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The integrated design of neuroarchitecture for human well-being: A Comprehensive Review

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Abstract— Currently, smart buildings can connect humans to their built environment, which allows for creating sustainable buildings that are sensitive to users' behavioral and physical requirements to improve human well-being. Recent years have seen the emergence of the notion of "Neuroarchitecture," which combines the fields of neuroscience and architecture to design spaces that satisfy four fundamental aspects of human well-being. Through this, we are better able to comprehend how architecture may influence our well-being on several levels: physically the body, cognitively the brain, emotionally the emotions, and socially the behavioral. The present research aimed to do a comprehensive review on "neurological architecture," encompassing an elucidation regarding the idea, its foundational principles, diverse terms, structural attributes, and its effects on people. The current research employed a qualitative approach wherein researchers collected publications on neurological architecture. Published during the last decade. Subsequently, they developed a systematic review by employing descriptive, theme, narrative, and critical analytic techniques. The authors suggested and discussed a model called "Neuro-architecture" based on the articles chosen from the body of research. In conclusion, the physiological, psychological, cognitive, and behavioural impacts of architecture demonstrated via experiments using neuroarchitecture were presented in a manner that corresponded to the qualities of the design.

Keywords- *Neuroarchitecture, cerebral (Brain) development and activation, constructed environment, cognitive emotional design, Interior design, human wellbeing.*

I. INTRODUCTION

Neuroarchitecture is an interdisciplinary domain that integrates neuroscience and architecture to create environments that enhance cognitive performance, emotional health, and human behavior. Neuroarchitecture utilizes ideas from neurology, psychology, and environmental design to construct constructed spaces that improve health, productivity, comfort, and enjoyment [1]. However, the notion of neuroarchitecture started to attract interest in the early 21st century as developments in neuroscience offered an enhanced understanding of the human brain's perception, processing, and reaction to environments [2, 3]. As evidence-based design (EBD) gains prominence and the impact of environments on mental health becomes more apparent, architects and researchers have begun to integrate cognitive science, sensory perception, and biophilic design into architectural practice. Organizations such as the Academy of Neuroscience for Architecture (ANFA) have led efforts to advance research that merges neuroscience with architectural design [4, 5].

Nevertheless, the achievement of "Sustainable Cities and Communities" and "Good Health and Wellbeing" are two of the seventeen Sustainable Development Goals (SDGs) that are included in the program of the International Nations [6]. The movement regarding environmental responsibility and the establishment of a green construction sector has substantially emphasized the financial and ecological viability of buildings [7]. However, the social component of urban regenerating to enhance human well-being must additionally be properly recognized as it is equally essential. This is especially true in light of the fact that it is equitably significant [8]. The eight groups comprising the health of people include the physical, psychological, cognitive, communal, monetary, religious professional, and surroundings of an individual's lifestyle. By enabling ecologically sound structures to adapt to user behaviors and requests through data networks, contemporary smart buildings enable the connection between individuals and their created environment [9]. This, in turn, improves the standard of living for individuals. Currently, human-centered design and robust user-building interaction are the two most important aspects of intelligent building designs [10]. In the last fifty years, scholars spanning several disciplines, including design, science, technology, engineering, and Medicine (STEM), have sought to investigate the impact of the built surroundings on the health of people across multiple domains [11].

Furthermore, Neuroscientists have studied the notion of "environmental enrichments," which enhances human stimulation. In contrast to neutral situations, aesthetically rich circumstances can induce substantial alterations in emotions, cellular and molecular activity, behavioural patterns, and brain functions, all of which may impact human health and well-being [12]. Consequently, neuroscientists and academics from adjacent disciplines are collaborating to discover novel methods for elucidating the intricate relationship between environmental factors and their effects on humans: neurologically, physically, psychologically, and behaviourally. Innovative and more precise methodologies for analysing these alterations are now being formulated by integrating technology's and machine learnings [13]. In contemporary smart cities, designers may create real or virtual settings while managing several design elements using information and communication technology (ICT). Consequently, it is essential to investigate the built environment's impact on individuals to design environments that promote human wellbeing [14, 15].

A. Neuroarchitecture Contribution to Human Well-being

The influence of the constructed surroundings, which includes architecture, on psychologically mental wellness and overall happiness of humans has been the subject of a substantial bargain of research in the field of social science [16]. Nonetheless, several researchers have historically employed subjective instruments such as self-assessment questionnaires or participant narratives to evaluate well-being [17]. While subjective indicators are crucial in conveying individual experiences, such as emotions and perceptions, relying only on them for comparisons, measurement, and explanation of their impact on individuals is challenging. This occurs because, at times, our bodies can react to external stimuli before the cognitive processing of that information by our brains, as seen by changes in heart rate. Consequently, with the advancement of technical gadgets, researchers have lately employed digital instruments that monitor physiological reactions in various architectural settings [18]. For the purpose of evaluating feelings, the theoretical frameworks of affect that were covered in prior sections are utilized. The fact that they were designed on the basis of the association among excitement and enjoyment (activation) is a crucial point to emphasize while discussing them. This section outlines methods for monitoring brain activity associated with emotions and physiological changes using digital equipment [19].

B. The Most Effective Instruments in Neuroscientific

The modern technology advancements have enabled neuroscientists to properly detect brain activity and its direct correlation with the environment. Furthermore, neuroscience employs various instruments and approaches to investigate the brain's structure, function, and activity at several levels, ranging from molecular and cellular to cognitive and behavioral [20]. Nevertheless, the latest effective neuroscientific instruments employed to assess and comprehend cerebral activity encompass the following: Imaging techniques such as the (fMRI) techniques, it examines the influence of aesthetically pleasing and unappealing architectural environments on the cerebral's functioning activity through studying neural networks developed throughout emotive variations and visualizing mental representations linked to these occurrences. Additionally, it offers images of brain function concerning variations in the flow of blood. This corresponds with the correlation between cerebral blood flow and neurons firing. The science of cognition employs it [21, 22].

Furthermore, the second method is Electroencephalography (EEG), an innovative method for measuring cerebral electrical activity by affixing electrodes to the scalp. The combination of fMRI and EEG models can provide a more comprehensive understanding of neural networks and the activated regions of the brain during visual perception and emotional fluctuations. The third method is fNIRS, which refers to Functional Near Infrared Spectroscopy. Like fMRI, fNIRS employs near-infrared radiation to detect fluctuations in blood oxygenation, which correlate with brain activity [23, 24]. Magnetic resonance imaging (MRI), capable of producing high-resolution pictures of the brain's architecture, is the fourth treatment option. Positron Emission Tomography (PET), a technique that employs radioactive tracers to investigate metabolic activity in the brain, is the fifth treatment option. The sixth method is Magnetoencephalography (MEG), which provides great temporal resolution and monitors Magnetic waves produced by neurons in the brain. Diffusion Tensor Imaging (DTI), a specific kind of magnetic resonance imaging (MRI) that maps white matter pathways, is the last approach [25, 26].

However, intracranial electroencephalography (EEG) and electrocorticography (ECoG) are two further electrophysiological techniques that assess brain activity directly from the cortical surface. Second, microelectrode-based

Single-Unit Recording, which monitors neuronal activity in isolation. Last but not least is patch-clamp recording, which probes neuronal ion channel activity on a cellular level [27, 28]. In addition, noninvasive stimulation techniques like transcranial magnetic stimulation (TMS) employ magnetic fields to induce or suppress brain activity. Secondly, another option is tDCS, which uses a little electrical current to influence brain activity. Finally, one prevalent method for treating Parkinson's disease is Deep Brain Stimulation (DBS), which involves stimulating specific brain areas using implanted electrodes [29]. Also, chemogenetics and optogenetics involve the manipulation of light-sensitive ion channels expressed by genetically engineered neurons and the latter by means of light alone. And then, there's chemogenetics, which is short for "designer receptors exclusively activated by designer drugs," It's a way to regulate brain activity through synthetic chemicals that activate created receptors [30, 31].

Nonetheless, molecular and genetic instruments, such as CRISPR-Cas9, serve as gene-editing tools for altering DNA sequences in neurons. Secondly, RNA Sequencing (RNA-Seq) evaluates gene expression across various brain areas and cell types. Thirdly, In Situ Hybridization (ISH) visualizes particular RNA sequences inside neurons. Finally, Western Blot and Immunohistochemistry (IHC) are employed to identify proteins in brain tissue [32]. Simultaneously, behavioral and cognitive testing, including neuropsychological assessments, is a mental evaluation designed to assess memory, attention, executive function, and other cognitive domains. Secondly, animal models, including rats, primates, and other animals, investigate the brain processes underlying behavior. Finally, Virtual Reality (VR) and Augmented Reality (AR) are developing instruments for investigating cognition and perception in controlled settings [33, 34]. Furthermore, Computational and Theoretical Neuroscience encompasses Artificial Neural Networks (ANNs), which has been designed to mimic cerebral activity to reproduce brain processes. Secondly, Brain-Computer Interfaces (BCIs) are devices that serve as anatomical connections with the cerebral cortex and other systems outside it. Finally, connectomics entails the representation of neural networks at several levels [35, 36].

Conversely, the human brain is an intricate organ that regulates all physiological systems, emotions, and cognitive activities. It operates through several interrelated systems, each designated for maintaining homeostasis, processing information, and responding to stimuli. Nevertheless, the primary systems of the human brain encompass: Firstly, Central Control Systems, such as the Cerebral Cortex, represent a higher cognitive system and the brain's outermost layer, responsible for thinking, reasoning, memory, perception, and voluntary movement. It is split into four lobes: The frontal lobes are responsible for decision-making, problem-solving, and motor control. The parietal lobe handles tactile sensations, nociception, and spatial orientation. The temporal lobe controls auditory processing, memory, and language functions. The occipital lobe handles visual information [37]. Secondly, the Limbic System regulates emotions, memory, and motivation. Key structures include the hippocampus, essential for memory formation and learning. The amygdala handles emotions such as fear and pleasure. The hypothalamus regulates appetite, thirst, body temperature, and hormonal activity. The thalamus functions as a sensory relay system, serving as a conduit for sensory information before its transmission to the cerebral cortex [38]. The Basal Ganglia is a motor control system regulating voluntary movements, learning, and habitual behaviors. Thirdly, communication and coordination systems, such as the brainstem, operate as the autonomic control system that governs essential processes, including heart rate, respiration, and digestion. The midbrain handles auditory and visual information. The ponses facilitate sleep, respiration, and intercommunication among many brain regions [39].

II. BACKGROUND THEORY OF NEUROARCHITECTURE

Neuroarchitectural research is a collaborative discipline that integrates neuroscience and architecture to investigate the influence of the constructed surroundings on the brains of people, behavior, and wellness. Its theoretical foundation is based on the notion that our environment directly influences our mental and emotional functions [40]. However, the following section elucidates neuroarchitecture's notion and foundational concepts, providing acomprehensive discussion of the primary word, its interrelation among its constituent areas, and its synonymous terminology.

A. Definition of The Principal Term

Neuroarchitecture has just emerged to reveal the significant impact architecture may exert on individuals. Neuroarchitecture is a multidisciplinary domain described as architecture developed according to concepts derived from neurology. Consequently, it makes it easier to create situations that encourage intellectual stimulation and have an effect on human psychology and physiology, which in turn reduces stress [41]. In addition to this, it has the ability to influence human actions and achievements, as well as improve human well-being. Dunn asserts that enriched settings providing sensory stimulation facilitate brain growth and enhance mental wellness in youngsters. Neuroarchitecture consists of four primary connected pillars: neuroscience, architecture, physiology, and psychology, regarding feelings and actions. Additional areas related to neurology might have tangential links to neurological architecture [42].

However, what is known as neurology is the academic study of the neural network, encompassing the brain, the vertebral column, and nerves throughout the body, as well as the processes that occur inside each of these systems. In and of it, component neuroscience is a medical discipline that examines the anatomy and function of the brain and spinal cord. Brain cells serve as the neural basis for the creation of memories, learned behaviors, impressions, and consciousne, therefore, these technological advances are absolutely necessary [43]. Over the course of its development, the field of neurobiology has gradually evolved to incorporate a wide range of approaches for exploring the workings and condition of the nervous system from a variety of perspectives, including architectural. These multidisciplinary studies are now being conducted in the domains of physiological science, mental health, computational healthcare, and various other fields that seek to elucidate the fundamental and newly identified characteristics of brains and neural systems [44].

B. Architecture-Emotion Connection

The perspectives humans have of the built environment consider aspects beyond the area's visible and physical qualities. Their perceptions about the environment are important in inferring their subjective descriptions of their feelings towards the surroundings, such as safe, calm, comfortable, dull, fascinating, and strange [45]. An individual's emotions, those are sometimes referred to as "the shortest song range feelings," and their consequences, those are related to as "long term feelings," are altered when they have access to their environment. Prior research has established that certain components of the design of buildings, including size, orders, adequate, height, the field of geometry, scales, and depth, can evoke emotional responses in individuals. The constructed surroundings demonstrate its capacity to affect humans' thoughts or sentiments. [46]. An individual's response to the environment is determined by emotional appraisal, which occurs after the individual has experienced these feelings. The factual and subjective effects of the environment on humans are the basis for deciding whether or not they find either a pleasant or an awful atmosphere [45, 46].

Additionally, the most effective models for assessing feelings incorporate ecological psychology. According to behavioral psychology, pleasure and arousal are two primary aspects of human feelings when exposed to the built environment, which describe the emotional experiences of humans. The effect might range from pleasurable to unfavorable as well as from stimulating to non-arousing, according to their "environmental issues psychology model." The fundamental influence, on the other hand, is defined by the supplementary model concept of "fundamental impact" as the corporeal neurophysiological condition that develops in people. This phenomenon is characterized by a subjective emotional experience dimension as well as a stimulation component [47]. A total of sixteen separate descriptors were incorporated into the previous model, which ranged from pleasure, which was described as "pleasant to unpleasant," to arousal, which was described as "high engagement to low stimulation." This paradigm posits that environments are preferred when they are pleasant and remarkable [46, 47]. Additionally, a third conceptual model of human primary emotional responses encompasses pleasure, characterised by happiness in contrast to sadness; dominance, defined as control versus obedience; and arousal, which pertains to stimulation for action as opposed to a lack thereof. These responses are shaped by surroundings components and personality-related emotions, like the joy derived from observation or engagement in activities [47, 48].

C. Neuroscience-Architecture Perception Connection

The foundation of perception is the process by which people are influenced by their surroundings, get information from those surroundings, and comprehend those surroundings by the ambient inputs which activate the senses in them. This could transpire both deliberately and inadvertently. In the course of its inquiry of psychological stimulation brought about emotions, the researchers realized that when people are exposed to particular feelings, particular regions of their brains might become active [49]. One of these regions is the primary visual cortex, which is the portion of the brain that is in charge of making visual perceptions. Moreover, during the process of determining the aesthetic appeal of construction in the context of produced environments, the components of the nervous system known as "orbitofrrontal cortex" and "subcallosal cingulate gyrus" of architects were shown to be more aroused of those who were not affiliated with the architectural profession [50, 51].

In addition, an examination of research that was conducted in the past revealed that the activation of the peripheral nervous system occurs when one is experiencing feelings of joy or sadness. As an illustration, the amygdala region of

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the brain is connected with the processing of feelings or mental pictures of pleasantness when an individual is exposed to stimuli in their surroundings [52]. In addition to its function in the processing of emotions and the reception of information from various perceived sources, the amygdala is also capable of transmitting signals to the brain's cerebral cortex, which is responsible for regulating awareness [53]. It is also possible for the amygdala to function as a regulator of both the behavior and responses of the body at the exact same moment whenever signals are passed from the hypothalamus to the autonomic nervous system and by the muscles of the skeleton [54]. The brains are responsible for improving concentration with regards to feelings and actions, taking decisions, memory, inspiration, cognitive mental processes, and perception of visuals, as a consequence of which a number of studies have highlighted its importance in contributing to a huge brain network. In order to create situations within the interior that are favorable to people's well-being, it is necessary to do study on the link among environmental stimuli in the environment and the brain [55, 56].

Additionally, any harm that is done against the neurological systems of the organism has a possibility of produce inadequacies in how humans respond to the created environment, which includes the construction of the structure itself. This is the case regardless of the nature of the injury [57]. Insufficiencies within the occipital cortex of the cerebral cortex, which belong to the parts situated at the rear of the brain and that are accountable for perception of sights, have the possibility of have a negative effect on the manner in which human beings react their sensory data obtained from the configuration of an area, encompassing what it can do to discern objects. This is because the oblique lobes are accountable for perception of sight. Conversely, another cohort of researchers concluded that dysfunctions in the occipital, parietal and temporal lobes may influence spatial perceptions of architectural attributes including "space, motion, and depth," along with elements like "form, color, and object recognition" [58]. The researchers arrived at this result. In a similar manner, inadequacies in the superior and middle temporal gyri can have an effect on the movement behaviour that is required for visuospatial experiences. Additionally, problems in the fusiform gyrus can have an effect on the ability to understand architectural styles since it contains brain representations for different architectural styles. In addition, aberrations in the central nervous system and the core accumbens, with medial prefrontal cortex may have an effect on the ability to convey emotions and their perception, as well as the ability to sense pleasure and learn, respectively [57, 58].

D. Neuroarchitecture Cyclic Model Proposed

When we talk about perception, we are referring to the capacity to visualize, listen to, and recognize the world that has been built by architecture. This capability is accomplished by the existence of cognitive processes in the environment. Cognitive processes, conversely, they are the cognitive processes that allow us to gather knowledge from our environment and interpret it by our memories and perceptions [59]. As a consequence of this, our capacity to form opinions and form judgments is enhanced. Perception and cognition, which were traditionally identified with psychology as a component of the study of mind and the study of thought is today seen as a field associated with neurology, and it's intrinsically linked to physiology.

This is an essential point to emphasize, according to the researchers, since it is crucial to remember that perception and cognition were once associated with psychology [60, 61]. Therefore, they are assembled together in the same manner as they were done and expressed by individuals who used the words neuroscience and cognitive science interchangeably. This implies that they are consistent with one another. Due to the general opinion, if psychological research, that examines all functions related with the brain's activity, were truly separated by its physical foundational research, understanding and interpreting it could become challenging. This indicates that such is the situation [62]. In addition to providing evidence that the nuanced intellectual and rigorous physiological explanations of the nervous system functioning are growing increasingly linked, the progress of technology has made it feasible for digital equipment to aid us in integrating the two types of readings of brain functioning called "soft cognitive" and "hard biological" [63, 64].

At the same time as they were developing neuroarchitecture, the researchers came up with a cycle model to illustrate the connection between design, neurology which encompasses "neural functions, perception, and cognition", biology, and mental which accounts for feelings and behavior as shown in below Figure 1. The first stimulus is architecture, although the circular loop remains closed and ongoing during the process [65]. Architecture acts as the first stimulus. Each and every setting is designed to incorporate a variety of stimuli that have an effect on the feelings that people experience. Certain parts of the brain are stimulated by these inputs, which in turn are responsible for initiating cognitive processes. If these stimuli are allowed to continue over an extended period of time, they may even result in the formation of new neurons, which can lead to changes in the neurological system [66]. According to the specifics

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of the situation, this reaction may have an impact on the choices that individuals make or may have consequences for the way they behave [67, 68]. The "theta and alpha bands" in the left-hand prefrontal areas of the brain, which are important for spatial navigation, can be triggered by the sensation of pleasure regions of the brain. These regions are linked to the ability to navigate spatial environments. Changes in human physiological condition, such as fluctuations in blood pressure, can be brought about by a variety of stimuli that originate from the built environment. These changes can take place at any instant, even before consciousness within people is even present [69, 70].

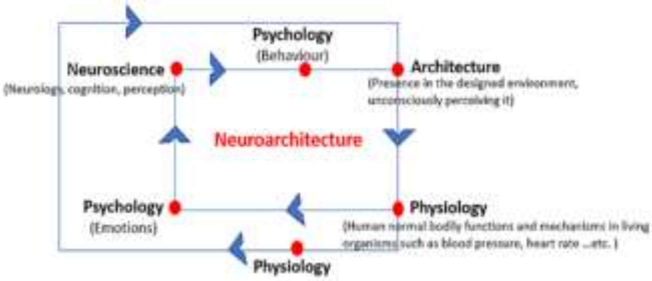

Figure.1. The interconnection among the fundamental components of Neuroarchitecture

Conversely, the loop remains intact as adverse effects from neurological defects may impair the interpretation of inputs inside the built setting, leading to the individual overlooking crucial data about their surroundings, including architectural elements. Consequently, this may lead to detrimental physiological, emotional, cognitive, and behavioural outcomes [71]. Conversely, positive effects may stimulate enhancements in specific brain regions, inducing physiological and psychological transformations. Cognitive-emotional and affective designing concepts have presently refered synonymously by neuroarchitecture in its literature. The primary distinction is that the initial two phrases may be applied concurrently across other design disciplines influencing cognition and emotions, such as art, whereas neuroarchitecture is exclusively linked to architecture [72, 73].

III. THE PURPOSE OF THE REVIEW

This study aims to examine journal publications that propose architecture grounded in neuroscience. The review will assess whether the current literature has promoted the integration of this notion into regarding indoor constructed settings or provided data concerning its effect on the health of people. The researchers aim to delineate the recently introduced concept "Neuroarchitecture" and investigate its possible mental, psychological, behavioral, and biological implications on people should these consequences be present. This text examines a couple of questions: what is the neuro-architecture of the built setting, what are its fundamental components, how can it be demonstrated, and what is the significance of neurological architecture for the health of humans.

IV. THE SIGNIFICANCE OF THE REVIEW

In prior decades, proponents of environmentally friendly building primarily concentrated on structural safeguarding, ecological efficiency of structures, and the financial dimensions of community sustainability. The article, which is based on the societal ecological standpoint of SMART designs for buildings, clarifies methods for evaluating the people-centered aspect of construction that prioritizes the health of people. It underscores the importance of integrating Neuroarchitecture into the sustainable construction process by illustrating its proven impacts on persons.

V. METHODOLOGY

The evaluation in question is a qualitative approach to systematic review. Over the course of the past decade (2015–2024), it focuses on journal articles that were published in English in peer-reviewed scientific journals accessible via Web of Science, Science Direct, Taylor & Francis, Scopus, Wiley, EBSCO, and Springer. Because of the tremendous developments in neuroarchitecture that have occurred over the past decade, the researchers focused their attention on the previous ten years. These advancements have been driven by the rise computational training and technological advancements have enabled a more precise examination of neurological architecture layout and its effects on individuals. Rather than concentrating on the neurological architecture development of the structure itself, the majority of systematic reviews that have been conducted over the past ten years have largely focused on unraveling the mysteries of neuroscience or the neuroarchitecture of the brain. New terminology approaches, and processes have been established in the field of neuroarchitecture as a result of research conducted over the past ten years. These studies have focused on the incorporation of neuroarchitecture into the design of physical environments and its influence on people through the use of investigations that have integrated neuroarchitecture.

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The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) approach was utilized for the process of conducting this study. The findings of the research that was carried out in May of 2025 revealed a total of 2,675 studies. A total of 2,610 studies were left investigations that were conducted in languages other than English were disregarded due to difficulties in providing an appropriate translation and time constraints. Ultimately, the authors choose study that examines neurological architecture via the lens of constructed surroundings. They omitted perspectives including neurological science, individual physiology, and the field of neuroscience, culminating in an aggregate of 245 papers. The researchers refined their research by multiple fields. The present inquiry focuses exclusively on architectural elements in a structure, hence excluding studies concerning interaction with urbanized and external surroundings. After analyzing all of the remaining publications, the study was categorized into six principal topics, each coupled with a corresponding subtheme related to the major theme. The researchers concluded that the present paper exclusively examines themes one and two, as it addresses the inquiry objectives of the research project and presents a thematic review of the results in a narrative with descriptions. The researchers established multiple "a high standard refining" parameters to ensure the results were of superiority. The previous requirements were employed to direct the pick of the ultimate quantity of investigations. On the basis of experimental procedures carried out with participants, the papers that have been selected as systematic reviews provide answers to the research issues that are being investigated in this study. By utilizing digital instruments that are specifically designed to evaluate impacts on humans, in conjunction with proven psychological models, these studies illustrate the influence that the built environment has on human well-being. Rather than depending merely on surveys or rating scales, this research reveals the impact that the built environment. Furthermore, after the elimination of additional investigations, a total of forty researches were found to be in accordance with the selection criteria. With regard to these studies, this assessment includes a comprehensive analysis. Figure 2. Below illustrates the PRISMA following process.

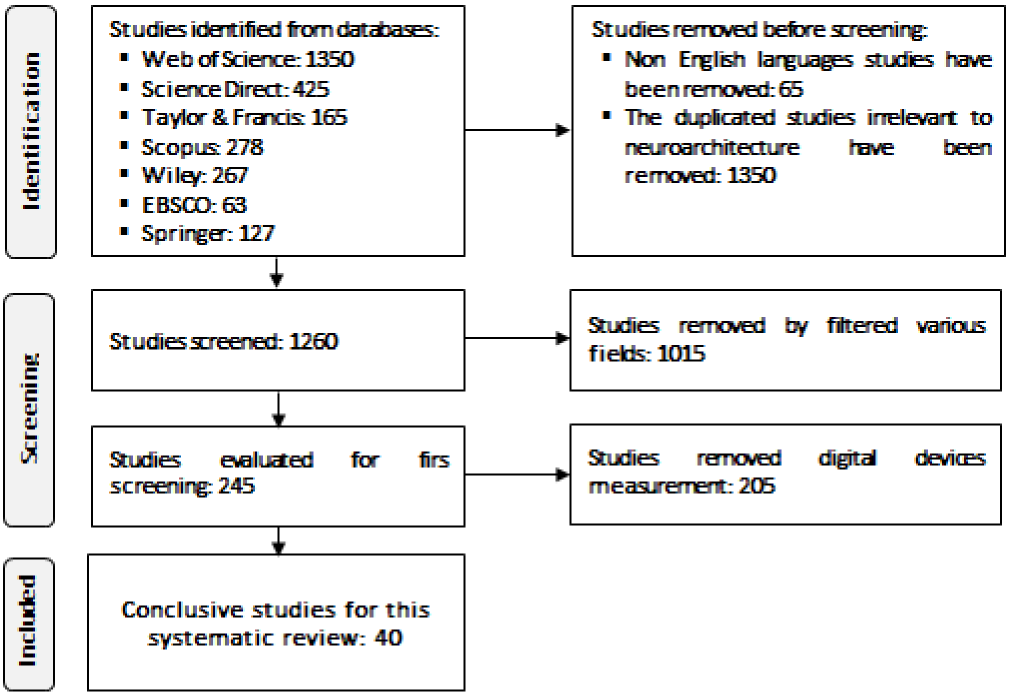

Figure.2. Methodology after PRISMA Steps for This Systematic Review.

VI. RESULTS AND RESTRICTION

All of the results and restrictions of this systematic review are presented in this section. Nevertheless, the interior constructed environments explored in the research contain two distinct settings include physical environments, in which individuals experience a room with regulated circumstances, and virtual settings, wherein individuals engage with a pre-established simulated context. The two kinds of habitats were examined. Additionally, there exist two categories of virtual settings: the Cave Automatic Virtual Environment (CAVE), which employs four projections or devices to construct a spatial area comprising three partitions and a platform, which is termed a "semi-enclosure," and a complete enclosing known as a simulated image of a confined, intended space which attendees' access by donning an item affixed to their forehead [39, 40]. Scholars can assess and analyze the physiological and neurological responses of individuals engaged in and traversing structured, monitored settings through the use of virtual reality (VR). This is because many architectural literatures imply that mobility is particularly important for perception and emotion [41, 42].

Additionally, researchers might meet the four pillars of human welfare via conduct in space by utilizing neuro architecture. These pillars include human wellness's physical, emotional, intellectual, and social aspects. It was possible to do this because of the interrelationship between these four components. The foundations of neuroarchitecture and the components that contribute to human well-being include physiology, physicat echniques, feelings mental behavior, and cognitive [43]. The study's findings revealed that individuals were influenced by being around a number of elements of the indoor setting. This was the case in both types of controlled settings, which are virtual and physical environments simultaneously [44]. However, only a few studies that met the criteria for selection were discovered to investigate the effects of scents or colours that were predominantly dark. Using natural materials, such as wood, resulted in a reduction in the cardiac pulse and perspiration reaction of individuals, devoid of their cognitive knowledge, in the virtual and actual surroundings. This was one of the most notable discoveries about design aspects [45]. Within the context of an architectural experience, physiological changes occurred either with or without awareness. The individuals' blood flow varied in certain brain regions, and a link was observed between these fluctuations and emotional changes. This association demonstrated that emotions might impact wellness by modulating the body's immune response [46].

Considering that there is evidence to show feelings may impact brain function in fields linked to focus, recall, inspiration, feelings attitude, and decisions. As a result, studies have been undertaken in schools and hospital environments to modify behaviors. This research has concentrated on enhancing studying, mental health, and general well-being, as well as expediting the process of recovery [47]. The results indicate that agreeable settings exert a greater influence on cognitive function than disagreeable surroundings. The use of fMRI has demonstrated that exposure to favorable stimuli from the outdoors, including pleasurable locales, activates distinct areas of the brain compared to exposure to adverse stimuli, for as unfavorable places [48]. In each instance, it was also shown that there were disparities in the regions of the brain that were stimulated in males and females. Among the brain regions that were shown to be active in every single instance, in both males and females, were the occipital and limbic lobes, which are accountable for how we perceive things as well as behavioral and emotional responses reactions, separately [49].

On the other hand, the research utilized a wide range of measurement methods on human subjects, making it challenging to compare the results of various experiments or connect them with one another [50]. Because many variables change concurrently in a manner that is not systematic, it is difficult to determine the influence that the impact of each perceptual aspect on the nervous system and cerebral cortex in experiments performed inside multimodal actual contexts [51]. To properly evaluate the many changes that have occurred in the variables of the environment, it is necessary to establish a suitable method for statistical analysis [52]. Moreover, to restrict the variables in specific trials and evaluate the influence of particular elements, it is essential to fix some of them, even though they would significantly impact the interior design if they were allowed to change [55]. Either the number of people who participated in the research was low, or they were all of the same age or belonging to the same group, such as students. Furthermore, a handful of the literature studies employed an objective evaluation method, without considering the subjective component that the participants provided. This would have provided further depth to the data that was gathered from their experiencing of the environment [70, 73].

VII. CONCLUSION

This systematic review explains fully, to what extent this field of inquiry is being studied, through which individuals, and which methodologies for analyzing feelings and neural processes currently exists. A description for the concept of neurological architecture was offered. The researchers described the relationship connecting neural architecture, neurological science, feelings, mental processes, awareness, behaviourl, and biological alterations in the recommended "periodic paradigm for neurological architecture.". The information processing approaches employed across the examined study exhibited a shortage of standardization. The employed statistics analysis necessitated further assessment with greater numbers of samples to yield greater certainty outcomes. To delineate the advancements achieved in the domain, namely the behavioral, psychological, biological, and cognition effects of neurological architecture features on individuals. The incorporation of Neuroarchitecture is likely to positively impact individuals engaged in promoting human well-being. It is recommended to establish standards that include neurological architecture concepts based on the identified effects on individuals. This overview can assist architects, researchers in Neuroarchitecture, officials, and users in their work with buildings.

REFERENCES

[1] E. Elbaiuomy, I. Hegazy, and S. Sheta, "The impact of architectural spaces' geometric forms and construction materials on the users' brainwaves and consciousness status," Int. J. Low-Carbon Technol., vol. 13, no. 1, pp. 43–51, 2018. Retrieved from doi: 10.1093/ijlct/ctx018.

[2] Z. Dai, J. Xue, and S. Wang, "Effects of wood texture and color on aesthetic pleasure: two experimental studies," Int. J. Reconfigurable Embed. Syst., vol. 12, no. 1, pp. 125–134, 2023. Retrieved from doi: 10.11591/ijres.v12.i1.pp125-134.

[3] L. Y. Liu and X. J. Fan, "The Design of System to Texture Feature Analysis Based on Gray Level Co-Occurrence Matrix," Appl. Mech. Mater., vol. 727–728, pp. 904–907, 2015. Retrieved from doi: 10.4028/www.scientific.net/amm.727-728.904.

[4] S. Sakuragawa, T. Kaneko, and Y. Miyazaki, "Effects of contact with wood on blood pressure and subjective evaluation," J. Wood Sci., vol. 54, no. 2, pp. 107–113, 2018. Retrieved from doi: 10.1007/s10086-007-0915-7.

[5] H. Paluš, H. Mat'ová, and V. Kaputa, "Consumer preferences for joinery products and furniture in Slovakia and Poland," Acta Fac. Xylologiae, vol. 54, no. 2, pp. 123–132, 2012.

[6] O. Høibø and A. Q. Nyrud, "Consumer perception of wood surfaces: The relationship between stated preferences and visual homogeneity," J. Wood Sci., vol. 56, no. 4, pp. 276–283, 2020. Retrieved from doi: 10.1007/s10086-009-1104-7.

[7] M. Nakamura and T. Kondo, "Quantification of visual inducement of knots by eye-tracking," J. Wood Sci., vol. 54, no. 1, pp. 22–27, 2008. Retrieved from doi: 10.1007/s10086-007-0910-z.

[8] A. Q. Nyrud, T. Bringslimark, and K. Bysheim, "Benefits from wood interior in a hospital room: A preference study," Archit. Sci. Rev., vol. 57, no. 2, pp. 125–131, 2024. Retrieved from doi: 10.1080/00038628.2013.816933.

[9] A. Manuel, R. Leonhart, O. Broman, and G. Becker, "Consumers' perceptions and preference profiles for wood surfaces tested with pairwise comparison in Germany," Ann. For. Sci., vol. 72, no. 6, pp. 741–751, 2015. Retrieved from doi: 10.1007/s13595-014-0452-7.

[10] T. Ramananantoandro, M. F. Ramanakoto, A. H. Rajemison, and F. Eyma, "Relationship between density and aesthetic attributes of wood and preference of Malagasy consumers," Ann. For. Sci., vol. 70, no. 6, pp. 649–658, 2023. Retrieved from doi: 10.1007/s13595-013-0299-3.

[11] A. Aloumi, S. Noroozi, B. Eves, and M. Dupac, "The impact of color contrast on the perception of complexity–simplicity of design product," Int. J. Des. Creat. Innov, vol. 1, no. 4, pp. 233–254, 2013. Retrieved from doi: 10.1080/21650349.2013.773879.

[12] A. Yoonessi and Q. Zaidi, "The role of color in recognizing material changes," Ophthalmic Physiol. Opt., vol. 30, no. 5, pp. 626–631, 2020. Retrieved from doi: 10.1111/j.1475-1313.2010.00722.x.

[13] S. Silva, B. Sousa Santos, and J. Madeira, "Using color in visualization: A survey," Comput. Graph, vol. 35, no. 2, pp. 320–333, 2011. Retrieved from doi: 10.1016/j.cag.2010.11.015.

[14] S. W. Hsiao and Y. C. Ko, "A study on bicycle appearance preference by using FCE and FAHP," Int. J. Ind. Ergon., vol. 43, no. 4, pp. 264–273, 2013. Retrieved from doi: 10.1016/j.ergon.2013.04.003.

[15] M. A. Artacho-Ramírez, J. A. Diego-Mas, and J. Alcaide-Marzal, "Influence of the mode of graphical representation on the perception of product aesthetic and emotional features: An exploratory study," Int. J. Ind. Ergon., vol. 38, no. 11–12, pp. 942–952, 2008. Retrieved from doi: 10.1016/j.ergon.2008.02.020.

[16] A. H. Ghaffarian, and et al., "What is an intelligent building? Analysis of recent interpretations from an international perspective," Arc hit Sci Rev Sep, 59 (5):338–57, 2016. Retrieved from doi: https://doi.org/10.1080/00038628.2015.1079164.

[17] A. D. Paiva, and R. Jedon, "Short- and long-term effects of architecture on the brain: Toward theoretical formalization," Frontiers of Architectural Research, 8(4):564–71, 2019. Retrieved from doi: https://doi.org/10.1016/j.foar.2019.07.004.

[18] I. Bower, R. Tucker, and P. Enticott, "Impact of built environment design on emotion measured via neurophysiological correlates and subjective indicators: A systematic review," Journal of Environmental Psychology, Academic Press, vol. 66, 2019. Retrieved from doi: 10.1016/j.jenvp.2019.101344.

[19] N. Khaled, H. Bala, G. Özmen, and S. Öztürk, "Neuroscience and architecture: What does the brain tell to an emotional experience of architecture via a functional MR study," Frontiers of Architectural Research, 2022. Retrieved from doi: https://doi.org/10.1016/j.foar.2022.02.007.

[20] E. Nicolini, "Built Environment and Wellbeing-Standards, Multi-Criteria Evaluation Methods, Certifications," Sustainability (Switzerland), vol. 14, no.8, 2022. Retrieved from doi: 10.3390/su14084754.

[21] A. Shemesh, R. Talmon, O. Karp, I. Amir, M. Bar, and Y. Grobman, "Affective response to architecture–investigating human reaction to spaces with different geometry," Ar chit Sci Rev Mar, 60(2):116–25, 2017. Retrieved from doi: https://doi.org/10.1080/00038628.2016.1266597.

[22] M. Banaei, J. Hatami, A. Yazdanfar, and K. Gramann, "Walking through architectural spaces: The impact of interior forms on human brain dynamics," Front Hum Neurosci, Vol. 11, 2017. Retrieved from doi: https://doi.org/10.3389/fnhum.2017.00477.

[23] G. Vecchiato, G. Tieri, A . Jelic, F. Matteis, A. Maglione, and F. Babiloni, "Electroencephalographic correlates of sensorimotor integration and embodiment during the appreciation of virtual architectural environments," Front Psychol, vol. 6, 2015. Retrieved from doi: https://doi.org/10.3389/fpsyg.2015.01944.

[24] M. Llorens-Gámez, J. Higuera-Trujillo, C. Omar, and C. Llinares, "The impact of the design of learning spaces on attention and memory from a Neuroarchitecture approach: A systematic review," Frontiers of Architectural Research, Higher Education Press Limited Company, vol. 11, no. 3, pp. 542–560, 2022. Retrieved from doi: 10.1016/j.foar.2021.12.002.

[25] D. Ahmed, S. Kamel, and L. Khodeir, "Exploring the Contribution of Neuroarchitecture in Learning Environments Design a review," International Journal of Architectural Engineering and Urban Research, 4(1):102–19, 2024. [Online]. Retrieved from www.egyptfuture.org/ojs/

[26] S. J. Robinson, "Dewey and the dialogue between architecture and neuroscience," Arc hit Res Q, 19(4):361–7, 2015. Retrieved from doi: https://doi.org/10.1017/S1359135515000627

[27] J. W. Rowe and et al., "Daedalus: What is the Brain Good For?," Journal of the American Academy of Arts & Sciences, 2015. [Online]. Retrieved from www.amacad.org.

[28] E. Elbaiuomy, I. Hegazy, and S. Sheta, "The impact of architectural spaces geometric forms and construction materials on the user's brainwaves and consciousness status. International Journal of Low-Carbon Technologies," 13 (1):43–51, 2018. Retrieved from doi: https://doi.org/10.1093/ijlct/ctx018.

[29] M. Cho, and M. Kim, "Measurement of User Emotion and Experience in Interaction with Space," Journal of Asian Architecture and Building Engineering, 16 (1), pp. 99–106, 2018. Retrieved from doi: https://doi.org/10.3130/jaabe.16.99.

[30] P. D. Andréa, "Neuroscience for Architecture: How Building Design Can Influence Behaviors and Performance," Journal of Civil Engineering and Architecture, vol. 12, no. 2, 2018. Retrieved from doi: 10.17265/1934-7359/2018.02.007.

[31] M. Hu, J. Roberts, "Built Environment Evaluation in Virtual Reality Environments—A Cognitive Neuroscience Approach," Urban Sci, 4 (4):48, 2020. Retrieved from doi: https://doi.org/10.3390/urbansci4040048.

[32] W. Zheng, "Spatial patterns of decreased cerebral blood flow and functional connectivity in multiple system atrophy (cerebellar-type): A combined arterial spin labeling perfusion and resting state functional magnetic resonance imaging study," Front Genet 2019, 10(JUL). Retrieved from doi: https://doi.org/10.3389/fnins.2019.00777.

[33] O. Vartanian, and et al, "Architectural design and the brain: Effects of ceiling height and perceived enclosure on beauty judgments and approach-avoidance decisions," J Environ Psychol, 41:10–8, 2015. Retrieved from doi: https://doi.org/10.1016/j.jenvp.2014.11.006.

[34] A. Shemesh, G. Leisman, M. Bar, and Y. Grobman, "The emotional influence of different geometries in virtual spaces: A neurocognitive examination," J Environ Psychol j.jenvp.2022.101802 Jun, Vol. 81, 2022. Retrieved from doi: https://doi.org/10.1016/.

[35] D. Shah, E. Kames, J. Pelham, and B. Morkos, "Design Evaluations in Educational Settings: A Neuroscientific Study of Incentivized Test/Retest on Student Performance," J Computer Info Sci Eng, 22(3), 2022. Retrieved from doi: ttps://doi.org/10.1115/1.4053801.

[36] T. Karakas, and D. Yildiz, "Exploring the Influence of the Built Environment on Human Experience through a Neuroscience Approach: A Systematic Review," Frontiers of Architectural Research, 2020. Retrieved from doi: https://doi.org/10.1016/j.foar.2019.10.005.

[37] J. Bermudez, and et al., "Externally-induced meditative states: an exploratory fMRI study of architects' responses to contemplative architecture," Frontiers of Architectural Research, 6(2):123–36, 2017. Retrieved from doi: https://doi.org/10.1016/j.foar.2017.02.002.

[38] G. Vecchiato, A. Jelic, G. Tieri, A. Maglione, F. D. Matteis, and F. Babiloni, "Neurophysiological correlates of embodiment and motivational factors during the perception of virtual architectural environments," Cogn Process Sep, 16:425–9, 2015. Retrieved from doi:https://doi.org/10.1007/s10339-015-0725-6.

[39] J. Li, C. Luo, Q. Zhang, and R. Shadiev, "Can Emotional Design Really Evoke Emotion in Multimedia Learning?" International Journal of Educational Technology," High Edu, 17(1), 2024. Retrieved from doi: https://doi.org/10.1186/s41239-020-00198-y.

[40] J. Higuera-Trujillo, C. Linares, and E. Macagno, "The cognitive-emotional design and study of architectural space: A scoping review of Neuroarchitecture and its precursor approaches," Sensors, vol. 21, no. 6. MDPI AG, pp. 1–47, 2021. Retrieved from doi: 10.3390/s21062193.

[41] S. Ergan, A. Radwan, Z. Zou, H. Tseng, and X. Han, "Quantifying Human Experience in Architectural Spaces with Integrated Virtual Reality and Body Sensor Networks," J computes Civ Eng, 33(2), 2019. Retrieved from doi: https://doi.org/10.1061/ (ASCE) cp.1943-5487.0000812.

[42] X. Zhang, Z. Lian, and Y. Wu, "Human physiological responses to wooden in door environment," Physiol Behav, 174:27–34, 2017. Retrieved from doi: https://doi.org/10.1016/j.physbeh.2017.02.043.

[43] A. M. Hossain, M. Homolja, M. S. Aurel, and A. H. Maghool, "The Impact of Moving through the Built Environment on Emotional and Neurophysiological State-A," Systematic Literature Review, 2020. [Online]. Retrieved from https://www.researchgate.net/publication/344646721.

[44] H. Choo, J. Nasar, B. Nikrahei, and D. B. Walther, "Neural codes of seeing architectural styles," Sci Rep Jan, Vol. 7, 2017. Retrieved from doi: https://doi.org/10.1038/srep40201.

[45] D. Pati, O. M. Boyle, J. Hou, U. Nanda, and H. Ghamari, "Can Hospital Form Trigger Fear Response?" Health Environments Research and Design Journal, 9 (3):162–75, 2016. Retrieved from doi:https://doi.org/10.1177/1937586715624210.

[46] J. Qin, C. Sun, X. Zhou, H. Leng, and Z. Lian, "The Effect of Indoor Plants on Human Comfort," Indoor Built Environ, 23(5):709–23, 2014. Retrieved from doi: https://doi.org/10.1177/1420326X13481372.

[47] P. Barrett, F. Davies, Y. Zhang, and L. Barrett, "The Holistic Impact of Classroom Spaces on Learning in Specific Subjects," Environ Behav, 49(4):425–51, 2017. Retrieved from doi: https://doi.org/10.1177/0013916516648735.

[48] Y. H. Min, and S. Lee, "Does interior color contrast enhance spatial memory?" Color Res Apple Apr, 45(2):352–61, 2020. Retrieved from doi: https://doi.org/10.1002/col.22463.

[49] C. Llinares, J. L. Higuera-Trujillo, and J. Serra, "Cold and warm coloured classrooms. Effects on student's attention and memory measured through psychological and neurophysiological responses," Build Environ, 196, 2021. Retrieved from doi: https://doi.org/10.1016/j.buildenv.2021.107726.

[50] J. L. Higuera-Trujillo, C. M. Llinares, i. A. Montañana, and J. C. Rojas, "Multisensory stress reduction: a neuro-architecture study of pediatric waiting rooms," Build Res Info Apr, 48(3):269–85, 2020. Retrieved from doi: https://doi.org/10.1080/09613218.2019.1612228.

[51] C. M. Llinares, J. L. Higuera-Trujillo, I. A. Montañana, J. Torres, and C. Sentieri, "The influence of classroom width on attention and memory: virtual-reality based task performance and neurophysiological effects," Build Res Info, 49 (7):813–26, 2021. Retrieved from doi: https://doi.org/10.1080/09613218.2021.1899798.

[52] P. Barrett, F. Davies, Y. Zhang, and L. Barrett, "The impact of classroom design on pupils' learning: Final results of holistic, multi-level analysis," Build Environ, 89:118–33, 2015. Retrieved from doi: https://doi.org/10.1016/j.buildenv.2015.02.013.

[53] D. Pati, P. Freier, M. O'Boyle, C. Amor, and S. Valipoor, "The Impact of Simulated Nature on Patient Outcomes: A Study of Photographic Sky Compositions," Health Environments Research and Design Journal, 9(2):36–51, 2016. Retrieved from doi: https://doi.org/10.1177/1937586715595505.

[54] S. Jamshidi, J. S. Parker, and S. Hashemi, "The effects of environmental factors on the patient outcomes in hospital environments: A review of literature," Frontiers of Architectural Research, vol. 9, no. 2. Higher Education Press Limited Company, pp. 249–263, 2020. Retrieved from doi: 10.1016/j.foar.2019.10.001.

[55] N. Castilla, C. Llinares, F. Bisegna, and V. Blanca-Giménez V, "Affective evaluation of the luminous environment in university classrooms," J Environ Psychol, 58:52–62, 2018. Retrieved from doi: https://doi.org/10.1016/j.jenvp.2018.07.010.

[56] N. Castilla, C. Llinares, F. Bisegna, and V. Blanca-Giménez, "Emotional evaluation of lighting in university classrooms: A preliminary study," Frontiers of Architectural Research, 7(4):600–9, 2018. Retrieved from doi: https://doi.org/10.1016/j.foar.2018.07.002.

[57] P. S. Robinson, and J. Green, "Ambient versus traditional environment in pediatric emergency department," Health Environments Research and Design Journal, 8(2):71–80, 2015. Retrieved from doi: https://doi.org/10.1177/1937586714566412.

[58] M. Banaei, A. Ahmadi, K. Gramann, and J. Hatami, "Emotional evaluation of architectural interior forms based on personality differences using virtual reality," Frontiers of Architectural Research, 9(1):138–47, 2020. Retrieved from doi: https://doi.org/10.1016/j.foar.2019.07.005.

[59] R. C. A. Bendall, S. Lambert, A. Galpin, L. P. Marrow, and S. Cassidy, "Psychophysiological indices of cognitive style: A triangulated study incorporating neuroimaging, eye-tracking, psychometric and behavioral measures," Pers. Individ. Dif., vol. 144, no. November 2018, pp. 68–78, 2019. Retrieved from doi: 10.1016/j.paid.2019.02.034.

[60] R. M. Rahal and S. Fiedler, "Understanding cognitive and affective mechanisms in social psychology through eye-tracking," J. Exp. Soc. Psychol., vol. 85, no. July, p. 103842, 2019. Retrieved from doi: 10.1016/j.jesp.2019.103842.

[61] M. D. Burnard, A. Q. Nyrud, K. Bysheim, A. Kutnar, K. Vahtikari, and M. Hughes, "Building material naturalness: Perceptions from Finland, Norway and Slovenia," Indoor Built Environ., vol. 26, no. 1, pp. 92–107, 2015. Retrieved from doi: 10.1177/1420326X15605162.

[62] M. Burnard, Č. Tavzes, A. Tošić, A. Brodnik, and A. Kutnar, "The role of reverse logistics in recycling of wood products," Environ. Footprints Eco-Design Prod. Process. pp. 1–30, 2015. Retrieved from doi: 10.1007/978-981-287-643-0_1.

[63] Q. Wan, X. Li, Y. Zhang, S. Song, and Q. Ke, "Visual perception of different wood surfaces: an event-related potentials study," Ann. For. Sci., vol. 78, no. 2, pp. 1–18, 2021. Retrieved from doi: 10.1007/s13595-021-01026-7.

[64] L. Allner and D. Kroehnert, "Natural complexity. An introduction to structural design with tree forks," Lect. Notes Civ. Eng., vol. 24, no. January, pp. 743–759, 2019. Retrieved from doi: 10.1007/978-3-030-03676-8_29.

[65] R. Mi et al., "Scalable aesthetic transparent wood for energy-efficient buildings," Nat. Commun., vol. 11, no. 1, pp. 1–9, 2020. Retrieved from doi: 10.1038/s41467-020-17513-w.

[66] A. K. Aagaard and N. M. Larsen, "Developing a fabrication workflow for irregular saw logs," Int. J. Archit. Comput., vol. 18, no. 3, pp. 270–283, 2020. Retrieved from doi: 10.1177/1478077120906736.

[67] D. Ezzat Ahmed, S. Kamel, and L. Khodeir, "Exploring the contribution of Neuroarchitecture in learning environments design 'A review,'" Int. J. Archit. Eng. Urban Res., vol. 4, no. 1, pp. 67–94, 2021. Retrieved from doi: 10.21608/ijaeur.2021.215924.

[68] M. Llorens-Gámez, J. L. Higuera-Trujillo, C. S. Omarrementeria, and C. Llinares, "The impact of the design of learning spaces on attention and memory from a Neuroarchitecture approach: A systematic review," Front. Archit. Res., vol. 11, no. 3, pp. 542–560, 2022. Retrieved from doi: 10.1016/j.foar.2021.12.002.

[69] T. Alapieti, R. Mikkola, P. Pasanen, and H. Salonen, "The influence of wooden interior materials on indoor environment: a review," Eur. J. Wood Wood Prod., vol. 78, no. 4, pp. 617–634, 2020. Retrieved from doi: 10.1007/s00107-020-01532-x.

[70] D. Lipovac and M. D. Burnard, "Effects of visual exposure to wood on human affective states, physiological arousal and cognitive performance: A systematic review of randomized trials," Indoor Built Environ., vol. 30, no. 8, pp. 1021–1041, 2021. Retrieved from doi: 10.1177/1420326X20927437.

[71] J. PETERSON, M. SHITARA, H. YOSHIDA, M. KAMIJO, G. FUJIMAKI, and H. YAMAGUCHI, "Emotional Differences in Tactile and Visual Sensation of Wood between Customers in Sweden and Japan for <I>Kansei</I> Engineering Application," Int. J. Affect. Eng., vol. 18, no. 4, pp. 181–188, 2019. Retrieved from doi: 10.5057/ijae.ijae-d-18-00018.

[72] Y. Zhu, Q. Wang, and F. Zhao, "Wood in office spaces: The impact of different wooden furniture on aesthetic evaluation," Front. Psychol., vol. 13, no. January, pp. 1–12, 2023. Retrieved from doi: 10.3389/fpsyg.2022.986627.

[73] D. Mamić and D. Domljan, "Positive Aspects of Using Solid Wood in Interiors on Human Wellbeing: A Review," Drv. Ind., vol. 74, no. 3, pp. 379–391, 2023. Retrieved from doi: 10.5552/drvind.2023.0130.