptual theories (like early articulations of Biophilia or Prospect-Refuge) towards frameworks that are more directly testable and linked to measurable physiological and psychological outcomes, such as SRT and aspects of Embodied Cognition investigated using neuroimaging techniques.[8] This evolution reflects the broader scientific maturation of the field, characterized by an increasing demand for empirical validation of its core tenets.

↑ III. Core Theoretical Frameworks in Neuroarchitecture

General Comprehension:

- What was the main purpose of this study?
- What were the two main groups of patients compared in this study?
- What type of surgery did all the patients in the study undergo?

Specific Details & Methodology:

- What specific criteria were used to match patients between the two groups?
- What were the key outcome measures examined in the study (e.g., how did they measure recovery)?
- How was the classification of analgesic strength (weak, moderate, strong) determined?

Results & Interpretation:

- What was the most significant finding regarding analgesic use between the two groups?
- Were there any differences in the use of anti-anxiety drugs between the groups? Why or why not?
- What did the nurses' notes indicate about the patients in each group?

Critical Thinking/Discussion:

- Do you think the findings of this study are convincing? Why or why not?
- If you were designing a follow-up study, what changes or additions would you make?

Significance

This framework represents an innovative approach to dementia care that goes beyond traditional music therapy by creating continuous, supportive acoustic environments tailored to residents' cognitive abilities and daily routines.

Main Focus

The paper addresses how to design supportive sonic environments for people with dementia in nursing homes, recognizing that sound plays a crucial role in how these residents perceive and interact with their surroundings.

Key Concepts

The Problem

- People with dementia often rely more on sound than vision due to higher prevalence of visual impairments
- They experience various auditory processing issues including:
  - Impaired perception of sound features
  - Difficulty recognizing sounds
  - Problems perceiving auditory scenes in noisy environments
  - Auditory hallucinations
  - Abnormal responses to sound (either aversion or excessive craving)

Proposed Framework

The authors propose adding carefully designed acoustic stimuli to existing soundscapes to achieve three main effects:

1. **Mood Changers**
   - Use sounds to influence valence (positive/negative feelings) and arousal levels
   - Examples: Morning bird sounds to increase arousal, low-frequency sounds to calm
   - Must use simple, easily predictable sounds due to cognitive limitations
2. **Safety Enhancers**
   - Provide temporal and spatial orientation (e.g., church bells marking hours)
   - Confirm presence of others through distant, repeating sounds
   - Use clear, high-fidelity sounds that are easily recognized
3. **Response Triggers**
   - Employ sounds that evoke automatic responses or behaviors

- Examples: Kitchen sounds signaling mealtime
- Build on life-long learned associations between sounds and activities

Implementation

- Sounds should be scheduled throughout the day according to residents' needs and activities
- Different personas (based on cognitive abilities) require different approaches
- Continuous 24/7 deployment is recommended to maintain familiarity
- Staff involvement in design and monitoring is crucial

Key Findings from Pilot Studies

- Soundscapes were generally experienced positively by healthcare professionals
- They helped with orientation and improved atmosphere
- Some habituation occurred but wasn't necessarily negative
- Specific sounds used included birdsong, church bells, cafeteria sounds, and heartbeats

↑ An Annotated Bibliography of Neuroarchitecture: Foundational Works, Key Theories, Leading Thinkers, and Critical Perspectives

The field of neuroarchitecture has been shaped by a diverse group of thinkers and researchers from neuroscience, architecture, psychology, and related disciplines. Their contributions have been pivotal in defining the field, establishing its theoretical underpinnings, developing research methodologies, and advocating for its application.

A. Jonas Salk

While primarily known as the developer of the polio vaccine, Jonas Salk's vision for the Salk Institute for Biological Studies in La Jolla, California, designed in collaboration with architect Louis Kahn, serves as an enduring and inspirational case study for neuroarchitecture.[7] Salk envisioned a facility that would not only be functional for scientific research but would also be a place of profound beauty and inspiration, capable of fostering creativity and deep thought among its inhabitants. His own reported experience of a creative breakthrough while visiting the Basilica of San Francesco d'Assisi in Italy underscored his belief in the power of the architectural environment to influence cognitive processes.[8] The Salk Institute, with its carefully considered spaces, materials, and relationship to the surrounding landscape and ocean, stands as an early, iconic example of architecture designed with deep consideration for human experience and intellectual endeavor, aligning closely with the core goals of neuroarchitecture. Salk's role was that of a catalyst, posing fundamental questions about the environment-mind connection that resonated deeply within both scientific and architectural communities.

B. Fred Gage

A prominent neuroscientist at the Salk Institute, Fred Gage is widely credited with coining the term "neuroarchitecture" during his influential address at the 2003 AIA National Convention.[9] He was also a key figure in the founding of the Academy of Neuroscience for Architecture (ANFA). Gage's fundamental assertion, often quoted, is that "changes in the environment change the brain, and therefore they change our behavior".[1] This statement encapsulates a core tenet of neuroarchitecture. While his primary research focuses on neurogenesis (the birth of new neurons) and brain plasticity, this work provides the essential scientific foundation for his claims about the environment's capacity to induce neural changes.

- Gage, F. H. (2003). AIA 2003 National Conference. San Diego, CA. (Referenced in [16] as the venue where he presented his influential ideas).

C. John P. Eberhard

John P. Eberhard was the founding president of ANFA and a crucial early advocate for bridging the disciplines of neuroscience and architecture.11 As a Latrobe Fellow of the AIA College of Fellows, he authored several early and influential books that aimed to create a knowledge base for architects grounded in neuroscientific findings.4 His work was instrumental in translating complex neuroscience concepts into a language accessible and relevant to architects.

- Eberhard, J. P. (2007). Architecture and the Brain: A New Knowledge Base from Neuroscience. Greenway Communications LLC.
- Eberhard, J. P. (2008). Brain Landscape: The Coexistence of Neuroscience and Architecture. Oxford University Press.
- Eberhard, J. P. (2009). Applying Neuroscience to Architecture. Neuron, 62(6), 753-756.

D. Eve Edelstein

Eve Edelstein is a uniquely positioned figure in neuroarchitecture, holding expertise as a neuroscientist, architect, and anthropologist. Her research focuses on the measurable impact of the built environment on human performance, health, and well-being, with a particular emphasis on healthcare design.[9] She has been a pioneer in the application of advanced research methodologies, including Virtual Reality (VR) and Electroencephalography (EEG), to study human responses to architectural settings in controlled yet realistic ways.[53] Edelstein co-founded Clinicians for Design, an organization dedicated to integrating clinical insights into design processes.[51]

- Edelstein, E. A., & Macagno, E. (2012). Form Follows Function: Bridging Neuroscience and Architecture. In S. T. Rassia & P. M. Pardalos (Eds.), Sustainable Environmental Design in Architecture: Impacts on Health (pp. 27-41). Springer.
- Edelstein, E. A. (2008). Building health. HERD: Health Environments Research & Design Journal, 1(2), 54-59.

- Zhang, L., Chi, Y. M., Edelstein, E., Schulze, J. P., & Macagno, E. (2010). Wireless Physiological Monitoring and Ocular Tracking: 3D Calibration in a Fully-Immersive Virtual Health Care Environment. Conference proceedings:... Annual International Conference of the IEEE Engineering in Medicine and Biology Society. IEEE Engineering in Medicine and Biology Society. Conference, 2010, 6519-6523.

E. Ann Sussman

Ann Sussman is an architect and researcher whose work centers on applying insights from cognitive science, biophilia, and human evolutionary biology to architectural and urban design. She is a strong proponent of using biometric tools, such as eye-tracking technology, to gain a deeper understanding of often subconscious human responses to the built environment. 2 She frequently collaborates with Justin B. Hollander.

- Sussman, A., & Hollander, J. B. (2015). Cognitive Architecture: Designing for How We Respond to the Built Environment. Routledge. (1st ed. published 2014/2015, 2nd ed. 2021). This book is a key text that translates findings from cognitive science and neuroscience for design professionals.
- Sussman, A., Lavdas, A. A., & Salingaros, N. A. (2021). Visual Attention Software: A New Tool for Understanding the “Subliminal” Experience of the Built Environment. Applied Sciences, 11(15), 6728.

F. Sarah Robinson

Sarah Robinson is a practicing architect and writer whose work thoughtfully explores the themes of embodiment, phenomenology, and the mind-body connection in the experience of architecture. She is a co-editor of the influential volume Mind in Architecture, which brings together diverse perspectives on these topics.

- Robinson, S., & Pallasmaa, J. (Eds.). (2015). Mind in Architecture: Neuroscience, Embodiment, and the Future of Design. MIT Press.
- Robinson, S. Nesting: Body, Dwelling, Mind. (Mentioned as authored by her in 31, this book likely delves further into her theories on dwelling and embodiment).

G. Other Key Theorists (Cross-Referenced from Section III)

The theorists discussed in Section III are also undeniably key thought leaders whose work is foundational to neuroarchitecture:

- Edward O. Wilson (Biophilia Hypothesis)
- Jay Appleton (Prospect-Refuge Theory)
- Roger S. Ulrich (Stress Reduction Theory)
- Juhani Pallasmaa (Embodied Cognition, Multi-sensory Experience)
- Harry Francis Mallgrave (Architecture and Embodiment, The Architect's Brain)
- Sarah Williams Goldhagen (Embodied Cognition, Experiential Design)
- Esther Sternberg (Healing Spaces, Science of Place and Well-Being)

The development of thought leadership in neuroarchitecture reflects the field's maturation. Early influences often came from those establishing broad conceptual theories (e.g., Wilson, Appleton). This was followed by figures who focused on empirical research and measurable outcomes (e.g., Ulrich, Edelstein with her use of VR/EEG). Concurrently, another stream of leadership emerged from those dedicated to synthesizing complex neuroscientific knowledge and translating it for architectural practice and theory (e.g., Eberhard, Mallgrave, Sussman). This evolution demonstrates a growing sophistication, where leadership now encompasses not only conceptual innovation but also methodological rigor and effective interdisciplinary translation.

Many of these key thought leaders, particularly figures like Gage, Eberhard, and Edelstein, have a deep and symbiotic relationship with the Academy of Neuroscience for Architecture (ANFA). 9 ANFA has served as a critical incubator, platform, and community for these individuals, facilitating the development and dissemination of neuroarchitectural ideas through conferences, publications, and collaborative projects. This indicates that ANFA itself is an active agent in shaping the field's intellectual landscape and its associated literature.

Table 1: Key Thought Leaders in Neuroarchitecture and Their Seminal Contributions

Thought Leader	**Key Contribution(s)/Area of Focus**	**Seminal Publication(s)**
Jonas Salk	Vision for the Salk Institute as an environment fostering creativity; catalytic role in linking environment and cognition.	N/A (Influence primarily through the Salk Institute project and his expressed vision 7)
Fred Gage	Coined "neuroarchitecture"; co-founder of ANFA; emphasized the environment's impact on brain and behavior.	Gage, F. H. (2003). AIA 2003 National Conference. San Diego, CA. (Influential speech 10)
John P. Eberhard	Founding president of ANFA; authored early books bridging neuroscience and architecture.	Eberhard, J. P. (2007). Architecture and the Brain: A New Knowledge Base from Neuroscience. Greenway Communications LLC. 11; Eberhard, J. P. (2008). Brain Landscape: The Coexistence of Neuroscience and Architecture. Oxford University Press. 11
Edward O. Wilson	Biophilia Hypothesis.	Wilson, E. O. (1984). Biophilia. Harvard University Press. 13
Jay Appleton	Prospect-Refuge Theory.	Appleton, J. (1975). The Experience of Landscape. John Wiley. 13

Roger S. Ulrich	Stress Reduction Theory; empirical research on nature's impact on healing and stress.	Ulrich, R. S. (1984). "View through a window may influence recovery from surgery." Science, 224(4647), 420-421. 15; Ulrich, R. S., et al. (1991). "Stress recovery during exposure to natural and urban environments." Journal of Environmental Psychology, 11(3), 201-230. 30
Juhani Pallasmaa	Embodied cognition; multi-sensory experience of architecture; critique of visual dominance.	Pallasmaa, J. The Eyes of the Skin: Architecture and the Senses (Key work, specific edition not consistently cited); Robinson, S., & Pallasmaa, J. (Eds.). (2015). Mind in Architecture. MIT Press. 31
Harry F. Mallgrave	Biological and neurological underpinnings of architectural experience; embodiment.	Mallgrave, H. F. (2010). The Architect's Brain: Neuroscience, Creativity, and Architecture. Wiley. 37; Mallgrave, H. F. (2013). Architecture and Embodiment. Routledge. 32
Sarah W. Goldhagen	Embodied cognition in architecture; how built environments shape lives; use of cognitive science.	Goldhagen, S. W. (2017). Welcome to Your World: How the Built Environment Shapes Our Lives. HarperCollins. 37
Esther Sternberg	Science of place and well-being; healing environments; impact of spaces on stress and immune system.	Sternberg, E. M. (2009). Healing Spaces: The Science of Place and Well-Being. Harvard University Press. 40
Eve Edelstein	Measurable impact of built environment on health/ performance; healthcare design; VR/EEG methodologies.	Edelstein, E. A., & Macagno, E. (2012). Form Follows Function: Bridging Neuroscience and Architecture. In Sustainable Environmental Design in Architecture (pp. 27-41). Springer. 37

Ann Sussman	Cognitive science in architecture; biophilia; biometric tools (eye-tracking) for environmental response.	Sussman, A., & Hollander, J. B. (2015/2021). Cognitive Architecture: Designing for How We Respond to the Built Environment. Routledge. 9
Sarah Robinson	Embodiment; mind-body connection in architecture.	Robinson, S., & Pallasmaa, J. (Eds.). (2015). Mind in Architecture. MIT Press. 31; Robinson, S. Nesting: Body, Dwelling, Mind. (Mentioned in 31)

↑ An Annotated Bibliography of Neuroarchitecture: Foundational Works, Key Theories, Leading Thinkers, and Critical Perspectives

Review articles, systematic reviews, and meta-analyses play a crucial role in any scientific discipline, particularly in an emerging and interdisciplinary field like neuroarchitecture. They synthesize existing knowledge, identify key findings, highlight research gaps, and provide researchers and practitioners with accessible overviews of the current state of the art. The recency and increasing volume of such reviews in neuroarchitecture, mostly appearing from 2020 onwards, suggest that the field is reaching a level of maturity where a substantial body of primary research exists to be synthesized. 1

A. General Overviews of Neuroarchitecture

Several recent reviews offer broad perspectives on the field, its theoretical foundations, methodologies, and applications:

- Abbas, S., Okdeh, N., Roufayel, R., Kovacic, H., Sabatier, J.-M., Fajloun, Z., & Abi Khattar, Z. (2024). Neuroarchitecture: How the Perception of Our Surroundings Impacts the Brain. *Biology*, *13*(4), 220. https://doi.org/10.3390/biology13040220 This comprehensive literature review delves into the relationship between the brain and perceived environments, focusing on the roles of specific brain regions like the Anterior Cingulate Cortex (ACC) and Parahippocampal Place Area (PPA) in processing architectural stimuli. It also discusses mirror neurons, cognitive maps, spatial navigation, and the application of neuroarchitecture in designing learning and healing environments.

- Anna, M. (2025). Mindful Space Design: The Rise of Neuroarchitecture. International Journal of Architecture, Arts and Applications, 11(1), 36-40. https://doi.org/10.11648/j.ijaaa.20251101.14 This review critically examines neuroarchitecture, discussing its key theoretical frameworks (Biophilia Hypothesis, Prospect-Refuge Theory, Stress Reduction Theory), common methodological approaches (fMRI, portable EEGs, MoBI), and current limitations, such as the lack of extensive empirical research and high implementation costs.
- Karakas, T., & Yildiz, D. (2020). Exploring the influence of the built environment on human experience through a neuroscience approach: A systematic review. Frontiers of Architectural Research, 9(1), 236–247. This systematic review provides a valuable overview of how neuroscientific methods are being employed to understand the human experience of the built environment, mapping out common research themes and approaches.
- Higuera-Trujillo, J. L., Llinares, C., & Macagno, E. (2021). The cognitive-emotional design and study of architectural space: A scoping review of neuroarchitecture and its precursor approaches. Sensors, 21(6), 2193. This scoping review offers a broad map of the neuroarchitecture field, tracing its historical antecedents and outlining current methodologies and theoretical underpinnings related to cognitive and emotional design.

B. Reviews on Specific Topics within Neuroarchitecture

As the field matures, reviews are beginning to focus on more specialized sub-topics, reflecting the development of distinct research streams:

- Assem, H. M., Khodeir, L. M., & Fathy, F. (2023). Designing for human wellbeing: The integration of neuroarchitecture in design – A systematic review. Ain Shams Engineering Journal, 14(6), 102102. This review specifically synthesizes research on how neuroarchitectural principles can be applied to design for human well-being.
- Zhong, W., Schröder, T., & Bekkering, J. (2021). Biophilic design in architecture and its contributions to health, well-being, and sustainability: A critical review. Frontiers of Architectural Research, 11(1), 114–141. This paper provides a critical examination of biophilic design, a key application area within neuroarchitecture, assessing its impact on health, well-being, and sustainability.
- Valentine, C. (2024). The Impact of Architectural Form on Physiological Stress: A Systematic Review. Frontiers in Computer Science. This review narrows its focus to the specific relationship between architectural form and physiological stress responses, synthesizing relevant empirical studies.
- Djebbara, Z., Bobadilla-Suarez, S., Chilver, M., & Gramann, K. (2025, preprint). Neuroscientific Insights into the Built Environment: A Systematic Review of Empirical Research on Indoor Environmental Quality, Physiological Dynamics, and Psychological Well-Being in Real-Life Contexts. This systematic review (currently a preprint) examines the impact of Indoor Environmental Quality (IEQ) variables (thermal comfort, air quality, noise, lighting) on physiological and psychological states, with a notable emphasis on the use of Mobile Brain/Body Imaging (MoBI) for data collection in real-world settings.

Many of these reviews highlight the evolving methodological landscape of neuroarchitecture. For instance, the Anna (2025) review discusses fMRI, EEG, and MoBI [13], while the Djebbara et al. (2025 preprint) strongly advocates for the expanded use of MoBI.[61] This focus indicates that methodology is a dynamic and critical area of development and discussion within the field, and reviews serve an important function in disseminating and evaluating these advancing research tools. The thematic specialization seen in some of these reviews is also a sign of a maturing discipline, where distinct sub-areas of research are becoming sufficiently developed to warrant their own comprehensive syntheses.

↑ An Annotated Bibliography of Neuroarchitecture: Foundational Works, Key Theories, Leading Thinkers, and Critical Perspectives

A hallmark of a maturing scientific field is its capacity for self-reflection, critical assessment of its methodologies and claims, and proactive engagement with its limitations and ethical responsibilities. Neuroarchitecture is increasingly demonstrating these characteristics.

A. Methodological Approaches and Their Challenges

Neuroarchitecture employs a diverse toolkit of research methods to investigate the complex interactions between humans and the built environment. Key approaches include:

- Functional Magnetic Resonance Imaging (fMRI): This neuroimaging technique measures brain activity by detecting changes in blood flow. In neuroarchitecture, fMRI is used in controlled laboratory settings to identify neural correlates of responses to specific architectural elements, such as different spatial configurations or visual features.[9] However, its use is limited by the stationary nature of the equipment, high operational costs, and the artificiality of the scanning environment, which may not fully replicate real-world experiences.[64]
- Electroencephalography (EEG): EEG records the electrical activity of the brain via electrodes placed on the scalp. Its relatively lower cost and potential for mobility (mobile EEG) make it attractive for studying brain responses in more naturalistic settings or in conjunction with VR.[3]
- Virtual Reality (VR): VR technology allows researchers to create immersive and highly controllable three-dimensional environments. This enables systematic manipulation of architectural variables (e.g., ceiling height, lighting, materials) to study their impact on perception, cognition, emotion, and behavior.[7]
- Mobile Brain/Body Imaging (MoBI): This approach integrates wearable neuroimaging technologies (like mobile EEG) with motion capture and other physiological sensors to collect data on brain activity and bodily responses as individuals actively move through and interact with real-world environments.[13] MoBI is seen as a promising avenue for overcoming the limitations of lab-based studies.
- Biometric Tools: A range of physiological measures are used, including eye-tracking (to understand visual attention), heart rate variability (HRV), skin conductance (GSR, an indicator of arousal), and hormonal assays (e.g., cortisol levels for stress).[3]

Despite the promise of these methods, their application in neuroarchitecture is not without challenges and critiques:

- Deficiencies in Mobile EEG Research: A significant critical review (Gepshtein et al., 2024, preprint, building on work by Gramann and others) has highlighted severe methodological flaws in a large portion of neurourbanism and neuroarchitecture studies employing mobile EEG.[64] Issues include the use of consumer-grade systems with an insufficient number of electrodes, inadequate reporting of hardware and software parameters, reliance on proprietary "black-box" analysis algorithms, incorrect application of artifact correction techniques like Independent Component Analysis (ICA) with low-density arrays, and insufficient attention to movement artifacts. These deficiencies render the findings of many such studies scientifically questionable and difficult to replicate.
- Gepshtein, S., et al. (2024). Mobile EEG for Neurourbanism Research - What Could Possibly Go Wrong? A Critical Review with Guidelines. bioRxiv (preprint).[64]
- Limitations of Virtual Reality as a Proxy: While VR offers excellent experimental control, questions remain about the direct transferability of findings from virtual architecture (VA) to physical architecture (PA). Research suggests that prolonged exposure to VA might induce unique physiological and psychological effects not captured in short-term proxy studies, due to confounding variables such as incomplete multisensory integration (VA often being primarily visual) and potential disruption of gravitational perception.[66]
- Generalizability Issues: Much neuroarchitecture research, particularly early studies, has relied on small sample sizes or highly controlled laboratory settings, which can limit the generalizability of findings to diverse populations and complex real-world contexts.[22]

The advancement of research technologies in neuroarchitecture presents a "methodological double-edged sword." While tools like VR and MoBI open exciting new avenues for immersive and real-world investigation[13], they simultaneously introduce significant methodological complexities. Their effective and ethical application demands high levels of interdisciplinary expertise to avoid generating flawed or misleading results, as underscored by the critiques of mobile EEG use.[64]

Table 2: Methodological Approaches in Neuroarchitecture Research

Methodology	**Description/ Application in Neuroarchitecture**	**Key Strengths (from research)**	**Key Limitations/ Critiques (from research)**
fMRI	Measures brain activity via blood flow changes; identifies neural correlates of responses to architectural stimuli (e.g., room geometry, aesthetics) in lab settings.[9]	High spatial resolution; good for localizing brain activity.	Expensive; requires stationary subjects; artificial environment; indirect measure of neural activity.[64]

EEG (Mobile & Stationary)	Measures electrical brain activity; mobile EEG allows for in-situ studies of responses to real or simulated environments.[3]	High temporal resolution; relatively inexpensive; mobile capability.	Lower spatial resolution; susceptible to muscle and movement artifacts, especially mobile EEG[64]; significant methodological flaws in many current mobile EEG studies (low electrode count, poor analysis).64
Virtual Reality (VR)	Creates immersive, interactive 3D simulations of architectural spaces for controlled experiments on perception, emotion, and behavior.[7]	High experimental control; allows testing of unbuilt designs; safe exploration of diverse environments.	Potential for cybersickness; questions about ecological validity and transferability to physical spaces; may lack full multisensory richness of PA; long-term VA exposure effects understudied.[66]
MoBI (Mobile Brain/ Body Imaging)	Integrates wearable neuroimaging (e.g., EEG) with motion capture and other physiological sensors to study brain-body-environment interactions in active, real-world behavior.[13]	High ecological validity; allows study of dynamic interactions in natural settings; captures embodied experience.	Complex data integration and analysis; susceptibility to artifacts in uncontrolled environments; still an emerging and developing methodology.[61]
Biometrics (Eye-tracking, HRV, GSR, Hormones)	Measures physiological responses like visual attention, autonomic arousal, and stress levels in response to environmental features.[3]	Objective measures of physiological state; can be used in real-world or lab settings; relatively non-invasive.	Can be influenced by multiple factors beyond architectural stimuli; interpretation requires careful contextualization; data collection can sometimes be obtrusive.

B. Critical Perspectives on Neuroarchitecture

Beyond methodological concerns, broader critiques of neuroarchitecture address its theoretical underpinnings, practical applicability, and scope:

- Empirical Gaps: Despite the field's promise, a comprehensive and robust body of empirical research is still needed to substantiate many of its claims and translate them into widely applicable design guidelines.[22]
- Implementation Costs and Accessibility: The use of advanced materials, cutting-edge technologies, and specialized expertise often required for neuroarchitecturally informed designs can make them expensive. This raises concerns about accessibility, potentially limiting their application to high-budget projects and exacerbating socio-economic disparities in access to health-promoting environments.[22]
- Designing for Diversity: A significant challenge lies in designing spaces that cater to the diverse neurological and psychological needs of varied populations. Human responses to architectural elements are highly individual, influenced by cultural background, personal experiences, age, and neurodiversity (e.g., autism, ADHD). Oversimplification in design can lead to environments that fail to meet these diverse needs.[9]
- Theoretical Narrowness and Risk of Reductionism: Some critics argue that neuroarchitecture, in its focus on measurable neural and physiological responses, may adopt an overly reductionist view of human experience.
- Marta Delgado, in "Beyond Neuroscience in Culture, Research and Design," contends that an exclusive focus on the brain and nervous system can overlook broader cultural values, social equity considerations, and the importance of participatory design processes. She proposes "Conscious Design" as a more holistic framework that integrates neuroscientific insights within a wider socio-cultural and ethical context.[67]
- The concept of "Psyhéarchitecture" similarly suggests that neuroarchitecture's current scope might be too narrow, not fully encompassing the spiritual, philosophical, or deeply symbolic dimensions of architectural experience.[68] This tension between seeking specific, measurable neural correlates and acknowledging the rich, multifaceted nature of human experience in built environments represents one of the "growing pains" of this interdisciplinary field. It highlights the ongoing need to balance rigorous scientific inquiry with a more holistic and humanistic understanding of place and dwelling.
- Risk of Superficial Application ("Neuro-sound-bites"): There is a concern, articulated by figures like Ian Ritchie, that "neuroarchitecture" could devolve into a superficial marketing buzzword, with principles applied superficially rather than through deep, evidence-informed understanding. Ritchie's book, Neuroarchitecture: Designing with the Mind in Mind, advocates for thoughtful application, exemplified by projects like the Sainsbury Wellcome Centre for Neural Circuits and Behaviour, which was meticulously designed based on how workspace affects behavior and collaboration.[14]
- Architecturally Mediated Allostasis and Neurosustainability: A recent theoretical critique by Valentine et al. (2025) posits that much of current neuroarchitecture research has not adequately considered the concept of "architecturally mediated allostatic load"—the chronic physiological stress resulting from prolonged exposure to suboptimal or stress-inducing built environments. They argue that this chronic stress can negatively impact neuroplasticity and "neurosustainability" (the brain's capacity for adaptive change and resilience), potentially contributing to adverse neurocognitive health outcomes.[69] This perspective calls for a greater focus on the long-term neurological consequences of environmental design.

C. Ethical Implications

As neuroarchitecture generates more specific knowledge about how design impacts brain function and well-being, the ethical responsibilities of architects and designers come into sharper focus.

- A paper by Valentine (2024), "Architecture and bioethics: investigating the ethical implications of emerging neuroarchitecture research," directly addresses this, arguing that evidence of neurophysiological impacts (e.g., stress responses to certain spatial configurations or visual patterns) reinforces architects' fundamental ethical duty to "do no harm" to occupants. 60
- This raises complex questions about accountability in building procurement, the potential need for specialist consultants in neuroarchitecture, and the development of auditing or compliance verification processes to ensure designs are genuinely health-supporting.
- Architects often face conflicts between integrating neuroarchitectural insights and other project constraints like budget, timelines, and client aesthetic preferences. The paper highlights the ethical dilemmas inherent in balancing these competing priorities. 60 The explicit theorization and debate around these ethical duties, moving from general research ethics to specific professional responsibilities, indicate that as neuroarchitecture's scientific claims become more robust, so too will the ethical obligations associated with their application in the real world.

D. Emerging Research and Future Trajectories

Neuroarchitecture is a dynamic field with several promising future directions:

- Designing for Neurodiversity: There is a growing emphasis on applying neuroarchitectural principles to create inclusive spaces that cater to the specific sensory and cognitive needs of neurodivergent individuals, including those with Autism Spectrum Disorder (ASD) or Attention-Deficit/Hyperactivity Disorder (ADHD). 22
- Advancements in Methodology: Continued development and refinement of research methods, particularly non-invasive and ecologically valid approaches like MoBI, are expected to yield more nuanced insights into real-world brain-environment interactions. 13
- Integration with AI and Big Data: The potential to leverage artificial intelligence and big data analytics to identify patterns in human responses to environments and inform design decisions is an emerging area. 56
- Long-Term Health Impacts and Neurosustainability: Future research will likely focus more on the cumulative, long-term effects of the built environment on neurological health, including concepts like allostatic load and neurosustainability. 66
- Active Publication Venues: The existence of special issues in established journals, such as the one in Buildings (MDPI) on "Human-Centric Architectural Design: Neuroarchitecture as a New Frontier," signals robust and ongoing research activity. 5
- Recent Impactful Research (2019-2025): Key studies from this period have investigated:
  - The effects of illuminance on memory in students (Castilla et al., 2023). 33
  - The impact of environmental modifications (e.g., enhanced natural light) on behavior in nursing home residents with dementia (Bautrant et al., 2019). 33

- The biological and mental health consequences of artificial light at night (Sanders et al., 2020; Paksarian et al., 2020). 33
- How environmental color modulates autonomic and EEG indices of emotional response (Bower et al., 2022). 33
- The influence of classroom design (traditional vs. active learning) on student satisfaction (Jin & Peng, 2022). 33
- The stress-reducing effects of multisensory, nature-inspired "recharge rooms" for frontline healthcare workers (Putrino et al., 2020). 13
- The impact of biophilic indoor environments on physiological and cognitive performance (Yin et al., 2018, though slightly predating the range, it is consistently cited in recent reviews as foundational for this period's research). 13

The presence of active critical discourse, coupled with the exploration of new research frontiers like neurodiversity and neurosustainability, indicates that neuroarchitecture is not a static discipline. Instead, it is a field engaged in a dynamic process of self-assessment, methodological refinement, and scope expansion, all of which are characteristic of a maturing scientific endeavor.

↑ An Annotated Bibliography of Neuroarchitecture: Foundational Works, Key Theories, Leading Thinkers, and Critical Perspectives

The development and dissemination of knowledge in neuroarchitecture are significantly supported by dedicated organizations and an evolving landscape of academic journals.

A. The Academy of Neuroscience for Architecture (ANFA)

ANFA stands as the primary international organization dedicated to advancing the field of neuroarchitecture.

- Mission: ANFA's core mission is to promote and advance knowledge that links neuroscience research to a growing understanding of human responses to the built environment. A key objective is to foster robust collaboration between neuroscientists, architects, and allied professionals to explore, through rigorous scientific methods, the spectrum of human experiences with architectural elements.4 Founded in 2003, ANFA was established as a Legacy Project for the American Institute of Architects (AIA) Convention. 9
- Activities: ANFA pursues its mission through a variety of activities, including organizing biennial international conferences, lectures, workshops, and supporting educational initiatives such as college-level courses.11 ANFA's conferences are particularly significant events, bringing together leading researchers and practitioners to share cutting-edge work. 70
- Key Publications/Proceedings: While ANFA does not publish its own journal, it plays a crucial role in facilitating the publication of research presented at its events.
- The ANFA website is noted as a resource providing an extensive list of publications relevant to the field. 9

- Robinson, S., & Pallasmaa, J. (Eds.). (2015). Mind in Architecture: Neuroscience, Embodiment, and the Future of Design. MIT Press. This influential volume, featuring contributions from many ANFA members and conference presenters, is often cited as a key collection of papers stemming from ANFA's intellectual community. 9
- Condia, B. (Ed.). (2023). Designing Atmospheres: Theory and Science. New Prairie Press. This book originated from the “Designing Atmospheres: Theory and Science” Symposium, an ANFA Interfaces event held in 2023, and includes essays by prominent figures in the field such as Elisabetta Canepa, Zakaria Djebbara, Kory Beighle, Harry Francis Mallgrave, and Bob Condia. 71
- ANFA conference proceedings are generally made available, with selected papers and posters undergoing peer review for publication. 70 For instance, the 2023 ANFA conference, "Behavior in the Built Environment: Measuring, Modeling, Theorizing," was reviewed in the journal Intelligent Buildings International, highlighting key presentations and themes. 71
- ANFA also supports the development of Special Issues in academic journals related to its conference themes, such as the issue on "Perception and Cognition of Architecture: Science, Education, Application" in 2024. 37

ANFA's role as a central hub for research, collaboration, and dissemination cannot be overstated. It has been instrumental in shaping the discourse, fostering a community of interdisciplinary scholars, and promoting the translation of neuroscientific knowledge into architectural practice. Tracking ANFA's outputs, including conference programs and associated publications, is therefore crucial for staying abreast of developments in neuroarchitecture.

B. Key Journals Publishing Neuroarchitecture Research

Currently, neuroarchitecture research is published across a wide array of interdisciplinary journals, reflecting its diverse intellectual roots. While no single journal held the exclusive title of "the journal of neuroarchitecture" for many years, the publication landscape is evolving. Key venues include:

- Frontiers in Human Neuroscience (e.g. 13)
- Journal of Environmental Psychology (e.g. 30)
- Environment and Behavior (e.g. 30)
- HERD: Health Environments Research & Design Journal (This journal is particularly relevant for applied neuroarchitecture research in healthcare settings, focusing on evidence-based design and its outcomes 30)
- Architectural Science Review (e.g. 37)
- Buildings (MDPI) (This journal has hosted Special Issues dedicated to neuroarchitecture, indicating its openness to the field 5)
- Sensors (e.g. 15 , particularly for research employing sensor-based methodologies)
- Intelligent Buildings International (Has published reviews of ANFA conferences 71)
- Consciousness and Cognition (While the example in 15 is a broad review touching on precursors, this journal is relevant for the cognitive science aspects of architectural experience.)

More recently, specialized journals dedicated to neuroarchitecture and related subfields have begun to emerge, signaling a consolidation and growing identity for the field's literature:

- Journal of Eco+urbanism & Neuroarchitecture (JEN) 75
- International Journal of Researches in Biophilic Architecture and Neuroarchitecture (IJRBAN) 76

The initially fragmented publication landscape, with research scattered across journals in neuroscience, psychology, architecture, and health design, is a common characteristic of emerging interdisciplinary fields. The appearance of dedicated journals like JEN and IJRBAN suggests a maturing discipline establishing its own distinct channels for scholarly communication. Furthermore, the importance of "grey literature"—such as conference proceedings, organizational reports (like those from ANFA), and preprints—should not be underestimated in a rapidly developing field like neuroarchitecture. These sources often contain cutting-edge research and preliminary findings that may precede formal publication in peer-reviewed journals, offering early insights into new directions and discoveries.

↑ An Annotated Bibliography of Neuroarchitecture: Foundational Works, Key Theories, Leading Thinkers, and Critical Perspectives

A. Recap of the Essential Literature Landscape

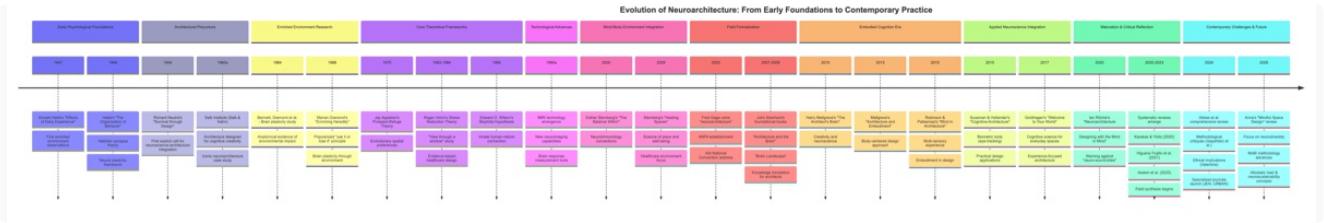
This exploration of essential readings in neuroarchitecture has charted a course from the discipline's conceptual precursors in perceptual psychology and enriched environment research to its contemporary theoretical frameworks, influential thought leaders, significant review articles, and ongoing critical evaluations. The journey reveals a field that is inherently interdisciplinary, drawing strength and complexity from its roots in neuroscience, architecture, psychology, and even philosophy. Seminal works by figures like Hebb, Diamond, Wilson, Appleton, Ulrich, Pallasmaa, Mallgrave, Sternberg, Gage, and Eberhard have laid critical foundations, while a new generation of researchers continues to expand the empirical and theoretical boundaries. Comprehensive reviews are increasingly vital for synthesizing the burgeoning literature, and critical perspectives are shaping a more rigorous and ethically aware trajectory for the field. The body of literature, encompassing foundational texts, established theories, recognized thought leaders, comprehensive reviews, and active critiques, suggests a field that is maturing from a nascent idea into a more established, albeit still evolving, area of scientific and design inquiry.

B. The Ongoing Importance of Critical Engagement with Neuroarchitecture Literature

Neuroarchitecture holds considerable promise for enhancing human well-being through the thoughtful design of our built environments. However, as this bibliography demonstrates, it is a field characterized by dynamic evolution, ongoing methodological refinement, and active debate. The "So What?" question—how to effectively and ethically translate research findings into tangible architectural practice and positive human outcomes—remains a central challenge and a primary driver for the field.[14] The value of the literature presented herein lies not merely in academic understanding but in its potential to inform better, more humane, and more effective design solutions.

Therefore, continued critical engagement with the neuroarchitecture literature is paramount. This involves not only absorbing the established knowledge but also scrutinizing methodological rigor, considering the ethical implications of new findings, and being aware of the field's current limitations and biases. As neuroarchitecture "comes of age," its capacity to contribute meaningfully to society will depend on the commitment of its researchers and practitioners to robust science, interdisciplinary collaboration, and a reflective approach to the profound responsibility of shaping the spaces that, in turn, shape us. This bibliography is offered as a foundational resource to support such critical engagement, encouraging readers to embark on their own in-depth exploration and, potentially, to contribute to the ongoing development of this fascinating and vital field.

C. Timeline



↑ An Annotated Bibliography of Neuroarchitecture: Foundational Works, Key Theories, Leading Thinkers, and Critical Perspectives

This annotated bibliography provides a curated list of essential readings in neuroarchitecture, categorized to reflect the structure of the preceding report. Each entry includes full bibliographic details and a concise annotation highlighting its significance to the field.

Foundational Concepts and Early Influences

- Bennett, E. L., Diamond, M. C., Krech, D., & Rosenzweig, M. R. (1964). Chemical and anatomical plasticity of the brain. Science, 146(3644), 610–619.
    - A seminal experimental paper providing tangible anatomical and chemical evidence that enriched environments can alter brain structure in rats. This work by Marian Diamond and colleagues was crucial in challenging the notion of a static adult brain and provided foundational support for the idea that the physical environment impacts brain plasticity, a core tenet of neuroarchitecture.
- Diamond, M. C. (1988). Enriching Heredity: The Impact of the Environment on the Anatomy of the Brain. New York: The Free Press.
    - This book by Marian Diamond summarizes her pioneering research on the effects of enriched and impoverished environments on brain anatomy and chemistry. It elaborates on the concept of brain plasticity and the importance of environmental stimulation for brain development and health, directly informing neuroarchitecture's premise.
- Hebb, D. O. (1947). The Effects of Early Experience on Problem-Solving at Maturity. American Psychologist, 2, 306–307.
    - This brief report by Donald Hebb is considered a foundational observation in enriched environment research. It documented that rats raised as pets (in an enriched setting) showed improved problem-solving skills compared to lab-reared rats, sparking decades of research into how experience shapes brain and behavior.
- Hebb, D. O. (1949). The Organization of Behavior: A Neuropsychological Theory. New York: Wiley.
    - Hebb's landmark monograph introduced his influential theory of synaptic plasticity (Hebbian learning) and cell assemblies. It provided a theoretical framework for understanding how environmental experiences could lead to lasting changes in neural organization, forming a critical conceptual basis for later neuroarchitecture research.
- Neutra, R. (1954). Survival through Design. Oxford University Press.
    - An early and prescient call from a prominent architect for the integration of biological and neurological knowledge into architectural design. Neutra argued that environments should be designed to support human physiological and psychological well-being, anticipating the core goals of neuroarchitecture by several decades.

Core Theoretical Frameworks

- Biophilia Hypothesis
    - Wilson, E. O. (1984). Biophilia. Harvard University Press.
        - The seminal work introducing the Biophilia Hypothesis, which posits an innate human tendency to connect with nature and living systems. This theory provides a fundamental evolutionary and psychological basis for biophilic design within neuroarchitecture, emphasizing the health and well-being benefits of incorporating natural elements into built environments.
- Prospect-Refuge Theory
    - Appleton, J. (1975). The Experience of Landscape. London: John Wiley.

        - This book (and related article) by Jay Appleton introduced Prospect-Refuge Theory, suggesting that human aesthetic preference for environments is linked to an evolutionary need for spaces offering both clear views (prospect) and opportunities for concealment (refuge). It provides an evolutionary psychological framework for understanding spatial preferences relevant to safety and comfort in architectural design.
- Stress Reduction Theory (SRT)
    - Ulrich, R. S. (1983). Aesthetic and affective response to natural environment. In I. Altman & J. Wohlwill (Eds.), Human behavior and environment, Vol. 6: Behavior and natural environment (pp. 85-125). New York: Plenum.
        - A foundational chapter by Roger Ulrich outlining the theoretical basis for Stress Reduction Theory (SRT), explaining how exposure to natural environments can lead to positive affective responses and physiological stress reduction. Essential for understanding the mechanisms behind nature's restorative effects.
    - Ulrich, R. S. (1984). View through a window may influence recovery from surgery. Science, 224(4647), 420-421.
        - A landmark empirical study demonstrating that hospital patients with window views of nature recovered faster and required less pain medication than those with views of a brick wall. This paper provided strong evidence for SRT and significantly influenced evidence-based healthcare design.
    - Ulrich, R. S., Simons, R. F., Losito, B. D., Fiorito, E., Miles, M. A., & Zelson, M. (1991). Stress recovery during exposure to natural and urban environments. Journal of Environmental Psychology, 11(3), 201-230.
        - This key experimental study used psychophysiological measures to show that exposure to natural scenes facilitated significantly faster and more complete stress recovery compared to urban scenes lacking nature. It offers robust empirical support for SRT.
- Embodied Cognition and Architectural Experience
    - Mallgrave, H. F. (2010). The Architect's Brain: Neuroscience, Creativity, and Architecture. John Wiley & Sons.
        - Mallgrave explores the relationship between neuroscience, particularly concepts of brain function and creativity, and architectural thought and practice. This work is important for understanding the neurological underpinnings of the design process and the experience of architecture from an embodied perspective.
    - Mallgrave, H. F. (2013). Architecture and Embodiment: The Implications of the New Sciences and Humanities for Design. Routledge.
        - This book argues for a shift in architectural focus towards the embodied experience of inhabitants, drawing on insights from neuroscience, biology, psychology, and philosophy. It is a key text for understanding the principles of embodied cognition in architecture.
    - Goldhagen, S. W. (2017). Welcome to Your World: How the Built Environment Shapes Our Lives. HarperCollins.

        - Goldhagen makes a compelling case for how the built environment profoundly shapes human feelings, memories, and well-being, drawing extensively on cognitive psychology and neuroscience. It advocates for an architecture grounded in the science of human experience and embodied cognition.
    - Robinson, S., & Pallasmaa, J. (Eds.). (2015). Mind in Architecture: Neuroscience, Embodiment, and the Future of Design. MIT Press.
        - This edited volume, featuring contributions from leading architects, neuroscientists, and philosophers (including Pallasmaa and Robinson), explores the critical intersections of neuroscience, embodied cognition, and architectural design. It is a significant collection that maps the theoretical landscape and future directions of this interdisciplinary inquiry.
- Place and Healing Environments
    - Sternberg, E. M. (2009). Healing Spaces: The Science of Place and Well-Being. Harvard University Press.
        - A seminal work by Esther Sternberg that meticulously details the scientific evidence for how physical environments can impact stress, the immune system, and the healing process. It bridges neuroscience, immunology, and environmental psychology to explain the mechanisms behind "healing places," profoundly influencing healthcare design.
    - Sternberg, E. M. (2000). The Balance Within: The Science Connecting Health and Emotions. W.H. Freeman.
        - This earlier book by Sternberg explores the intricate mind-body connections, particularly how emotions and stress impact physical health via the nervous and immune systems. It provides foundational knowledge for understanding how environments that modulate stress can influence well-being.

Key Thought Leaders (Selected Definitive Works)

(Many key works are already listed above under theoretical frameworks; this section highlights specific books that encapsulate their broader contributions to neuroarchitecture, beyond single theories.)

- Eberhard, J. P. (2007). Architecture and the Brain: A New Knowledge Base from Neuroscience. Greenway Communications LLC.
    - As the founding president of ANFA, Eberhard's book was an early and influential effort to synthesize neuroscientific knowledge for architects, aiming to provide an evidence base for design decisions.
- Eberhard, J. P. (2008). Brain Landscape: The Coexistence of Neuroscience and Architecture. Oxford University Press.
    - Further developing his thesis, Eberhard explores the symbiotic relationship between neuroscience and architecture, advocating for a deeper integration of brain science into architectural education and practice.
- Edelstein, E. A., & Macagno, E. (2012). Form Follows Function: Bridging Neuroscience and Architecture. In S. T. Rassia & P. M. Pardalos (Eds.), Sustainable Environmental Design in Architecture: Impacts on Health (pp. 27-41). Springer.

    - This chapter by neuroscientist and architect Eve Edelstein and neurobiologist Eduardo Macagno outlines how neuroscientific methods and findings can be applied to architectural design, particularly in creating healthier and more effective environments, with a focus on healthcare.
- Sussman, A., & Hollander, J. B. (2015/2021). Cognitive Architecture: Designing for How We Respond to the Built Environment. Routledge.
    - This book by Ann Sussman and Justin Hollander translates findings from cognitive science, neuroscience, and evolutionary biology into practical insights for architects and urban planners, emphasizing biometric tools and understanding subconscious environmental responses.

Comprehensive Reviews and Syntheses

- Abbas, S., Okdeh, N., Roufayel, R., Kovacic, H., Sabatier, J.-M., Fajloun, Z., & Abi Khattar, Z. (2024). Neuroarchitecture: How the Perception of Our Surroundings Impacts the Brain. *Biology*, *13*(4), 220. https://doi.org/10.3390/biology13040220
    - A recent and comprehensive literature review discussing the impact of architecture on behavior, emotions, and well-being, focusing on the roles of specific brain areas (ACC, PPA), mirror neurons, cognitive maps, and applications in learning/healing environments.
- Anna, M. (2025). Mindful Space Design: The Rise of Neuroarchitecture. International Journal of Architecture, Arts and Applications, 11(1), 36-40.13 https://doi.org/10.11648/j.ijaaa.20251101.14
    - This review critically examines neuroarchitecture, its theoretical frameworks (Biophilia, Prospect-Refuge, Stress Reduction), methodologies (fMRI, EEG, MoBI), limitations, and potential, offering a concise overview of the field's current state.
- Higuera-Trujillo, J. L., Llinares, C., & Macagno, E. (2021). The cognitive-emotional design and study of architectural space: A scoping review of neuroarchitecture and its precursor approaches. Sensors, 21(6), 2193. https://doi.org/10.3390/s21062193
    - This scoping review maps the field of neuroarchitecture, its historical precursors, and current methodological and theoretical approaches to understanding the cognitive and emotional dimensions of architectural space. It is valuable for its breadth and systematic approach.
- Karakas, T., & Yildiz, D. (2020). Exploring the influence of the built environment on human experience through a neuroscience approach: A systematic review. Frontiers of Architectural Research, 9(1), 236–247. https://doi.org/10.1016/j.foar.2019.10.005
    - This systematic review analyzes how neuroscience methodologies are used to investigate human experiences of the built environment, identifying key research themes and trends. It provides a good overview of empirical approaches in the field.

Methodology, Rigor, and Critical Perspectives

- Delgado, M. (2025, January 23). Beyond Neuroscience in Culture, Research and Design. The Centre for Conscious Design.

    - A critical essay arguing that neuroarchitecture, while valuable, can be theoretically narrow and overlook broader cultural, social equity, and participatory design aspects. Proposes "Conscious Design" as a more holistic framework.
- Gepshtein, S., et al. (2024). Mobile EEG for Neurourbanism Research - What Could Possibly Go Wrong? A Critical Review with Guidelines. bioRxiv (preprint).
    - This critical review (preprint) examines the widespread methodological deficiencies in neurourbanism and neuroarchitecture studies using mobile EEG, highlighting issues with hardware, data processing, and interpretation, and offers guidelines for improving rigor. Essential reading for researchers using or evaluating mobile EEG studies.
- Ritchie, I. (Ed.). (2020). Neuroarchitecture: Designing with the Mind in Mind. John Wiley & Sons.
    - This edited volume, guest-edited by Ian Ritchie, offers an alternative to superficial "neuro-sound-bites." It explores the thoughtful application of neuroscientific insights to design, exemplified by the Sainsbury Wellcome Centre, and cautions against the trivialization of the field.
- Valentine, C. (2023). The Unintended Health Consequences of Extended Exposure to Virtual Architecture: A Narrative Review of an Emerging Public Health Issue. Buildings, 13(3), 735. (This appears to be the paper discussed as 66 based on its content, though the year in the snippet was 2023 and the topic matches. Full citation reconstructed for clarity).
    - This paper critiques the use of Virtual Architecture (VA) as a straightforward proxy for Physical Architecture (PA) in health research, highlighting potential confounding variables unique to extended VA exposure (multisensory integration, gravitational perception) and calling for dedicated research into VA's long-term health impacts.
- Valentine, C., Mitcheltree, H., Sjövall, I. A. K., & Khalil, M. H. (2025). Architecturally Mediated Allostasis and Neurosustainability: A Proposed Theoretical Framework for the Impact of the Built Environment on Neurocognitive Health. Brain Sciences, 15(2), 201.
    - This paper proposes a theoretical framework arguing that neuroarchitecture research needs to more fully consider "architecturally mediated allostatic load" (chronic stress from built environments) and its impact on "neurosustainability" (adaptive neuroplasticity), linking these to neurocognitive health outcomes.
- Valentine, C. (2024). Architecture and bioethics: investigating the ethical implications of emerging neuroarchitecture research. City, Territory and Architecture, 11(1), Article 30. (Reconstructed citation for the paper discussed in 60, matching content and typical journal format).
    - This paper explores the significant ethical duties and questions arising for architects as neuroarchitecture provides more evidence on how design impacts occupants' neurophysiological health and well-being. It calls for integrating these findings into ethical practice and potentially regulations.

Key Organizational Publications (ANFA Related)

- Condia, B. (Ed.). (2023). Designing Atmospheres: Theory and Science. New Prairie Press.

- This book is a direct outcome of the Academy of Neuroscience for Architecture (ANFA) symposium "Designing Atmospheres: Theory and Science." It collects essays from key figures in the field, exploring phenomenological and neuroscientific methods for investigating architectural atmospheres.

- Note: Specific ANFA conference proceedings are often disseminated through special journal issues or collections rather than standalone, consistently titled book series. Researchers should monitor ANFA's official communications and associated journal partnerships for the latest proceedings.

↑ An Annotated Bibliography of Neuroarchitecture: Foundational Works, Key Theories, Leading Thinkers, and Critical Perspectives

1. Neuroarchitecture: How the Perception of Our Surroundings Impacts the Brain - PMC
2. The Science of Design: How Neuroscience can Help Architects Shape the Built Environment | ArchDaily
3. 12 Principles of NeuroArchitecture and NeuroUrbanism
4. (PDF) Neuroarchitecture: how the built environment influences the human brain
5. Special Issue : Human-Centric Architectural Design: Neuroarchitecture as a New Tool to Shape Futureproof Inclusive Buildings
6. Creating Harmonious Spaces: The Impact of Environmental Neuroscience on Architecture
7. Approaching to «neuroarchitecture - AHEAD – Barcelona Healthcare Architecture
8. The Legacy of Jonas Salk and the Evolution of Neuroarchitecture
9. Between Objective and Subjective Architectural Experiences: Conceptualizing Refractive Neuroarchitecture Phenomenology
10. An overview of Neuroarchitecture in the past - RTF | Rethinking The Future
11. Academy of Neuroscience for Architecture - Wikipedia
12. Neuroarchitecture | United Workplace
13. Mindful Space Design: The Rise of Neuroarchitecture, International Journal of Architecture, Arts and Applications, Science Publishing Group
14. Neuroarchitecture: Designing with the Mind in Mind | Wiley
15. The Cognitive-Emotional Design and Study of Architectural Space: A Scoping Review of Neuroarchitecture and Its Precursor Approaches - PMC
16. Full article: Methodological challenges in neuroarchitecture: towards a better understanding on how architecture affects cognitive reserve
17. Environmental Enrichment as a Viable Neurorehabilitation Strategy for Experimental Traumatic Brain Injury - PMC
18. The Organization of Behavior: A Neuropsychological Theory - 1st Edition - Routledge
19. The Organization of Behavior: Hebb, D.O.: 9780805843002: Amazon.com: Books

20. Editorial: Environmental Enrichment: Enhancing Neural Plasticity, Resilience, and Repair - PMC
21. Enriching Heredity: Impact of the Environment on the Anatomy of the Brain by Marion C. Diamond (1988-11-30)
22. (PDF) Mindful Space Design: The Rise of Neuroarchitecture
23. Biophilia: Wilson, Edward O.: 9780674074422: Amazon.com: Books
24. 23
25. Designing for the Mind: Neuroarchitecture's Role in Creating Serene Spaces
26. Inside the World of 'Neuroarchitecture': How Buildings Affect Your Brain - Newsweek
27. (PDF) Literature Review of Prospect and Refuge Theory: the first 214 references
28. What is Prospect-Refuge Theory? - ArchPsych.
29. Ulrich, RS (2023). Stress reduction theory. - In D. Marchand, E. Pol & K. Weiss (Eds.)
30. Roger S. Ulrich - Google Scholar
31. Mind in Architecture: Neuroscience, Embodiment, and the Future of Design (Mit Press)
32. Architecture and Embodiment: Mallgrave, Harry Francis: 9780415810203: Amazon.com: Books
33. Neuroarchitecture: How the Perception of Our Surroundings Impacts the Brain
34. Mind in Architecture: Neuroscience, Embodiment, and the Future of Design
35. Applying Neuroscience to Architecture
36. Mind in Architecture: Neuroscience, Embodiment, and the Future of Design
37. ANFA | PERCEPTION AND COGNITION OF ARCHITECTURE: Science, Education, Application
38. Sarah Williams Goldhagen
39. Sarah Williams Goldhagen - Wikipedia
40. Esther Sternberg — The Science of Healing Places | The On Being Project
41. Healing Spaces - MDPI press
42. 41
43. 41
44. 41
45. Books by Esther M. Sternberg (Author of The Balance Within)
46. Esther Sternberg, Arizona.edu
47. 41
48. 41
49. Explore Salk – Architecture Guide - Salk Institute for Biological Studies
50. Architecture and the Brain: A New Knowledge Base from Neuroscience: John P. Eberhard: 9780978555214
51. Eve Edelstein | Stanford Medicine
52. About us: Clinicians for Design Founders.
53. Eve Edelstein's research works | University of California
54. Design on the brain: Combining neuroscience and architecture | Articles

55. Neuro-architecture comes to Health Care / Health Design | ArchitectureAu
56. Research Topics | ANFA
57. (PDF) Form Follows Function: Bridging Neuroscience and Architecture
58. Sustainable Environmental Design in Architecture
59. Ann SUSSMAN | President | Master of Arts | Research profile
60. Full article: Architecture and bioethics: investigating the ethical implications of recent advances in the field of neuroarchitecture
61. Neuroscientific Insights into the Built Environment: A Systematic Review of Empirical Research on Indoor Environmental Quality,
62. Neuroarchitecture: How the Perception of Our Surroundings Impacts the Brain - PubMed
63. Between Objective and Subjective Architectural Experiences: Conceptualizing Refractive Neuroarchitecture Phenomenology
64. (PDF) Mobile EEG for Neurourbanism Research - What Could Possibly Go Wrong? A Critical Review with Guidelines
65. Neuroarchitecture: intelligently designed buildings
66. Health Implications of Virtual Architecture: An Interdisciplinary Exploration of the Transferability of Findings from Neuroarchitecture - PMC
67. Beyond Neuroscience in Culture, Research and Design
68. Psyhéarchitecture: A New Architectural Paradigm | PDF | Human | Mind
69. Architecturally Mediated Allostasis and Neurosustainability: A Proposed Theoretical Framework for the Impact of the Built Environment on Neurocognitive Health
70. ANFA | 2025 Conference - Call for papers and posters
71. Review of academy of neuroscience for architecture biennial international conference behavior in the built environment: measuring, modeling, theorizing September 13–16, 2023
72. "Designing Atmospheres: Theory and Science" by Kory Beighle, Elisabetta Canepa et al.
73. Health Environments Research & Design Journal
74. HERD Journal | The Center for Health Design
75. Journal of Eco+urbanism & Neuroarchitecture | CCR - Centre for Climate Resilience
76. About the Journal | International Journal of Researches in Biophilic Architecture and Neuroarchitecture

This bibliography is being written by someone from outside the field and likely has large gaps and misconceptions. It is certainly incomplete and intended as a starting point. Particular things I would like to add are:

- A discussion of the research on Parkinson's and especially the effect of the built environment on freezing of gait (FOG) and the fascinating experimental work on cueing as a mitigation strategy.
- Circadian rhythms
- Quality of Light, intensity, color and spectra. (mentioned above)

↑ An Annotated Bibliography of Neuroarchitecture: Foundational Works, Key Theories, Leading Thinkers, and Critical Perspectives

- Arthur, P.and Passini, R. (1992), Wayfinding: People, Signs, and Architecture McGraw-Hill. Reissued as a collector's edition in 2002 by Focus Strategic Communications, Inc. https://trid.trb.org/View/367500
- Downs, R. and Stea, D. (eds.). (1977). Maps in Minds, New York: Harper and Row. https://archive.org/details/mapsinmindsrefle00roge
- Evans, G. and McCoy, M. (1998). When Buildings Don't Work: The Role of Architecture in Human Health, Journal of Environmental Psychology, v. 18: 85-94. https://www.sciencedirect.com/science/article/pii/S0272494498900895
- Golledge, R.G. (ed). (1999). Wayfinding Behavior: Cognitive Mapping and Other Spatial Processes, Baltimore, Maryland: The Johns Hopkins University Press.
- Hillier, B. and Hanson, J. (1988). The Social Logic of Space, Cambridge: Cambridge University Press.
- Lynch, K. (1960). The Image of the City, Cambridge, Massachusetts: MIT Press.
- Peponis, J., and Wineman, J. (2002). Spatial Structure of Environment and Behavior, pp. 271-291 in Bechtel, R. and A. Churchman, eds., 2002, Handbook of Environmental Psychology, New York: John Wiley & Sons.
- Weisman, J. (1981). Evaluating Architectural Legibility: Way-finding and the Built Environment, Environment and Behavior, v. 13(2): 189-20
- Universal Design as a Rehabilitation Strategy: Design for the Ages: This book by Jon Sanford (2012) provides a framework for creating environments that are usable by people with a wide range of abilities, a concept that intersects with the challenges of complex healthcare settings. https://www.google.com/books/edition/Universal_Design_as_a_Rehabilitation_Str/xquDZ8ncUA4C?hl=en&gbpv=1&printsec=frontcover Jon Sanford has contributed to the understanding of how people navigate larger community spaces, which has implications for the design of large, complex buildings like hospitals.

Environmental psychology is an established interdisciplinary field that investigates the complex and reciprocal relationships between individuals and their physical environments. It explores how our surroundings—encompassing everything from the natural world to the buildings we inhabit and the cities we construct—shape our thoughts, emotions, and actions. Conversely, it also examines how our behaviors and attitudes impact the environment.

At its core, environmental psychology operates on the principle of a continuous transaction between people and their settings. This means that not only does the environment influence individuals, but individuals also actively shape and are shaped by their environments. This dynamic interplay is the central focus of research and application in the field.

Environmental Neuroscience vs. Environmental Psychology

While closely related and complementary, these two fields differ in their primary focus and methodologies. Your understanding of environmental psychology provides the perfect foundation for appreciating the neuroscientific approach.

Aspect	Environmental Psychology	Environmental Neuroscience
Primary Focus	Observable behaviors, perceptions, attitudes, and well-being in relation to the environment.	The underlying neural and physiological mechanisms that mediate the person-environment interaction.
Guiding Question	How does the environment affect behavior and mental health?	Why and through what brain mechanisms does the environment affect behavior and mental health?
Typical Methods	Surveys, behavioral observations, questionnaires, self-reports, mapping exercises.	fMRI, EEG, MEG, PET, psychophysiological measures (heart rate, skin conductance), epigenetic analysis, animal models, GIS data integration.
Level of Analysis	Individual, group, and community behavior and subjective experience.	Molecular, cellular, neural circuits, and large-scale brain networks.
Example Study	Investigating if people report feeling less stressed and perform better on cognitive tests after a walk in a park versus a city street.	Using fMRI to show decreased amygdala activation and changes in DMN connectivity after a walk in a park, linking this to stress reduction.

Key Areas of Study

Environmental psychology is a broad field with several key areas of focus:

- Environmental Perception and Cognition: This area explores how we perceive, process, and mentally represent our physical surroundings. It delves into topics such as cognitive mapping (our mental layout of a place), wayfinding (how we navigate), and spatial awareness. It examines how we make sense of our environment and what cues we use to understand and move through it.
- The Impact of Built Environments: A significant portion of environmental psychology research focuses on how human-made, or "built," environments affect our well-being and behavior. This includes studying the psychological effects of architectural design, urban planning, and interior design. Researchers in this area might investigate how office layouts influence productivity and collaboration, how classroom design impacts learning, or how neighborhood characteristics affect social interaction and crime rates.
- Nature and Well-being: There is a robust body of evidence, and growing interest, in the restorative effects of natural environments. This research demonstrates that exposure to nature can reduce stress, improve mood, enhance cognitive function, and promote physical health. This subfield, sometimes called ecopsychology, investigates the human need for connection with nature.
- Pro-Environmental Behavior: Understanding the psychological drivers and barriers to environmentally responsible behavior is a critical area of study. Researchers investigate what motivates individuals and communities to engage in actions such as recycling, conserving energy and water, and adopting sustainable lifestyles. This knowledge is crucial for developing effective interventions to address pressing environmental challenges like climate change.
- Place Attachment and Identity: This area examines the emotional bonds people form with specific locations, from their homes and neighborhoods to significant landscapes. "Place attachment" refers to this deep connection, while "place identity" explores how these places become integrated into our sense of self. These connections can influence our willingness to care for and protect our environments.
- Environmental Stressors: Environmental psychologists also study the impact of environmental stressors such as noise, crowding, pollution, and traffic on human health and well-being. This research informs policies and design strategies aimed at mitigating these negative effects.

Real-World Applications

The principles of environmental psychology are applied in numerous practical ways to improve quality of life and create more humane and sustainable environments:

- Architecture and Urban Planning: Architects and planners use insights from environmental psychology to design buildings and cities that are more navigable, less stressful, and more conducive to social interaction and well-being. This can range from the layout of a public park to the design of an entire neighborhood.
- Interior Design: The design of interior spaces, including homes, offices, schools, and hospitals, is heavily influenced by environmental psychology. For example, research on the effects of lighting, color, and spatial arrangement is used to create environments that support the specific functions of those spaces and the psychological needs of their occupants.

- Healthcare Design: In healthcare settings, evidence-based design principles are used to create environments that promote healing. This can include providing patients with views of nature, designing rooms to reduce stress and anxiety, and creating layouts that are easy for patients and staff to navigate.
- Workplace Strategy: Companies apply principles of environmental psychology to design offices that enhance employee satisfaction, productivity, and collaboration. This includes considering factors like noise levels, lighting, personal space, and opportunities for social interaction.
- Conservation and Sustainability: Government agencies and non-profit organizations use research on pro-environmental behavior to develop campaigns and interventions that effectively encourage sustainable practices.

Methodologies in Environmental Psychology

Environmental psychology employs a diverse range of research methods to study the person-environment relationship. These methods often involve studying people in their everyday settings to ensure the findings are relevant to real-world situations. Common methods include:

- Observational Studies: Researchers observe and record behavior in natural or built environments.
- Surveys and Questionnaires: These are used to gather data on people's perceptions, attitudes, and reported behaviors related to their surroundings.
- Experimental Studies: Both laboratory and field experiments are used to determine cause-and-effect relationships between environmental variables and psychological responses.
- Case Studies: In-depth investigations of a particular individual, group, or setting provide rich, detailed information.

Methodologies in Environmental Neuroscience

The toolkit of an environmental neuroscientist is inherently multimodal, often combining large-scale environmental data with precise neural measurements:

- Neuroimaging: fMRI and EEG are used to measure brain activity and connectivity in response to environmental stimuli (e.g., images or virtual reality simulations of natural vs. urban scenes) or during pro-environmental decision-making tasks.
- Geospatial Data (GIS): Researchers correlate individuals' neural data with objective, quantifiable environmental features of their homes and neighborhoods, such as the density of tree canopy, proximity to parks, levels of air pollution, or walkability scores.
- Mobile Sensing: Using wearable sensors to track physiological responses (e.g., heart rate variability, electrodermal activity) and location data as individuals move through different real-world environments.
- Epigenetic and Molecular Analysis: Examining how environmental factors can lead to changes in gene expression (e.g., DNA methylation) that affect neural development and function.
- Animal Models: Using controlled laboratory settings to investigate the causal effects of specific environmental exposures (e.g., pollutants, enriched environments) on brain structure and function at a molecular and cellular level.

Harmonizing Methodologies in Environmental Psychology and Neuroscience

Both environmental psychology and environmental neuroscience utilize a wide array of research methods to study how environments influence human behavior and brain function, integrating real-world relevance with scientific precision.

- **Observational Studies and Mobile Sensing**: While environmental psychologists observe and record behaviors in natural or built settings to maintain ecological validity, environmental neuroscientists employ mobile sensing technologies. Wearable sensors track physiological responses and location data, providing valuable insights as individuals navigate different environments.
- **Surveys, Questionnaires, and Geospatial Data**: Environmental psychologists frequently use surveys and questionnaires to collect data on perceptions, attitudes, and behaviors. In parallel, environmental neuroscientists utilize geospatial data (GIS) to correlate neural measurements with objective environmental characteristics, such as green spaces or pollution levels, offering a quantifiable basis for understanding the person-environment interaction.
- **Experimental and Neuroimaging Studies**: Experimental studies in environmental psychology often include both laboratory and field experiments to uncover cause-and-effect relationships. Environmental neuroscientists similarly employ neuroimaging techniques like fMRI and EEG to observe brain activity and connectivity in response to different environmental stimuli or during decision-making tasks related to environmental choices.
- **Case Studies and Epigenetic/Molecular Analysis**: Environmental psychologists conduct case studies to gain in-depth insights into specific individuals, groups, or settings. Complementarily, environmental neuroscientists explore epigenetic and molecular analyses to examine how environmental conditions impact gene expression and neural function.
- **Animal Models**: In both fields, although particularly prominent in neuroscience, animal models help elucidate the causal effects of environmental exposures on behavior and brain structure. These controlled studies provide critical data on molecular and cellular processes.

By integrating these methodologies, researchers can comprehensively explore the multifaceted interactions between humans and their environments, bridging psychological insights and neural mechanisms to advance our understanding of environmental influences on behavior and mental processes.