Architecture as a Stimulus for Child Development: The Integration of Neuroarchitecture into Design

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Abstract: The 2030 United Nations Sustainable Development Goals (SDGs) encompass a wide range of critical objectives, including "Sustainable cities and communities" and "Good health and wellbeing." As an increasing number of families with children reside in densely populated urban areas, it is imperative to rethink the design of compact neighborhoods to prioritize the well-being and lifestyle requirements of this demographic. Integrating neuroarchitecture principles into the development of child-friendly environments can significantly enhance the overall quality of these spaces, fostering cognitive development, emotional well-being, and a sense of security for children. By acknowledging the profound impact of architectural design on the human brain and behavior, architects and designers can fashion environments that cater to the distinct needs and experiences of children. In essence, spaces purposefully designed for children using neuroarchitecture principles hold the potential to create settings that support comprehensive development, overall well-being, and an enriched quality of life. Whether within educational institutions, healthcare facilities, or public areas, the deliberate incorporation of neuroarchitecture principles can optimize environments for children, enabling them to flourish, learn, and engage in activities within surroundings that nourish their physical and emotional growth. The core objective of this research is to delve into the insights provided by neuroscience and advocate for their integration into architectural designs for children, thus deepening our comprehension of how the human body interacts with its architectural environment.

Keywords: *neuroarchitecture, child-friendly environment, body-conscious design, human-centered design, evidence-based design, data-driven design, virtual reality*

1 Introduction

Neuroarchitecture, a new field at the intersection of architecture, neuroscience, and psychology, explores how the environment affects people's emotional, psychological, and physical well-being. It prioritizes user experience and aims to create healthier, more humane spaces by understanding their impact on brain chemistry and emotions. However, there's no one-size-fits-all solution, as the brain's response depends on genetics, culture, and individual differences. To apply neuroarchitecture effectively, it's essential to consider the unique needs of users.

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This interdisciplinary approach, combining neuroscience and architecture, recognizes that the spaces where children live, play, and learn profoundly impact their development. By integrating neuroscience into design, architects can enhance children's growth and learning experiences. Creating smart cities that prioritize well-being is a key goal.

The Salk Institute for Biological Studies in San Diego exemplifies a deliberate fusion of neuroscience and architectural design. It has redefined our relationship with the built environment. Neuroarchitecture principles emphasize natural elements, sensory experiences, and emotional influences on design. These principles serve as flexible guidelines adaptable to specific projects and contexts.

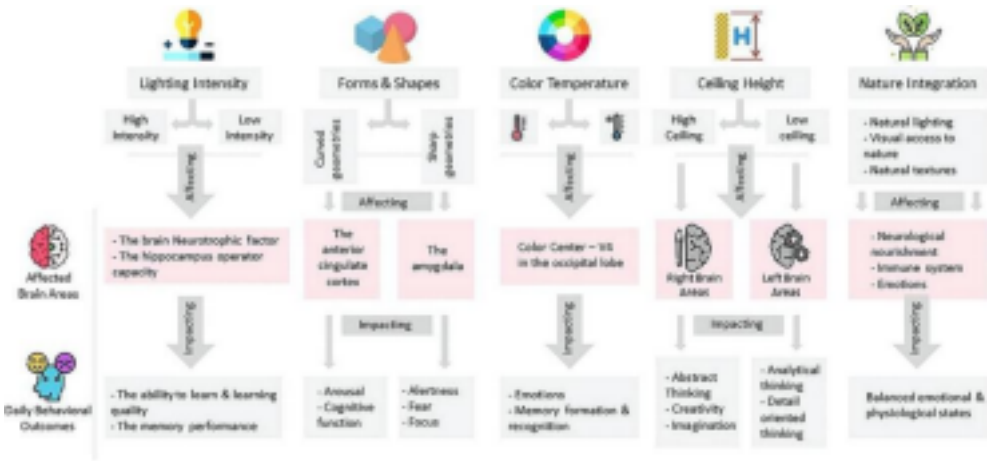

Figure 1. The design impact guide' main highlights. *Source: https://www.sciencedirect.com/science/article/pii/S209044792200418X#bi005*

Neuroarchitecture has generated significant interest among architects and scientists, sparking exploration in various fields. This research can serve as both an example and a catalyst for students and architects, providing insights into how design impacts users. It encourages a fresh perspective on the connection between architectural structures and their potential effects on both physical and psychological well-being.

Our buildings are crucial extensions of ourselves, both individually and collectively. Buildings mediate between the world and our consciousness through internalizing the world and externalizing the mind. Architecture is a materialized expression of mental space, and our mental space itself is structured by architecture. [1] Throughout history, designers aimed to create environments in which humans could thrive, drawing on their knowledge and intuition to shape spaces that impact human experiences. More recently, designers have begun to question the dynamic interaction between humans and buildings and how people respond to environmental stimuli. While today's technology has provided some insights, there is still much to discover in this evolving field.

2 Research background

Mental health issues are increasingly recognized as a critical concern for children and adolescents in developed countries. The World Health Organization (WHO) estimates that approximately 25% of the global population experiences mental disorders at some point in

their lives. A study involving 6,245 children aged 6–12 from eight European countries revealed that 22.0% reported having at least one mental disorder, with varying prevalence from 16.4% in the Netherlands to 27.9% in Bulgaria. [2] Suicide is the leading cause of death among 10–19year-olds in the WHO European region, particularly in low- and middle-income countries, and the second-leading cause in high-income countries. Additionally, depression and anxiety disorders rank among the top five causes of disease burden for children and adolescents in Europe. Despite these challenges, there are significant disparities between mental health needs and funding, with only about 2% of government health budgets globally allocated to mental health spending. [3]

Furthermore, the United Nations predicts that two-thirds of the world's population will be residing in urban environments by 2050. Creating nature-inspired, dynamic, and well considered spaces within cities can help alleviate stress and unhappiness. Researchers are systematically exploring the neurological and psychological responses to architectural design to develop evidence-based principles that enhance the quality of built environments and support human well-being.

The idea of a child-friendly city originates from the United Nations Convention on the Rights of the Child. [4] To further this concept, the UNICEF Child Friendly City Initiative (CFCI) was established with the aim of assisting local governments in the development of child-friendly environments on a global scale. [5] The CFCI has introduced various assessment and monitoring tools and suggested indicators to address a broad spectrum of issues concerning children, with a particular focus on cities in less developed countries. [6]

In their book "Mind Child Architecture," Bard and Lutkus assert that physicians, including pediatricians and psychologists, hold the belief that a lack of stimulating experiences can lead to perceptual and learning deficiencies in developing children. Conversely, they argue that an enriched environment can enhance the development of perceptual, motor, and cognitive abilities in children. [7] Within this enriched environment, various elements such as landscapes, buildings, people, and animals offer distinct scales of size and semantic value, which are instrumental in capturing the attention of children and fostering their development.

This research seeks to explore the role of neuroscientific findings in understanding the impact of architectural design on its users, specifically focusing on children's perception of their built environment. Children are highly susceptible to external stimuli, including architectural environments, due to their absorbent minds. [8] Their critical brain development periods and knowledge absorption occur during early childhood. Research by Dunn (2012) indicates that environmental elements begin to significantly influence children from the age of 3 due to the expansion of their geographical range. [9]

Play plays a pivotal role in children's cognitive and physical development, as well as their overall well-being. It fosters active lifestyles and healthy behavioral patterns from an early age, helping children make sense of the world. Exploratory play with caregivers supports foundational development, and as children grow, play transitions from solo to group play, promoting cognitive, social, and emotional growth. [10]Physical activities like running, jumping, climbing, and balancing enhance motor skills, proprioception, and risk understanding, while fine motor skills and social abilities are honed through interaction with toys, loose parts, and imaginative games.

Safe and healthy environments often include nature and greenspaces, which provide various recognized benefits for children. Outdoor education emphasizes the educational advantages of natural settings, particularly for children facing educational disadvantages. Conversely, children with limited exposure to nature may encounter issues related to behavior, peer interactions, and overall health and well-being during childhood and adulthood. [11]

Even before the emergence of the field of neuroarchitecture, people recognized the profound effects of the environment on the mind, body, and spirituality. Neuroarchitecture,

as a hybrid field, offers unique opportunities by providing insights into how architecture influences us by tracking the body's response to various stimuli from the built environment. [12] Emerging neuroarchitecture technologies, such as eye-tracking, mobile electroencephalography, and galvanic skin response, offer new ways to directly measure the impact of architectural design on its users. This technology can validate existing design principles and suggest new ones that measurably enhance human well-being.

3 Existing solutions

Numerous studies in the social sciences have explored how the built environment, including architecture, impacts psychological health and overall well-being. However, many of these studies have traditionally relied on subjective tools for assessing well-being, such as self-rating scales or participant descriptions. While subjective indicators are valuable for understanding individual experiences, like emotions and perceptions, relying solely on them for comparing, quantifying, and justifying the effects on human consciousness can be challenging. [13] Several architectural elements are known to influence our mental state. For instance, architectural designs with prominent or pointed corners can induce stress, while rectangular spaces may make people feel confined. Lighting is another critical factor, as poor artificial light can strain the brain and affect productivity. High ceilings are conducive to creative and artistic activities, whereas low ceilings support concentration and routine work. Colors also play a role in affecting mood, which, in turn, influences decision-making and attitudes. [14] For example, green colors can lower heart rate and reduce stress, while red colors stimulate cognitive and attention processes, making them useful for tasks requiring mental concentration.

With the advancement of technology, researchers have started using digital devices to track body responses in various architectural environments. These include fMRI (Functional Magnetic Resonance Imaging), fNIRS (Functional Near Infrared Spectroscopy), EEG (Electroencephalography) to detect brain activation, as well as measurements of pulse rate, heart rate, blood pressure, breathing rate, and galvanic skin response (GSR) to identify psychological changes.

However, interpreting the impact of each sensory element on the brain and nervous system in multisensory physical settings' experiments can be challenging due to the simultaneous variation of numerous variables in a non-systematic manner. Developing a statistically sound approach for understanding the complex interplay of environmental variables is a pressing need in this field.

4 Methodology

Research methodology in neuroarchitecture involves a systematic examination of how architectural design influences brain function and human behavior. This field aims to comprehend the neurological and psychological responses to various architectural elements and environments, applicable to diverse age groups, whether children or adults. Advances in neuroscience have made it increasingly feasible to measure these indices, shedding light on how shapes, colors, and scales impact human perceptions. Technologies like MRI and virtual reality enable the observation of brain activity in response to spaces through biofeedback. Scientific research contributes to expanding knowledge, while biosensors make it possible to measure human behavior in various settings, facilitating a clearer understanding of the world.

The use of virtual reality (VR) technology has made neuroarchitecture research more cost-effective and accessible. VR simulations enable the creation of multiple building versions for study, a process that would be impractical in full-scale reality. VR goggles allow users to closely interact with the environment. The adoption of VR and augmented

reality is
expected to increase as architects and designers become more familiar with these technologies. Instead of making professionals obsolete, these technologies expedite the design process by facilitating rapid design creation, testing, and editing.

The research methodology in neuroarchitecture aligns with evidence-based design typologies. It begins with a literature review that synthesizes neuroscience research findings and their applicability to architectural design. Understanding the human body's anatomy, senses, and neurobiology serves as the foundation for discerning how individuals react to architectural stimuli. This is followed by the development of a prototypical design that integrates research findings to enhance the connection between neuroscience and architecture, with a particular focus on improving the experience, especially for children. Behavioral observations and subjective assessments, such as surveys, are also employed in the research process and questionnaires are also employed as research methods.

iMotions, a leading software platform for studying human behavior, has partnered to expand and enhance research and analysis capabilities in this field. iMotions offers a fully-integrated, hardware-agnostic software platform that empowers researchers to harness various neuroscience technologies, along with traditional methods like surveys and focus groups, to gain unparalleled insights into people's thoughts and emotions. Eye tracking is a key component of this platform, enabling the analysis of what individuals, including children, notice and don't notice. Eye tracking typically involves reflecting near-infrared light onto the retina to obtain highly precise measurements. Academic researchers utilize information about eye movements and fixations to evaluate attention processes, compare group behavior, measure visual responses induced by stimuli, and much more. The platform offers different modules for research, including screen-based eye tracking, eye tracking glasses, and VR eye tracking, providing a comprehensive toolkit for understanding human behavior.

Figure 2. iMotion feature highlights. Source: https://imotions.com/applications/academia/

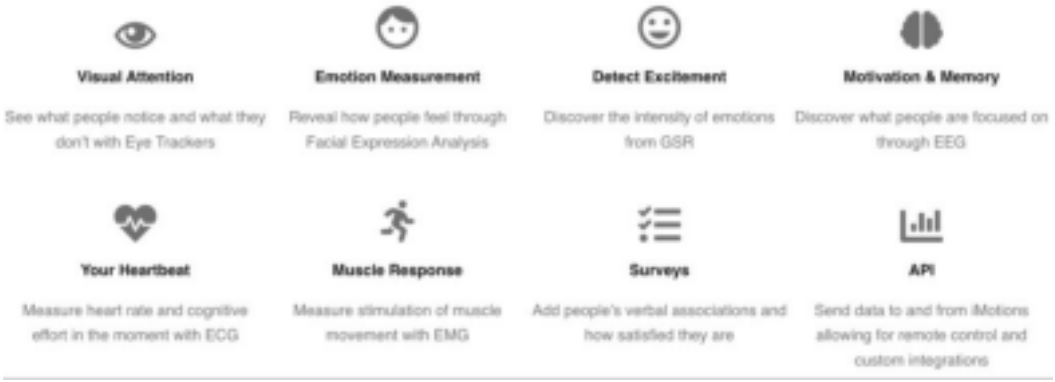

Figure 3. iMotion feature highlights. Source: https://imotions.com/applications/academia/

5 Further work and results

In conclusion, recent neuroscientific research findings have highlighted the critical need for a seamless connection between architects who wish to apply neuroarchitecture principles and the wealth of complex neuroscientific data and research. Architects should not be burdened with the necessity of in-depth neuroscientific study but instead should be empowered to efficiently leverage the potential of their design decisions. This approach allows architects to clearly articulate their intended outcomes for the environments they create and execute these concepts. It represents a promising shift from conventional design methodologies, which often prioritize visual aesthetics, client preferences, or personal architectural preferences.

We are currently witnessing a significant paradigm shift in architectural research and practice, where the emerging field of neuroarchitecture places people at the center of design. As the concept of smart cities revolves around citizen-centric design, the interdisciplinary approach of neuroarchitecture holds great potential for enhancing human well-being.

Our ongoing objectives include defining empirical study experiments to:

- Investigate the emotional response process and its relationship with design. - Identify patterns connecting the emotional component to the user experience of digital products.
- Develop guidelines and strategies to help designers enhance emotional connections and human well-being in their designs.

We also plan to collaborate with experts in neuroscience, psychology, architecture, and related fields to interpret and validate our findings.

6 Conclusion

We believe that a deeper understanding of how the human body responds to various stimuli will empower architects to create more meaningful designs in the future. Our objectives are to translate research findings into practical design recommendations for architects, urban planners, and designers. We also aim to disseminate these findings through peer-reviewed journals, conferences, and publications to contribute to the growing body of knowledge in neuroarchitecture. Additionally, we plan to collaborate with professionals to implement neuroarchitecture principles in real-world projects.

Through a systematic investigation of neurological and psychological responses to architectural design, researchers seek to establish evidence-based design principles that enhance the quality of built environments and support human well-being. As this field advances, it has the potential to transform the way we design and interact with our surroundings, leading to more supportive and health-promoting spaces for everyone.

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