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Relationship between Neuroarchitecture and Stress Reduction Compared to Conventional Architecture in Healthcare Personnel

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Abstract

This study investigates the influence of hospitals built with conventional architecture compared to those built using neuroarchitecture which is a branch of architecture that considers the impact of design on cognitive and emotional responses, particularly in relation to stress reduction. A device sensitive to skin impedance was used to measure symptoms of stress. A total of 28 participants were shown two videos, one featuring conventional architecture and the other showcasing neuroarchitecture. Additionally, the Depression, Anxiety and Stress Scale - 21 Items (DASS-21) questionnaire was administered to assess the symptomatology of stress, depression, and anxiety. Significant differences in skin impedance were found between subjects exposed to Neuroarchitecture and Conventional Architecture environments. In the Tococirugía data, Neuroarchitecture showed an average impedance of 355 $K\Omega$ compared to 287 $K\Omega$ in the conventional environment. Similarly, in the UCIN data, Neuroarchitecture had an average impedance of 302 $K\Omega$ while the conventional environment had 230 $K\Omega$. For the UTIN data, Neuroarchitecture exhibited an average impedance of 377 $K\Omega$, whereas the conventional environment had 235 $K\Omega$. The DASS-21 questionnaire results indicated higher levels of moderate stress (53.5%) compared to mild anxiety (46.4%) and mild depression (50%) among medical personnel in the evaluated clinical services.

Introduction

Stress is a significant factor that impacts individuals' health and well-being, with the brain playing a crucial role in our stress response. Chronic or excessive stress can have negative effects on health, while moderate stress can have positive effects on adaptability. Stress activates the hypothalamic-pituitary- adrenal and sympathetic-adrenomedullary axes, triggering physiological responses to maintain homeostasis. Disruptions in these axes are associated with psychological disorders and health problems [1]. Stress also affects memory, behavior, and overall health. The American Psychiatric Association (2017) points out anxiety and depression disorders can lead to suicidality, increased cardiovascular risk, sleep problems, and other symptoms [2].

In Mexico, occupational stress affects 63% of workers, the highest percentage globally [3]. Healthcare professionals are particularly vulnerable due to overwhelming demands [4]. Environmental demands impact satisfaction, well-being, and functioning [5]. Neuroarchitecture explores design's influence on cognitive and emotional responses. Effective spaces prioritize continuity, spatial perception, lighting, green areas, natural light, colors, temperature, and noise [7]. Research demonstrates Neuroarchitecture's benefits in healthcare, reducing pain, stress, and anxiety medication use, and enhancing patient and staff satisfaction [8, 9]. Neuroimaging reveals the Parahippocampal place area's role in processing and storing information, intensifying in response to specific places and visual scenes [6].

As mentioned above, the occupational stress among healthcare workers is a significant concern [10], and the situation in our country is not an exception. Hence, this study aims to corroborate the following hypothesis: "There are differences in psychological stress among medical personnel, as measured by skin impedance when observing Neuroarchitecture in comparison to Conventional Architecture at the Guadalupe Victoria Maternal and Child Hospital in Atizapán de Zaragoza." To achieve this, measures regarding stress response through galvanic skin impedance (GSR), aka electrodermal activity (EDA), and Likert-type questionnaires like Depression, Anxiety and Stress Scale - 21 Items (DASS-21) were employed as the have shown to provide valuable insights into anxiety, depression, and stress levels.

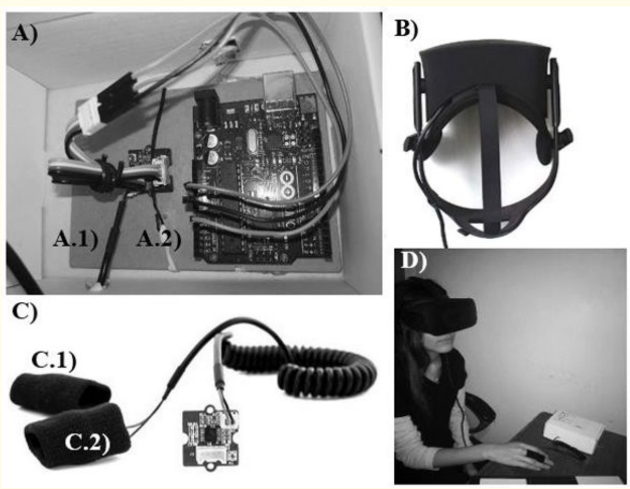

Figure 1: In section A, the sensor (Grove - GSR Sensor) connected to the Arduino is observed. Section B shows the virtual reality glasses (Oculus Rift), section C displays the sensor with electrodes, and section D depicts the sensor and VR glasses placed on the user.

Materials and Methods

A system was developed to measure skin impedance using an impedance sensor as well as to showcase virtual reality videos created with Conventional Architecture and Neuroarchitecture, aiming to provide visual representation of the investigated environments. At the end the DASS-21 questionnaire was administered to obtain levels of depression, anxiety, and stress experienced by the medical personnel at the Guadalupe Victoria Maternal and Child Hospital in Atizapán de Zaragoza. The following sections details the developed system, data acquisition and data analysis performed in this study.

System Development

Skin impedance measurement was conducted using the Grove - GSR sensor (Seeed Studio, Shenzhen, China), which measures skin impedance connecting two electrodes to different fingers. It is well-known that skin conductance, or impedance, directly provides information about human emotional behavioral regulation, justifying its use for stress detection applications. The sensor sends the signal as voltage to an Arduino UNO board (Arduino, New York, USA), where the voltage is converted into impedance.

Physically, the used Grove - GSR sensor, shown in Figure 1A, was connected to two nickel electrodes (labels A.1 and A.2). Additionally, as shown in Figure 1.B, virtual reality goggles (Oculus Rift, California, USA) were used to show a video of Conventional Architecture and a video with Neuroarchitecture in hospitals. To conduct the study, the nickel electrodes were inserted into a pair of elastic garments, shown in Figure 1C and labels C.1 and C.2, to ensure contact with the fingers. Finally, during the study, the sensor electrodes were placed on the middle and ring fingers to measure skin impedance while videos were presented.

To create the architectural environments, virtual reality videos were download, showcasing Neuroarchitecture and Conventional Architecture in hospitals. The videos were sourced from the websites of Hospital Serena del Mar in Colombia (Figure 2, labels A, C, E, G) and Hospital General 450 in Mexico (Figure 2, labels B, D, F, H). The videos were randomly played for participants using the virtual reality headsets, and the skin impedance measurements were taken while they were exposed to each environment.

Data acquisition

This non-randomized experimental study compares the psychological stress response of medical personnel when observing Neuroarchitecture in hospitals versus Conventional Architecture. Three physicians and 25 nurses (N = 28) aged between 25 and 45 years, who are part of the medical staff at Guadalupe Victoria Maternal and Child Hospital in Atizapán de Zaragoza, with an 8-hour work shift from 7:00 am to 3:00 pm, Monday to Friday, and with 2 to 10 years of work experience at the hospital, were selected. The medical staff from the Neonatal Intensive Care Unit (known as *UCIN* in Mexico), Neonatal Intermediate Care Unit (known as *UTIN* in Mexico), and Labor and Delivery (known as *Tococirugía* in Mexico) provided their support. Inclusion criteria were the acceptance and signing of the informed consent letter by the medical personnel. Exclusion criteria included individuals who were unable to tolerate the test. Ethical considerations were addressed throughout the study, ensuring the dignity and rights of the subjects. Confidentiality of information and data was guaranteed, and informed consent was obtained from the medical personnel. The study adhered to the standards established in the General Health Law for Health Research in Mexico.

Skin impedance measurements were taken while participants used the Grove - GSR sensor and virtual reality headsets, allowing for a comparison of the results obtained from subjects exposed to Neuroarchitecture (control group) and Conventional Architecture (study group). The acquisition of impedance signals lasted for 2 minutes, which is the duration of the first video, and the data were immediately acquired for the same duration for the next video.

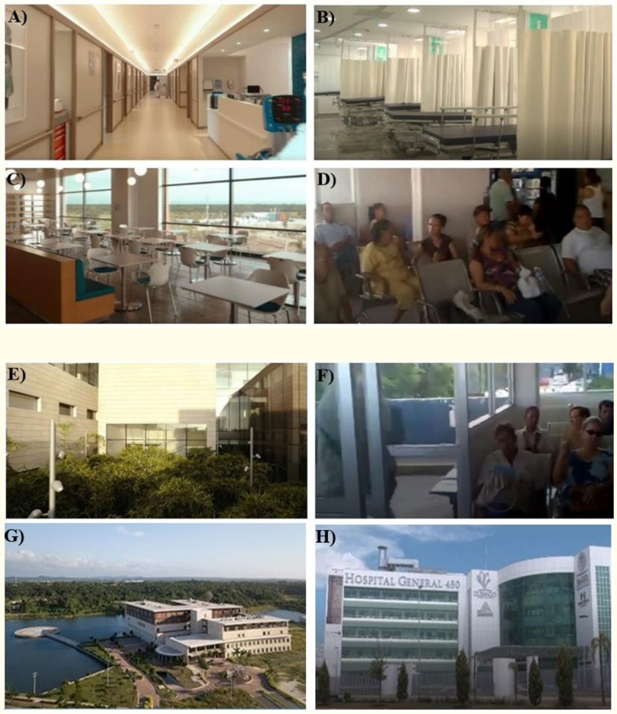

Figure 2: Hospitals with Neuroarchitecture and Conventional Architecture: A), B) Hospitalization Spaces; C), D) Waiting Areas; E), F) Green Areas; G), H) Exterior Views of Both Hospitals, Serena del Mar Healthcare Center (A), C), E), G)) and Hospital General 450 in Durango (B), D), F), H)).

After each impedance measurement, participants were provided with a link to the DASS-21 questionnaire via Google Forms (Google LLC, Mountain View, CA, USA). The questionnaire aimed to collect information on the presence of symptoms of depression, anxiety, and stress among medical personnel and to compare this information with skin impedance data to determine any relationship between psychological symptoms and electrodermal activity (EDA). The questionnaire used a response scale from 0 to 3, where 0 indicated that the symptom did not apply at all and 3 indicated that it applied completely. Google Forms was used to facilitate data collection and ensure the confidentiality of participants' responses.

Data analysis

The collected data were analyzed using descriptive statistics, including box plots to visualize the distribution of skin impedance data. The data from the DASS-21 questionnaire were also analyzed to determine the levels of depression, anxiety, and stress in the medical personnel. This analysis provided information on the impact of Neuroarchitecture on the mental health of medical staff.

Statistical analysis was performed using R Studio Ver. 1.4.1703 (RStudio, Inc., Boston, MA, USA), to evaluate the difference in skin impedance levels between the two hospital environments. For each impedance signal, the last 30 seconds of each signal were analyzed, considering that a transition from one psychological state to another had already occurred at that point. Finally, these values were averaged for each subject. An unequal variance t-test was conducted on dependent samples with a significance level of $p < 0.05$, and a left-tailed hypothesis to determine whether the two groups had a statistically significant difference in terms of their mean skin impedance values.

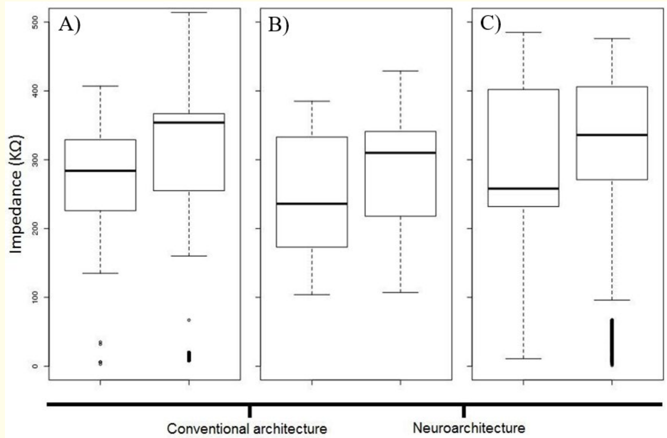

Figure 3: Mean differences obtained in: A) Tococirugía, B) UCIN, and C) UTIN. All graphs (x-axis) depict the comparison between conventional architecture and neuroarchitecture, while the y-axis represents the change in impedance, using the same scale for all graphs.

Results

The results of the test to verify if there was a difference in skin impedance between subjects exposed to Neuroarchitecture and Conventional Architecture environments were found to be the following.

For the *Tococirugía* data, as shown in boxplots from Figure 3A, a statistically significant difference was observed (t = -64.699, p = $2.2x10^{-16}$) in the average skin impedance between neuroarchitectural and conventional environments. The average impedance in the Neuroarchitecture environment was 355 KΩ, while in the conventional environment, it was 287 $K\Omega$.

Regarding the results for the *UCIN* data, shown in Figure 3B, a significant difference (p = $2.2x10^{-16}$) in the average skin impedance between the two environments was also found. In this case, the average impedance in the Neuroarchitecture environment was 302 KΩ, while in the conventional environment, it was 230 KΩ.

Finally, for the *UTIN* data, shown in Figure 3C, a statistically significant difference (p = $2.2x10^{-16}$) in the average skin impedance was also observed between the neuroarchitectural and conventional environments. The average impedance in the Neuroarchitecture environment was 377 $K\Omega$, while in the conventional environment, it was 235 $K\Omega$.

Table 1 summarizes the results regarding the DASS-21 questionnaire. They indicate that 14.3% of the medical personnel in the Hospital presented normal levels of stress, followed by 21.5% for mild, 53.5% for moderate, and 10.7% for severe. Also, they indicate that 14.3% of the medical personnel in the Hospital presented normal levels of anxiety, followed by 46.4% for mild, 35.8% for moderate, and 3.5% for severe. Finally, for the depression section of the DASS-21 questionnaire indicates that 21.5% of the medical personnel presented normal levels of depression, followed by 50% for mild, 25% for moderate and 3.5% for severe. These results suggest a higher stress prevalence than anxiety and depression in the three evaluated clinical services.

Symptomatology	*Percentage of Incidents*				
	Normal	***Mild***	***Moderate***	***Severe***	***Extremelysevere***
Stress	14.3%	21.5%	53.5%	10.7%	0
Anxiety	14.3%	46.4%	35.8%	3.5%	0
Depression	21.5%	50%	25%	3.5%	0

Table 1: DASS-21 Scores (N=38).

Discussion

This study examined the relationship between hospital architecture and the physiological response of healthcare workers using skin impedance measurements. The results indicated that Neuroarchitecture environments influenced the psychological stress and average skin impedance in the Tococirugía subjects. The higher impedance observed in the Neuroarchitecture environment may be attributed to its design factors aligned with Neuroarchitecture principles [10]. These findings align with previous studies suggesting that Neuroarchitecture-built environments positively impact sensory experience and well-being [11, 12].

However, this study had limitations, including a small sample size and focus on a single Tococirugía service in a specific hospital. Factors such as age, specific medical conditions, and patient stress were not evaluated, which could influence skin impedance. Further research should assess each Neuroarchitecture factor independently and explore whether their combination contributes to the observed statistical difference. Larger-scale investigations in diverse hospitals, considering these factors, are recommended to enhance understanding of the influence of Neuroarchitecture environments on psychological stress and their potential association with skin impedance.

Furthermore, the results in subjects working in *UCIN* and *UTIN* services were very similar to those obtained in *Tococirugía*. Therefore, we believe that regardless of the clinical area in which this study is conducted, the results will be consistent with our findings in *Tococirugía*. It worths noting that, we believe that the results of *UCIN* and *UTIN* present the same limitations as the Tococirugía study.

The results of the DASS-21 questionnaire highlight the importance of addressing psychological stress in healthcare personnel in the *UCIN*, *UTIN*, and *Tococirugía* services. However, particularly in the *UCIN*, the results showed a higher prevalence of psychological stress. We believe that the stress experienced by the subjects in this service is due to the emotional burden of caring for critically ill patients, as well as the physical demands involved [13], which may contribute to higher levels of stress compared to other areas. Therefore, since these hospitals are unlikely to change their architecture from conventional to Neuroarchitecture, we believe it is necessary to implement stress management strategies and provide appropriate psychological support to ensure the well-being of healthcare personnel.

Moreover, it worths highlighting that, although the results showed that stress was the most prevalent condition in all three services, significant levels of anxiety and depression were also observed. Therefore, we believe that it is necessary to comprehensively address the mental health of healthcare professionals by offering courses and workshops that address psychological stress, anxiety, and depression in this population. Finally, we acknowledge that a limitation of the study with the DASS-21 questionnaire is the lack of a control group, and we believe it is necessary to include one in future studies.

Results emphasize addressing stress, anxiety, and depression through tailored interventions and psychological therapies to improve mental health [14]. Additionally, we believe it is necessary to provide Special attention needed for individuals with severe conditions.

Conclusion

This study provides evidence that Neuroarchitecture can have a positive impact on reducing stress among healthcare personnel compared to a hospital with conventional architecture. These findings are important as stress can significantly affect the quality of care provided by medical staff to patients.

Furthermore, the implementation of Neuroarchitecture principles can contribute to improving patient care. This study suggests that biomedical engineers, architects, and designers involved in hospital construction should consider incorporating Neuroarchitecture principles when designing a hospital.

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