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Review Article

Mindful Space Design: The Rise of Neuroarchitecture

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Abstract

This review critically examines the field of neuroarchitecture, an interdisciplinary approach combining neuroscience and architectural design to analyze how built environments affect human emotions, cognition, and behavior. The primary objectives are to explore foundational theories, evaluate practical applications, and identify the challenges and opportunities within the field. The review discusses key theoretical frameworks, including the Biophilia Hypothesis, Prospect-Refuge Theory, and Stress Reduction Theory, which provide a scientific basis for understanding how spatial design elements such as natural light, the use of greenery, and spatial configurations influence neural and psychological responses. Methodological approaches are discussed, including functional magnetic resonance imaging (fMRI), portable electroencephalograms (EEGs), and mobile brain/body imaging (MoBI), a promising technology that is gaining recognition in neuroarchitecture for its ability to study neural responses in real-world environments. These methods offer valuable insights into the relationship between architectural design and human behavior. Practical applications are illustrated through a case study of the Google Engineering Hub in Zurich, which integrates multiple neuroarchitecture principles to improve user satisfaction, productivity, and well-being. Key findings suggest that while the neuroarchitectural approach has the potential to transform our vision of spatial design, it faces several limitations. These include a lack of empirical research, high implementation costs, and the complexity of designing for diverse cultural and individual needs. Addressing these barriers will require interdisciplinary research and collaboration to expand the field's practical applications. Ultimately, this paper highlights the transformative potential of neuroarchitecture in redefining built environments to align with human cognitive and emotional responses. It advocates for design principles that enhance mental health, and improve well-being, productivity, and quality of life.

Keywords

Neuroarchitecture, Biophilic Design, Prospect-Refuge Theory, The Stress Reduction Theory, Spatial Design, Google Engineering Hub, fMRI

1. Introduction

In the age of urban planning, where city landscapes and architectural wonders shape the backdrop of our daily lives, scientists have discovered a connection between neuroscience and architecture, forming an optimal living environment. This new frontier, known as neuroarchitecture, aims to explore how architectural designs influence the human brain, emotions, and behavior.

Neuroarchitecture studies space design and takes into consideration things such as human psychological and neural responses. It is the latest development in the evolution of architecture and is highly driven by technological advancements [1].

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Neural responses are how the nervous system, including the brain, reacts to environmental triggers. In the context of neuroarchitecture, it involves how certain design elements influence neural processes, such as stress reduction or cognitive function.

2. Historical Overview

Traditionally, architecture has always focused on aspects such as aesthetics and functionality. During the Renaissance, proportion and harmony became the central themes, while the Industrial Revolution introduced new materials and construction techniques. In the early 20th century, Modernism emphasized simplicity and functionality. Post-modernism occurred during the mid-20th century and brought diversity into architecture.

As the late 20th century approached, the understanding of psychology and neuroscience advanced, and architects began recognizing the profound influence of the built environment on human behavior and well-being. Neuroarchitecture is a relatively new interdisciplinary field. The first breakthrough in the field occurred in the late 20th century, approximately around 1990. The first successful fMRI (functional magnetic resonance imaging) experiments were conducted in the early 1990s and led to massive revelations in a group of fields, including neuroscience and, consequently, neuroarchitecture by providing a tool to study how architectural designs affect brain activity. Researchers can witness neural responses using fMRI, which helps to identify patterns related to emotions and stress, influenced by architectural elements [2].

3. Theoretical Foundations

3.1. The Biophilia Hypothesis

One of the theoretical foundations is *The Biophilia Hypothesis*. This concept was introduced by Edward O. Wilson in 1984 in his book *"Biophilia"* [3]. It claims that humans have an innate desire to connect with other forms of life. Those can be incorporated either through direct (light, water, plants, fire) or indirect (images of nature, natural colors, shapes, and forms) experiences of nature. We call spatial design that integrates these *biophilic design.*

3.2. Prospect-Refuge Theory

This theory was originally published in 1975 by theorist Jay Appleton [4]. It states that humans are naturally drawn to spaces that both provide the feeling of enclosure (refuge) and a full view of the surrounding environment (prospect). The cause of such an effect could be our predator nature, a need to be able to see the prey and stay hidden from potential dangers, such as bigger and stronger predators. In neuroarchitecture, incorporating elements that provide both prospect and refuge contributes to a sense of safety and well-being.

3.3. The Stress Reduction Theory

Published by Roger Ulrich in 1991, this theory follows up on the concept of biophilia in design and looks into how our brain reacts to natural elements. It goes beyond the innate desire highlighted in *The Biophilia Hypothesis* and claims that looking at natural elements can positively affect your mood, anxiety levels and provide a sense of relaxation [5]. Some of the studies based on this theory have shown that such design elements as spatial openness, natural light, and comfortable layouts directly contribute to a level of stress [6].

4. Research Methods

4.1. Stationary Approaches

Scientists create and conduct controlled experiments or observations in fixed settings. For example:

1. Studies with the use of fMRI, analysis of brain responses to specific design choices [7]
2. Virtual reality and simulation studies [8, 9]

4.2. Mobile Approaches

Mobile approaches involve studying individuals' brain activity in real-world environments. For example:

1. Monitoring with portable EEG (electroencephalogram) devices
2. EMA (Ecological Momentary Assessment)
3. MoBI (mobile brain/body imaging) — wearable neuroimaging technology that collects data during active behavior [10]

5. Case Study: Google Engineering Hub

One of the most famous examples of a building that considers people's well-being is the Google Engineering Hub in Zurich, Switzerland. This example has served as a role of inspiration for many offices around the globe and there are plenty of reasons [11]. The two key methods were used during the creation of said project: the use of biophilic design, based on the previously mentioned Biophilia Hypothesis, and cooperation with the local Google team, which has set a new standard in the design world. One of the architects explained that they formed a committee out of a group of workers who represented the whole office. They were allowed to approve and review each step of the project. Looking from the neuroarchitecture perspective, these are a few of the included elements proven to have positive effects on neural responses:

1. Spatial openness

Examples: open floor plans, transparent partitions, and minimal physical barriers. (Figure 1)

Effects: more positive and interactive workplace culture, enhanced collaboration and communication.

2. Biophilic Design

Examples: indoor plants, green walls, and views of nature.

Effects: stress reduction, increased creativity, improved well-being [12, 13].

3. Dynamic Lighting Systems

Example: lighting systems that mimic natural light patterns.

Effects: enhanced mood, alertness, and productivity.

4. Personalization and Flexibility

Examples: individualized workspaces, flexible seating arrangements, and a variety of collaborative zones. Google Office workers have a choice between multiple workspaces, systemized by topics, such as jungle, arctics, cities, and others. (Figure 2)

Effects: a sense of control and autonomy that positively influences motivation and job satisfaction.

Figure 1. *Google Engineering Hub in Zurich, Switzerland floor plan (level 2).*

Figure 2. *Zones systemized by topics at Google Engineering Hub in Zurich, Switzerland, designed by Evolution Design.*

6. The Future of Neuroarchitecture

6.1. Opportunities in Neuroarchitecture

Neuroarchitecture is a growing interdisciplinary field that continues to advance our understanding of how the built environment influences the human brain. In the future, neuroarchitecture can make a big impact on the lives of neurodivergent people, like those with Autism or ADHD (attention deficit hyperactivity disorder), by creating spaces that would be considerate of their needs. Imagine places with special design elements, like calm spots or flexible layouts that cater to different needs. The use of neuroarchitecture in this direction could potentially revolutionize the architecture field by bringing in diversity. Putting it into practice involves collaboration between architects, neuroscientists, healthcare professionals, and individuals with syndromes [14]. The designs might include adaptable layouts, calming areas, inclusive furniture, and much more. Further research is essential to identify needed elements in designing spaces for individuals with syndromes, using methods such as fMRI scans.

6.2. Potential Limitations and Challenges

Neuroarchitecture is a relatively new field, and while promising, it lacks a comprehensive body of studies to substantiate many of its claims. Much of the research relies on small sample sizes or controlled laboratory settings, which may not fully capture real-world complexities [15].

Human neural and psychological responses to architectural elements can be highly individual, influenced by factors such as culture, personal preferences, and neurodiversity. Designing spaces that cater to diverse populations without oversimplifying these differences remains a significant challenge.

Implementing neuroarchitectural designs often requires advanced materials, technology, and specialized expertise, making them expensive. This limits their accessibility, particularly in low-income or underfunded projects, potentially widening socio-economic disparities.

7. Conclusion

While the trend of human-centered design continues to grow, we are going to see more projects that incorporate principles of neuroarchitecture. Understanding how specific architectural elements influence neural responses changes the perspective on designing living and working spaces. As the field is relatively new, emerging in the late 20th century, there is plenty of room for following research. In the future, neuroarchitecture could be a revolutionary approach to crafting spaces that cater to the unique needs of neurodivergent people. Neuroarchitecture not only promotes human-centered spatial design but also starts a positive development toward a more inclusive environment.

Abbreviations

fMRI	Functional Magnetic Resonance Imaging
EEG	Electroencephalogram
MoBI	Mobile Brain/Body Imaging
EMA	Ecological Momentary Assessment
ADHD	Attention Deficit Hyperactivity Disorder

Author Contributions

Mashchenko Anna is the sole author. The author read and approved the final manuscript.

Conflicts of Interest

The author declares no conflicts of interest.

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