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OPTIMIZATION OF SMART HOME TECHNOLOGY IN INTERIOR DESIGN : A NEUROARCHITECTURE PERSPECTIVE

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Abstract:
Purpose: To identify smart home technology that supports the principles of neuroarchitecture and optimize the use of smart home in interiors.
Research methods: This study uses a qualitative research method with a literature study approach. The literature used is literature related to neuroarchitecture, neuroarchitecture in interiors, and smart home technology used in residential areas. Data were analyzed using thematic analysis.
Findings: Smart Home technology such as smart lighting, voice control, security, and biophilia can be integrated with neuroarchitecture. The integration of smart home technology in residential areas with neuroarchitecture produces types of technology that can improve the welfare of the community in terms of psychology and neurology.
Implications: Through this study, it is hoped that the public can get references related to the selection of smart home technology so that it can be maximally useful, not only functionally but can also improve the comfort and welfare of the community in the house.

Keywords: Smart Home Technology, Neuroarchitecture, Interior

INTRODUCTION

Technological advances have brought significant evolution to interiors. The emergence of AI technology makes it easier for designers to comprehensively understand user needs in order to create functional, technology-based spaces. The use of AI technology in interiors has given rise to a trend that is starting to be widely used in residential interiors. The Smart Home Technology trend shows that deep personalization, integration, and security will become mainstream in the future and create a unique smart home experience [1]. Smart home technology is an innovative solution to make everyday life easier [2]. This technology includes automation systems such as smart lighting, temperature control, security devices to internet of things (IoT) devices that are controlled through digital devices. Amid the increasing demand for smart homes that support environmental conservation and energy optimization movements, there is a need to utilize this technology from a psychological and neurological aspect to support user well-being.

The well-being of the community based on psychological and neurological aspects in space is now starting to be a concern for interior designers. The neuroarchitectural approach is relevant in this topic. Neuroarchitecture refers to a multidisciplinary design approach that combines neuroscience, architecture, and cognitive psychology to optimize the relationship between the environment and human cognition, emotion, and

behavior [3]. Thus, neuroarchitecture studies how humans respond to built spaces, with a focus on stimulating a symbiotic relationship between architecture and neuroscience [4]. The main principle is that the built space directly affects the human brain, some basic principles in this discipline must be applied correctly to improve human life. The principles of neuroarchitecture consist of sensation and perception, learning and memory, decision making, new experiences [5]. These basic principles then translated into interior design principles of light, color, texture, proportion and scale, and biophilia. These principles have been shown to improve comfort, productivity, and psychological well-being of occupants. Therefore, the integration of smart home technology with a neuroarchitectural approach offers the opportunity to create residential spaces that are not only technologically efficient but also support the holistic well-being of occupants.

However, the application of smart home technology often focuses on technical functions without considering its impact on the psychological and neurological aspects of the occupants. For example, the use of smart lighting that does not match the human circadian rhythm can disrupt sleep quality and mental health. Or a room layout that is too complex can increase occupant stress even though it is supported by sophisticated technology. Thus, a design approach is needed that optimizes the use of smart home technology while adhering to the principles of neuroarchitecture. This study aims to identify smart home technology that supports the principles of neuroarchitecture and optimizes the use of smart homes in residential interiors. By combining technological innovation and neuroscience-based design principles, it is hoped that this study can contribute to creating a home that is adaptive, efficient, and supports the overall well-being of occupants.

RESEARCH METHODS

This study uses a qualitative research method with a literature study approach. The literature used is literature related to neuroarchitecture, neuroarchitecture in the interior, and smart home technology used in residential. With a research focus on neuroarchitecture and smart home technology that is in accordance with neuroarchitecture. The data that has been collected is analyzed using the thematic analysis method. Thematic analysis is one of the methods used in analyzing data with the aim of finding patterns or themes through the data that has been collected. [6].

FINDINGS

Neuroarchitecture is a multidisciplinary field that can be defined as architecture designed following principles derived from neuroscience. Therefore, it helps to create spaces that cause mental stimulation and impact human psychology and body physiology thus avoiding stress [7]. This science can also regulate human performance, human behavior, and achieve well-being. Neuroarchitecture consists of four main parts that are interrelated with each other such as neuroscience, architecture, physiology, and psychology that specializes in emotions and behavior.

The relationship between architecture and human emotions

Human perceptions of the surrounding environment include factors beyond its visual and physical characteristics. Perceptions of the environment come from subjective descriptions of one's own emotions such as feeling safe, calm, comfortable, boring, exciting, and mysterious. When individuals are in the environment, their emotions (both short-term and long-term feelings) will be affected. Research on the interaction between architecture and emotions suggests that design characteristics such as volume,

proportion, height, geometry, scale, and width act as stimuli that trigger human emotions [8]. In fact, humans judge the environment as pleasant or unpleasant objectively and subjectively based on the environment around them.

The Relationship Between Architectural Perception and Neuroscience

Perception is dependent on the process by which humans are influenced by their surroundings, acquiring information and understanding it through environmental stimuli that trigger the senses. This process occurs consciously or unconsciously [9]. Some researchers have outlined that when humans experience emotions, certain parts of the brain are active such as the primary visual cortex which receives and processes visual information from the retina which is responsible for visual perception [10]. When assessing the aesthetics of a space, the orbitofrontal cortex (the part of the brain involved in emotion, taste, smell, and reward) and the subcallosal cingulate gyrus (a part of the limbic system involved in emotion and behavior) of architects' brains were more stimulated than those of non-architects [11]. In addition, the role of the amygdala is important for increasing attention to emotions and behavior, decision making, memory, motivation, conscious thought, and visual perception [12]. Therefore, studying the relationship between environmental stimuli in space and neuroscience is important to know. In order to create interiors that prioritize human well-being. Because the spatial perception of architectural characteristics such as space, form elements, colors, objects, etc. is affected by deficiencies in the occipital, parietal, and temporal lobes.

Neuroscience that influences perception in architecture together with physiology and psychology forms a unity that defines Neuroarchitecture. These sciences form a cycle that expresses the relationship between Architecture, physiology and psychology (emotions and behavior), and neuroscience. Starting from architecture as a stimulus that influences human emotions which then activates certain parts of the brain that trigger cognitive processes and can even form new neurons in the long term that cause neurological changes. However, various stimuli from the built environment can cause negative physiological, emotional, cognitive, and behavioral changes and vice versa. This process is often referred to as cognitive-emotional design or emotional design which is used interchangeably with the term neuroarchitecture.

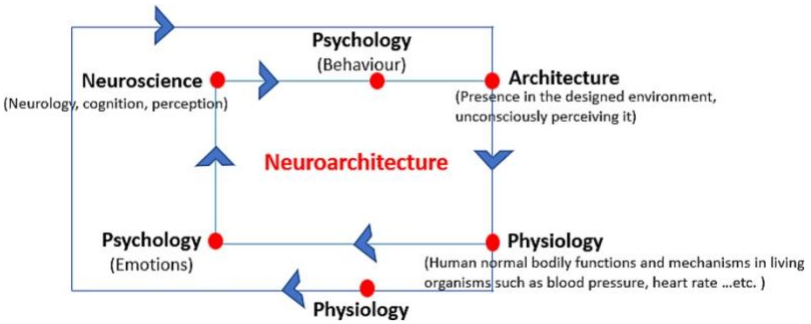

Figure 1. The Cyclic Model
[Source : Medhat Assem et al. 2018]

Design Principles And Their Effects According To Neuroarchitecture

1. Form

In the principle of neuroarchitecture, shape is a trigger that will have an impact after the senses see/feel the shape or movement which is then processed by the brain into a memory. Symmetrical and asymmetrical shapes have different effects on humans. Symmetrical shapes in an emotional context can arouse emotions, reduce satisfaction and joy [13]. Neuro-cognitively, different shapes provide brain activity for different parts of the temporal cortex. Symmetrical shapes or soft geometric shapes can stimulate activity in the posterior part of the brain compared to rigid shapes. Soft geometric shapes are considered easier to form positive characters, compared to aligned shapes that evoke negative feelings and tend to be lazy. Therefore, symmetrical shapes are more preferred. In addition to symmetrical shapes, curved shapes neuro-cognitively have enhanced memory in square or cylindrical areas made of cones, glass rooms, concrete. This shape activates visual and spatial perception. Emotionally, curved contours evoke higher fear than sharp-angled contours [14]. Curved shapes are also sociopetal space formers, where these shapes can increase the possibility for people to gather and can stimulate people to interact. While sharp-angled shapes look more attractive and are preferred by designers.

2. Color

The choice of colors in design greatly affects the performance of the human brain. Differences in color temperature will produce different perceptions in each individual. Cool/warm colors are seen through the neuro-cognitive aspect, namely the activity of the prefrontal cortex related to colored objects. The difference between cool & neutral colors is related to alertness, fatigue, cognitive function. Cool colors (between yellowish green and purple) increase attention and memory, cool colors also cause less arousal than warm colors when sleeping. However, cool colors increase attention. While warm colors increase memory. Viewed from a physiological/emotional perspective, both color temperatures cause HRV heart rate variability & EDA electrodermal activity. Warm colors are preferred by adults, while cool colors are preferred by children. In addition to warm and cool colors, the use of contrasting colors, especially high contrast colors, can improve memory in space. The use of certain bright colors such as purple can provide higher attention and problem solving than blue, green, yellow and red. Colors that are bright enough or very bright can improve perception. Bright white can provide better performance in learning. Emotionally, bright colors evoke positive emotions such as red. Green is believed to create satisfaction & comfort. In terms of behavior, the color of the sun has a positive effect. Physiologically, human sweat production is the least in a room with dark brown wood color [9].

3. Furniture

Furnished rooms physiologically increase heart rate and greater theta brain power in the front due to higher furniture or open offices. In terms of behavior, furnished rooms provide more physical activity. Furniture placement can reduce stress levels, especially in the use of flexible furniture. From a neuro-cognitive aspect, flexible furniture design correlates with better brain functional ability for

performance in mathematics. Meanwhile, rooms with minimal furniture or no furniture have less association than rooms with furniture.

4. Lighting

Lighting is included in the principle of sensation and perception. Lighting affects the impulses distributed by the senses on what is obtained from the surrounding environment, then interpreted by the brain. Lighting is in the form of a beam and exposure that can be felt by the senses directly. When using natural lighting, physiologically it can reduce cortisol and stress levels, this results in a decrease in the number of patients being treated in hospitals. Neuro-cognitively, good natural lighting correlates with better brain functional ability when used for writing. The emotional effect of natural lighting can reduce excess stress.

For artificial lighting, light above 7500 K can increase blood pressure and white light regulates sleep rhythm. Emotionally, light temperatures of 5000 K and 3000 K cause different emotions. White light regulates mood, blue light accelerates post-stress relaxation. Artificial lighting makes individuals feel cooler & more pleasant than direct light. The use of LED lights has an attractive, comfortable, and sophisticated feel. LED lighting is more stimulating than neon lights. While artificial ambient light reduces pain. Lighting that provides a sense of comfort and can facilitate reflective discussions is the type of warm-comfortable lighting and non-intense brilliant lighting.

5. Ceiling Height and Proportion

Low ceilings tend to have low aesthetics when viewed from a neuro-cognitive aspect and require special processing. Emotionally, low ceilings on the one hand provide calmness while on the other hand cause negative emotions. Viewed from a behavioral perspective, low ceilings cause individuals in them to immediately leave the room [15].

High ceilings stimulate high creativity, especially stimulating rational processing and areas involved in visual and spatial perception. Emotionally, rooms with high ceilings express freedom, which has a positive impact on finding a way. High ceilings also give a more interesting impression. In addition to ceiling height, proportions such as width and narrowness are very important in designing a space. In neuroarchitecture, the proportion of area is not measured experimentally in many studies, but rather in its application. For example, a wider classroom is associated with worse attention, memory, and performance. Physiologically, rooms with wider proportions have lower emotional arousal. While rooms with narrower proportions can improve brain attention and memory.

6. Smell, Sound, and Biophilia

Human comfort is seen from the smell factor in the environment. A room with fragrant plants is the smell that humans like the most and provides comfort. No human being likes an unpleasant smell. In addition to smell, the sound factor should be considered in the environment. A quiet room increases attention and improves perception. Conversely, noise causes feelings of stress. Stress can be reduced by natural sounds. Biophilia is an important aspect in the principles of neuroarchitecture. If the environment or space where the community's activities take place does not have many plants, it will cause feelings of stress, oppression,

and lack of enthusiasm. Meanwhile, a room with plants or an environment close to nature can reduce stress and anxiety levels. Pleasure will increase based on tree density. The presence of plants is also an attraction and can affect the perception of brightness. Natural scenery has a positive effect and can reduce pain intensity. Natural forms are always preferred.

Smart Home Technology

Smart home technology, as the name suggests, is a smart home technology that is an innovative solution to simplify everyday life using IoT technology. This concept involves combining various electronic devices and computers with the aim of automating various aspects of the household. The main advantage of this technology is that it provides comfort and efficiency. Another advantage is energy savings that are optimized through the control of electronic devices such as lights, air conditioners, and other equipment. Here are examples of smart home technology according to the context of interior design [16] :

1. Smart Door and Smart Lock

Figure 2. Smart Door
[Source: Metland Cikarang, 2023]

Smart doors and locks are security devices that are often used in addition to CCTV. This system allows users to control access to the house via their smartphones. How to use it is that the door can be opened using the occupant's fingerprint or using a special code like the security system on a smartphone. Smart doors and locks are chosen because users do not need to use manual physical keys and seem up-to-date.

2. Smart Lighting

Figure 3. Smart Light
[Source: Google,2024]

As an important aspect of interior design, smart lighting has changed the way users control lighting in their homes. Big companies like Philips have introduced smart lights that are connected to smartphone apps. Through this app, users can set the color, intensity, and schedule of lighting according to the desired mood, creating an atmosphere that suits the interior of the user's home.

3. Voice Control System

Voice control systems or virtual assistants such as Amazon's Alexa or Google Assistant are now increasingly popular. The use of virtual assistants opens up new opportunities in interior design. This system gives users the freedom to control various devices in the house with just their voice. For example, room temperature, controlling lights, or playing music without having to touch a physical device. Interior design can be optimized by including hidden microphones and speakers so that the use of virtual assistants is more practical and integrated.

4. Temperature and Ventilation Control

The installation of a smart thermostat that can be adjusted via a smartphone application allows users to adjust the temperature of the house according to their wishes. Such as air conditioning with remote automatic control techniques, the use of exhaust fans or ventilating fans. All electronic devices can be controlled remotely via a smartphone.

5. Smart Curtain and Sunshade System

Smart curtain and sunshade systems can be driven by motors and controlled by sensors for automatic opening and closing, timer control, and remote control. The system can automatically adjust the opening and closing degree of the curtain according to the light intensity and indoor temperature to achieve the effects of sun shading, heat insulation, and energy saving.

6. Smart Air Purifier

This technology is equipped with a filter-shaped filter. Where this filter can filter all dirt and dust contained in the air. That way, the air that is released becomes cleaner and healthier. Air purifiers can prevent the spread of infectious diseases through the air.

7. Smart Furniture

Smart furniture is a furniture product that integrates technology as an added value of functionality, comfort, and beauty for its users. Smart furniture prioritizes multifunctionality by focusing on saving space and integrating IT technology into a product. Real examples are multifunctional sofas that can be converted into beds, multipurpose tables with sensor features, and many more.

Smart Home Technology Integration With Neuroarchitecture & Its Applications

Diverse Smart Home technologies, when combined with neuroarchitecture, will have an impact on the comfort and well-being of residents. The personalization features offered in smart home technology allow users to set household devices according to their

personal comfort level, thereby improving brain performance and improving individual perception of space.

The following are some technologies that can be integrated with neuroarchitecture based on the principles of neuroarchitecture.

Artificial Lighting : Smart lighting that adjusts to circadian rhythms can improve sleep quality and physical health. Light color settings such as blue lighting in the morning can increase energy and warm lighting at night is used for relaxation. Lighting is related to color, dim red lights can be used as night lights in the bedroom. This color is suitable for use during meditation, guided breathing, and so on. Pink lights can be considered for use if the user needs light to wake up in the morning with the sun rising too early. This color is a good light color to apply to babies and young children's rooms and can be used to provide a relaxing feel. Green lights are often used by professional gamers to help focus during important sessions because green is a calming color and increases alertness. The use of voice-controlled lighting technology can make it easier for users to adjust lighting with certain modes.

Natural lighting: natural light obtained from sunlight entering the room can reduce stress and increase the productivity of the community. To maximize and regulate natural light entering the room, smart curtain and sunshade systems technology can be used. This technology is in the form of automatic curtains that can adjust to the time and lighting conditions outside. The positive impact is to regulate the entry of sunlight according to needs and reduce glare, as well as increase connection with nature. smart curtain settings make it easier for users to see the scenery if the home environment has a view with natural vegetation. Seeing natural scenery can reduce stress and increase happiness hormones.

Smell and Sound: Smart audio technology such as smart speakers can automatically play music, white noise, or nature sounds. Certain nature sounds or music can reduce stress levels and improve focus. Noise-canceling technology can help create a calmer environment amidst external noise. In addition to sound, managing odors in the environment is important for occupant comfort. The use of smart aromatherapy technology or smart air purifiers can be used in the home according to the needs of the user.

Security: Smart security systems such as motion sensors, smart doors to CCTV can reduce the anxiety level of residents through full control of home security such as instant notifications if there is suspicious activity. Remotely controlled security access provides additional convenience.

Furniture : The use of flexible furniture can reduce user stress and can increase user physical activity. Flexible furniture or smart furniture can improve brain performance and can reduce the risk of injury due to poor posture. The use of flexible furniture can increase efficiency and comfort during activities at home. Furniture with technology such as work desks with automatic height adjustments and smart ergonomic chairs that can adjust the user's posture can be used in the home.

Ventilation: Temperature control in a room is important so that the body can work optimally. If the room is too hot or too cold, the performance of the nervous system will decrease and affect the user's mood. A smart thermostat system or smart AC can automatically adjust the temperature based on user preferences and weather patterns.

The use of a smart thermostat can reduce environmental impact through smarter energy management and create a stable environment.

CONCLUSION

Smart home technology that continues to be a trend in interior design such as smart lighting, automatic thermostats, audio systems to smart furniture can be optimized using a neuroarchitectural perspective to create an environment that supports physical comfort, mental well-being, and occupant productivity. Neuroarchitectural principles such as lighting that is in accordance with circadian rhythms, color selection, proportions, and biophilia serve as a guide in the application of this technology. The results of this literature study show that the synergy between smart home technology and neuroarchitectural principles not only increases the efficiency of space functions, but also has a significant positive impact on occupant well-being. Not only creating a modern residential space, but also providing a positive emotional experience. However, this study also found that a lack of understanding of the psychological and neurological needs of occupants is often an obstacle to optimal application of technology. Therefore, a more holistic and human-centered design approach is needed in integrating smart home technology into residential interior design.

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