Journal Homepage: -www.journalijar.com

INTERNATIONAL JOURNAL OF ADVANCED RESEARCH (IJAR)

Article DOI:10.21474/IJAR01/16878
DOI URL: http://dx.doi.org/10.21474/IJAR01/16878

RESEARCH ARTICLE

THE HUMAN BRAIN AND A THEORETICAL RESEARCH ABOUT USING THE EEG IN ARCHITECTURE, WITH A PRESENTING OF SOME STUDY CASES

Rasha Elborgy
Architect. Ph.D.

Manuscript Info

Manuscript History
Received: 10 March 2023
Final Accepted: 14 April 2023
Published: May 2023

Key words:-
Neuroarchitecture, Electroencephalogram (EEG) Features, Space Impact, Human Brain

Abstract

Neuroarchitecture is the way dealing with the design of spaces by studying the relationship between people health and behaviour and buildings with the application of neuroscience. Neuroarchitecture focuses on emotion, happiness, and well-being, which mean it focuses more on people and how they react or feel texture, curves, symmetry, also, the temperature, lighting, colors, scents, and how brains respond to different spaces. It is based on the architectural elements added to a space and have a significant impact on the function of the brain and the nervous system. It is an integration of three fields, namely, neurology, psychology, and architecture. The paper aim to study the human brain and know how is the EEG recording the brain waves, through these waves, we can know the effect of spaces on the brain. With an analytical presentation of some examples in which electroencephalography was combined with the use of spaces.

Introduction:-

Spaces and buildings are places where people spend most of their time, they grow up, study, work, meet friends, making families, memories they are emotionally linked those buildings. Behaviors, choices, emotions, physical and mental health can be influenced by spaces. Architects and environmental psychologists have long been aware of the importance of understanding how spaces affect people. “It turns out people have multiple subconscious tendencies and behaviors that govern their responses to build environments” [3]. Recent technologies, and research in neuroscience can help understand physiological transformations in the brain that make changes in people behavior. The neuroarchitecture field seeks to identify the emotional and cognitive impact of visual forms and incorporate it into architectural design [1]. Until the late 20th century the relationship between the brain and the immune system was found for health maintenance and the potential effects of architectural space on health were scientifically explored. The research efforts have expanded the breadth of the studies on the methods of designing the physical space inducing comfort or relaxation beyond psychological or observational surveys [25]. In the 1950s, architects came to collaborate with behavioral scientists, later on the architecture teamed up with neuroscience, by launching the Academy of Neuroscience for Architecture (ANFA) by neuroscientists and architects in San Diego in the U.S. in 2004. Invigorated the research on humans living in artificial architectural structures, engendering a new field of ‘neuroarchitecture’ [33, 28]. Largely, neuroarchitecture is based on two assumptions. One is ‘human cognitive thinking process’ is directly and indirectly influenced by space, the other is ‘cognitive influence’ of space on humans is physically observable and measurable [25]. To understand how people realize the characteristics of the environments and design elements. The neuroscientists provided some new tools and methods for investigating the relationship between environmental stimuli and human emotions and behaviors. Among the various methods, the

Corresponding Author:- Rasha Elborgy
Address:- Architect. Ph.D.

electroencephalogram (EEG) has been used by researchers in the design and architectural environments since the 1980s. "It is now possible to collect physiological data such as heart rate, as well as brain activity data using portable electroencephalogram (EEG), all of which can help generate a more complete understanding of a human's response to build environments," says Vartanian [32].
Reading an EEG depends on measuring the brain waves that are emitted as a result of the electrical signals that occur in the brain, Those waves are emitted as a result of external stimuli to which the brain is exposed, that stimuli are reflected on the brain through the human senses (Visuals, hearing, touch, smell and taste), those senses activate the relevant part of the brain. For example, each lobe in the brain is responsible for a specific function, if we look at the occipital lobe, for example, is the center of visual processing and contains most of the anatomical area of the visual cortex [42], and so the rest of the brain parts and contains. Therefore, it is necessary to know the anatomical parts of the brain, and the waves that emanate from the brain which are measured by the EEG, learning how the electroencephalogram (EEG) works and, accordingly, know the extent to how spaces and architectural elements affect users, which subsequently affect their lifestyle and behavior in the environment.

The Nervous System:
The nervous system is one of the most important devices in the body and is found in all organisms.
The human nervous system consists of two main parts:
1. The Central Nervous System (CNS): It consists of the brain and spinal cord.
2. The Peripheral Nervous System (PNS): It consists of nerves that transmit the impulses between the central nervous system and the rest of the body [29]

Human brain controls body function, such as heart rate, movement, speech, also controls thinking, memory and emotion perception.So, what is the central nervous system consist of?

The Central Nervous System:
The CNS consists of the brain and spinal cord. The brain can be divided into three basic units: the forebrain, the midbrain, and the hindbrain as in figure 1. The hindbrain includes the upper part of the spinal cord, the brain stem, and the cerebellum, and it coordinates the main functions to survival, such as breathing, motor activity, sleep, and wakefulness. The midbrainconsists of the colliculi, the tegmentum, and the cerebral peduncles, and it is associated with vision, hearing, motor control, sleep and wake, arousal, and temperature regulation, it also acting as a sort of shifting point for the auditory and visual information. The forebrainis the most developed part of the human brain, it consists the cerebrum, thalamus, hypothalamus, pituitary gland, limbic system, and the olfactory bulb, it is responsible for a variety of functions such as receiving and processing sensory information, thinking, perceiving, language, and controlling motor function [43].

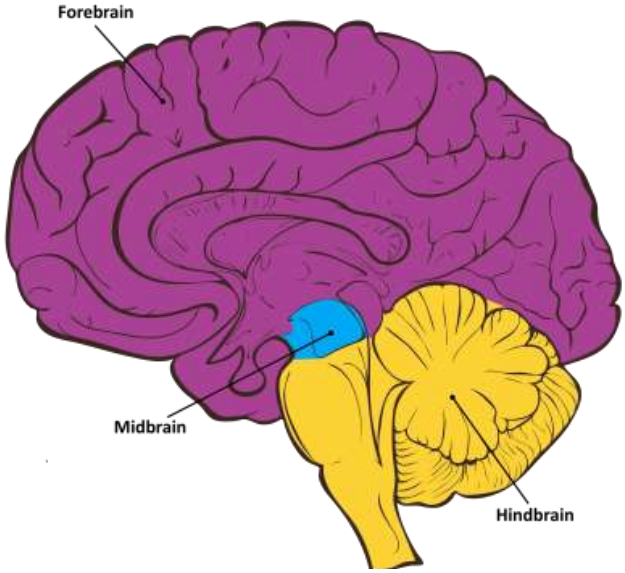
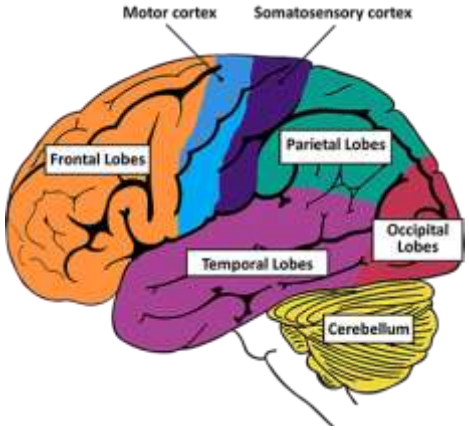


Figure1:- The three main parts of human brain: the forebrain, midbrain, and hindbrain. [43].

Because of the complexity of the central nervous system, a parts of the brain will be clarified and the function of each of them that affected by the human senses.
The cerebrum: is the source of intellectual activities, memories, planning, imagination and thinking, andit can be divided into two halves (called hemispheres) by a deep fissure, the two cerebral hemispheres communicate with each other through a nerve fibers, the right half of the hemispheres is responsible for the creative process and the left half is responsible for the analytical processes [39].

The Cerebral Cortex: The surface of the cerebrum and the cerebellum is covering by a vital layer of tissue, it called the cortex [27, 45].

Cerebral hemisphere is divided into four lobes, frontal, parietal, temporal and occipital [43, 52], as it shown in figure 2 and figure 3, each lobe specializes in different functions.



Pic2
Figure2:- Left pic. The cerebral hemisphere lobes [43].

pic3
Figure 3:-Right pic. Shows what each lobe consist of.

The frontal lobe: It contains most of the dopamine-delicate neurons in the cerebral cortex. The dopamine system is associated with reward, attention, short-term memory, planning, and motivation, the frontal lobe consists of the prefrontal cortex, It is critical for one's working memory and executive control which helps keep goals and complex tasks organized [29].

The parietal lobe: Involved in processing information from the body's senses. It contains the somatosensory cortex, which is essential for processing sensory information from across the body, such as touch, temperature, and pain.

The occipital lobe: located at the back of the brain and it is the visual processing center and containing most of the anatomical region of the visual cortex.

The temporal lobe: located on the side of the head, under the lateral fissure on both cerebral hemispheres. It is associated with hearing, memory, emotion, and some aspects of language. In the temporal lobe there is an area of the brain called the hippocampus which is associated with new memories formation and learning new things [45, 52]

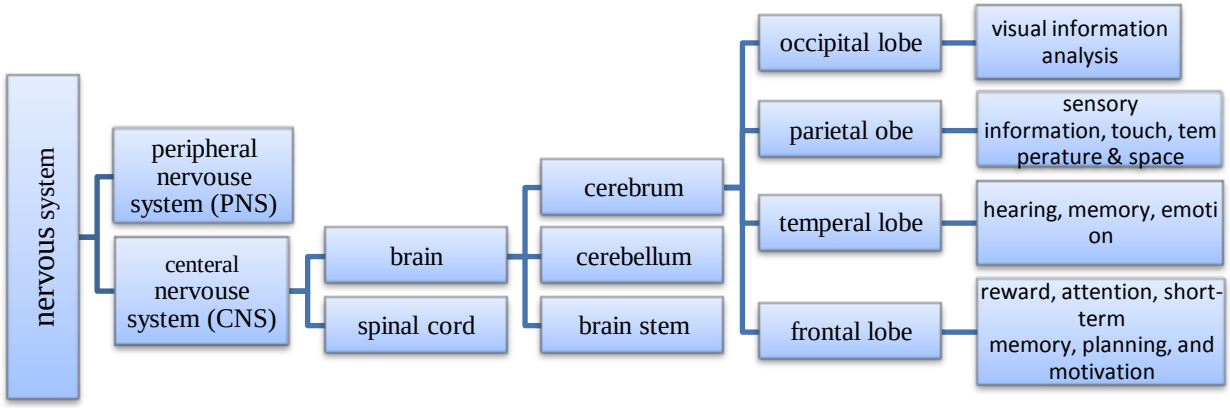


Figure 4:- The nervous system dividing as it explain above (the author).

The cerebral cortex consists of folds and groove as shown in figure 5, thatfolds and groove help to increase the area of the cortex, the folds consist of many deep grooves called sulci and raised areas called gyri, It dividing the brain into functional areas, so that each region is responsible for a specific function, which increases specialization and accuracy in the work of the human brain [27, 52, 55]

This transmit us to the part of the gray and white matter in the brain, the part where the chemical massages are exchanging in the brain.

Gray and white matter: The brain and the rest of the nervous system are consists of many different types of cells, but the primary functional unit is a cell called the neuron. All sensations, movements, thoughts, memories, and feelings are the result of signals that pass through neurons. Neurons consist of three parts: the cell body, dendrites, and the axon. The white matter is contains many neurons that are covered in the white fatty insulating protein called myelin, that helps connect nerve signals and protect the axons. The white matter can be found in the inner layer of the cortex, the optic nerves, the central and lower areas of the brain or brainstem, and surrounding the central shaft of gray matter in the spinal cord, White matter conducts, processes, and send nerve signals up and down the spinal cord. [27, 29, 52]
Gray matter, is home to neural cell, axon terminals, and dendrites, as well as all nerve synapses. This brain tissue is abundant in the cerebellum, cerebrum, and brain stem, this part, sends nerve signals governing motor activities to your autonomic nerves [43]

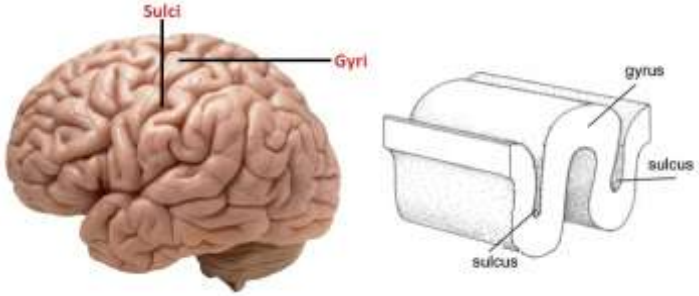


Figure 5:- The folds and grooves shape [55].

The Neurotransmitters.

Neurotransmitters, as shown in table 1, are chemical messengers in our body. Their task is to carry chemical signals from one neuron to the next cell. The next cell can be another nerve cell, a muscle cell or a gland [50]. Communication between nerve cells occurs in a synaptic cleft, electrical signals that are transmitted along the axon are converted into chemical signals through neurotransmitters [43,51]
Nerve cells are generally consist of three parts:
A cellbody, an axon, an axon terminal [43]
There are two types of neurotransmitters, as it shown in table I: I.Amino acids neurotransmitters such as, Glutamate. This is the most common excitatory neurotransmitter of nervous system. It plays a role in cognitive functions like thinking, learning and memory.
Gamma-aminobutryic acid (GABA). Is the most common inhibitory neurotransmitter of the nervous system, it organizes the brain activity to prevent problems of anxiety, irritability, concentration, sleep, seizures and depression. [43,50,51]
II. Monoamines neurotransmitters: it organizes consciousness, cognition, attention and emotion, such as,

Serotonin. An inhibitory neurotransmitter, it helps regulate mood, sleep patterns, sexuality, anxiety, appetite and pain.

Dopamine. Plays a role in our body's reward system, which includes feeling pleasure, achieving arousal and learning, it also helps with focus, concentration, memory, sleep, mood and motivation.

Epinephrine. Also called adrenaline, is responsible for the "fight-or-flight response" to fear and stress. These neurotransmitters stimulate the response of our body by increasing the heart rate, breathing, blood pressure, blood sugar and blood flow to the muscles, as well as height attention and focus to allow us to act or react to different stressors.

Norepinephrine. Called noradrenaline, increases blood pressure and heart rate. It's known for its effects on alertness, arousal, decision-making, attention and focus [43, 50, 51].

This lead us to the brain waves, which are measured by an electroencephalographic (EEG) device.

Table 1:- Show the types of the neurotransmitters and its functions (The Author).

	The neurotransmitters name	Function
Aminoacids neurotransmitters	Glutamate	cognitive functions like thinking, learning and memory
	Gamma-aminobutryic acid	Prevent problems of anxiety, irritability, concentration, sleep, seizures and depression.
Monoamines neurotransmitters	Serotonin	Regulate mood, sleep patterns, sexuality, anxiety, appetite and pain.
	Dopamine	Reward system, feeling pleasure, achieving heightened arousal and learning. Concentration, memory, sleep, mood and motivation.
	Epinephrine	Responsible for so-called "fight-or-flight response" to fear and stress.
	Norepinephrine	Alertness, arousal, decision-making, attention and focus.

The Brain Waves.

Brain is an electrochemical organ in our body, waves are the evidence of electrical activity produced by the brain. When a group of neurons sends an explosion of electrical pulses to another group of neurons, it creates a wave like pattern [20] these waves are measured in speed cycles per second, called Hertz (Hz). Depending on how awake and alert we are, the waves be very fast, or very slow, they can do change, based on what and how we are doing and feeling, Many action potentials combine to form bigger patterns of brain activity. These patterns become thoughts, movements and more [38, 48]. for example, some nerve cells involved in vision blaze when the human eye sees certain colors, others fire when the eye detects basic shapes, or edges of objects.

Types of Brain Waves and Functions

There are five different types of brain waves:

Delta: (0.5-4 Hz) are the slower brainwaves, at this wave, healing and regeneration are stimulated, higher frequency of delta rhythms are an radical property of thalamacortical cells and intracortical network interactions, delta may also reflect general neurotransmitter activity, specifically dopamine and acetylcholine.
Theta: (4-8 Hz) involved in daydreaming and sleep. Too much theta in the left hemisphere is thought to result in lack of organization, while too much theta on the right hemisphere results in impulsivity. It is associated with working memory, episodic encoding and retrieval. It also appears during deep meditation.
Alpha: (8-12 Hz) appears on quiet thought, and meditative states. It helps overall mental coordination, calmness and alertness, mind/body integration and learning. Alpha tends to be highest in the right hemisphere, and too few alpha in the right hemisphere correlates with negative behaviours. It produced as a result of a resonance process between the thalamus and the cortex.
Beta: (12-38 Hz) represent the normal waking state of consciousness when attention is directed at cognitive tasks and the outside world. Beta is 'fast wave' activity and control when we are alert, attentive and engages in problem-solving, decision making and focussed mental activity. Beta waves tend to dominate in the left hemisphere, and too much beta on the right can be correlated with mania. [10,31,35,36,38]
Gamma: the highest frequency of brain waves, between 30 to 100 Hz., associated with high concentration and high levels of cognitive functioning. Low levels of gamma activity have been linked with difficulties of learning, weakened mental processing and limited memory, while high gamma activity is correlated with a high IQ, compassion, excellent memory, and happiness. Gamma is currently of limited clinical value, as it is argued that it cannot be effectively measured using current EEG [35]. Figure 6 below shows the five wave'stypes.

As we mentioned earlier, external stimuli affects some parts of the brain, thus a communication occurs between neurons, the cells releases an electrical shock that results in the aforementioned waves. These brain waves are measured through the electroencephalography (EEG). Which will be explained later in a simple method in terms of the technique and montage reading. This part may seems more relevant to clinical professionals, but as an architects must understand it to facilitate the research process.

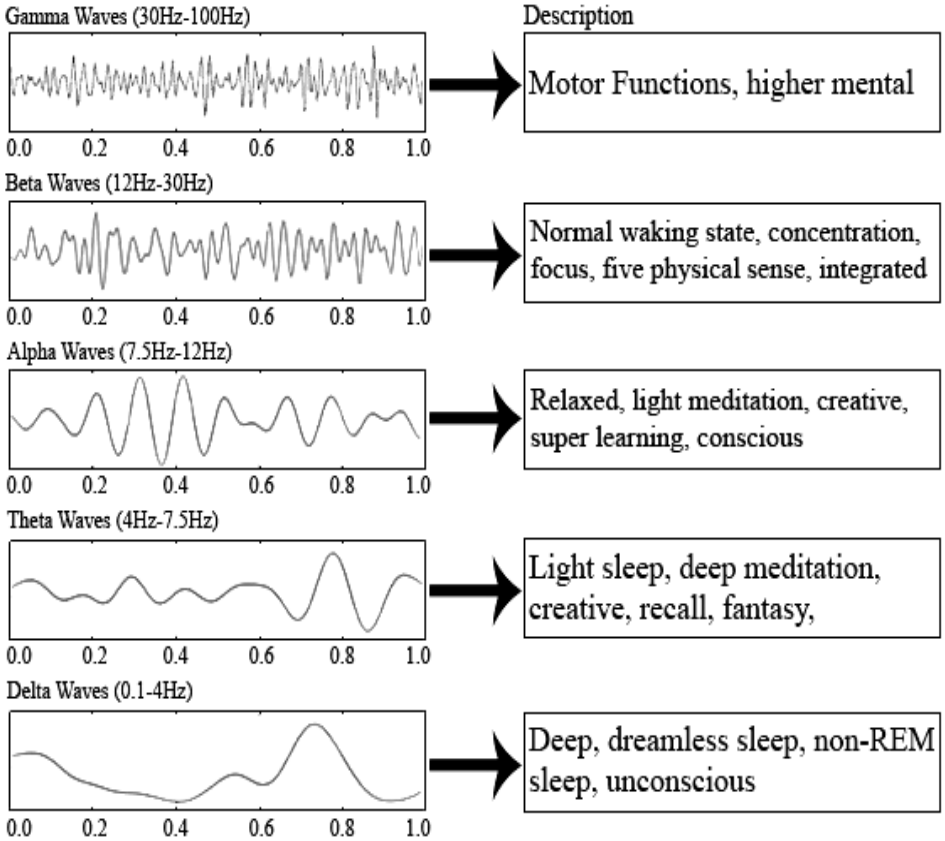


Figure 6:- The five wave frequencies shape and theirfunctions [49].

The Electroencephalogram (EEG).

People have different physiological reactions when they are in a different environments. So, measuring of brain activity is an effective way of evaluate the physiological perception of spaces, environment, or other objects. EEG technology has been applied to different fields, including environmental perception, EEG technology helped us more to emotion recognition, object structure, color, and spaces impact on us [15,41].
An electroencephalogram (EEG) is a recording of brain activity. During this painless test, small sensors are attached to the scalp to pick up the electrical signals produced by the brain. The charges are amplified and appear as a graph on a computer screen, or as a recording that may be printed out on paper.
An EEG can be used to help diagnose and monitor a number of conditions affecting the brain. It may help identify the cause of certain symptoms such as memory problems. Mainly EEG use to detect and examine epilepsy, but recently EEG is using also for discovering the environment's impact on our brain and the brain waves activity according to this impact, such as colors, sounds and shapes and in architectural researches [17].

There are several types of EEG: Routine EEG: scans take 23 minutes, may need to breathe differently or look at flashing lights. Prolonged EEG: it usually takes one hour and 15 minutes, it gives more information than a routine EEG. Video EEG: making a video recording during the EEG. Sleep EEG: it is a test while you sleep [37].

How does it work?

The EEG is recorded from the surface of the head. Measurable surface potentials are produce by neurons in the brain in the top layer of the cortex, the cortex contains the outer information processes of the brain, the main EEG signals are produced by pyramidal cells, these signals are oriented in a manner that produces measurable voltage [10, 35, 47]. The brains electrical sources are dipoles, it is a charged structure that had a positive and negative side (similar to a battery). The EEG is an epiphenomenon (side effect) of the brain's activity, but is not a direct measure of information processing [46, 53].

The Techniqueof Recording EEG

In conventional scalp EEG, the recording is obtained by placing electrodes on the scalp with a conductive gel, usually after preparing the scalp area by light scraping to reduce impedance due to dead skin cells. Many systems use electrodes each of which is attached to an individual wire. Some systems use caps or nets into which electrodes are embedded. Reading is done by 10-20 international system.Electrode locations and names are specified by the International 10–20 system, each electrode is connected to one input of a differential amplifier; during the recording, a series of activation procedures may be used. These procedures include hyperventilation, photic stimulation, eye closure, mental activity, using pictures. The representation of the EEG channels is referred to as a montage [10,16,46,53].

The EEG montage

The first step to any EEG study is the placement of the electrodes, and this is most commonly done via the international standardized 10-20 System. This system is so named because it divides the skull into increments of 10% or 20% to place the electrodes. It depends on four main points on the head, 1.Nasion is the front point of the head, 2.Inion is the back point of the head and 3. and 4. are the Pre-auricular points, we connect the Nasion point to Inion point, from there, we divide the head into consecutive percentage of 10% and 20% to find the placement of the electrodes, as shown in figure 7, and the same between the Pre-auricular points, the appearing points are the electrodes points, each electrode is identified with a letter and a number.
The letter corresponds to its region of the brain: F for frontal region, T for temporal, P for parietal, and O for occipital, the only exception to this is that F7 and F8, they are actually over the anterior temporal region, the number corresponds to the side of the brain, odds on the left and evens on the right. For the midline/central electrodes, instead of a number their letters are clarified with a "z." [25,46,48,54], and table 2 explains the electrodes positions in figure 7.

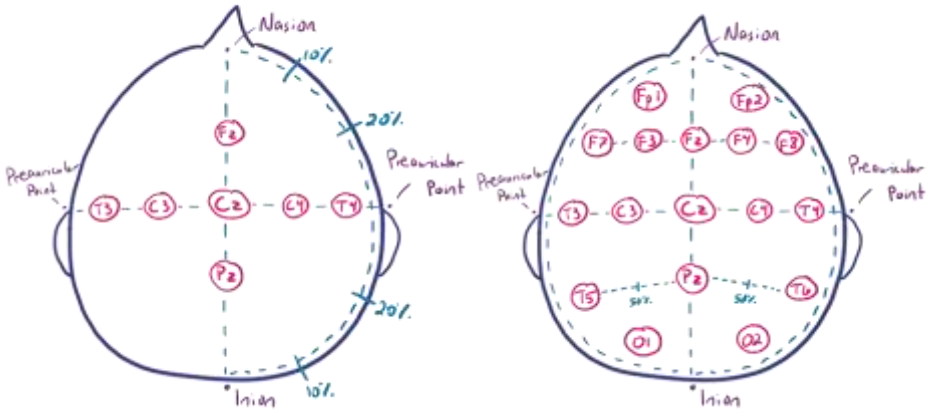


Figure 7:- Division of the head according to the international 10-20 system for placing the electrodes of the EEG[46]

Table 2:- Illustration of the symbols and numbers in Figure 7 that show where the electrodes are placed on the head (The Author).

Left	Brain Area	Right
Fp1	Frontoporal	Fp2
F3	Frontal	F4
F7	Anterior Temporal	F8
T3	Mid Temporal	T4
T5	Posterior Temporal	T6
C3	Central	C4
P3	Parietal	P4
O1	Occipital	O2

Bipolar Montages.

There are two primary types of display montages: bipolar and monopolar/referential, In a bipolar montage, which is also called the "double banana,", each electrode's voltage is linked to one or two neighboring electrodes and compared to the next one to form a chain; so Fp2 is compared to F8, and F8 is compared to T4, and so on all the electrodes points. There are two chains per side as in figure8, an outside temporal chain involving Fp2→F8→T4→T6→O2, and then an inside parasagittal chain involving Fp2→F4→C4→P4→O2. The "z" electrodes Fz→Cz→Pz form a small central chain [41,46,53].The bipolar transverse montage links adjacent electrodes in a chain, going from left to right.

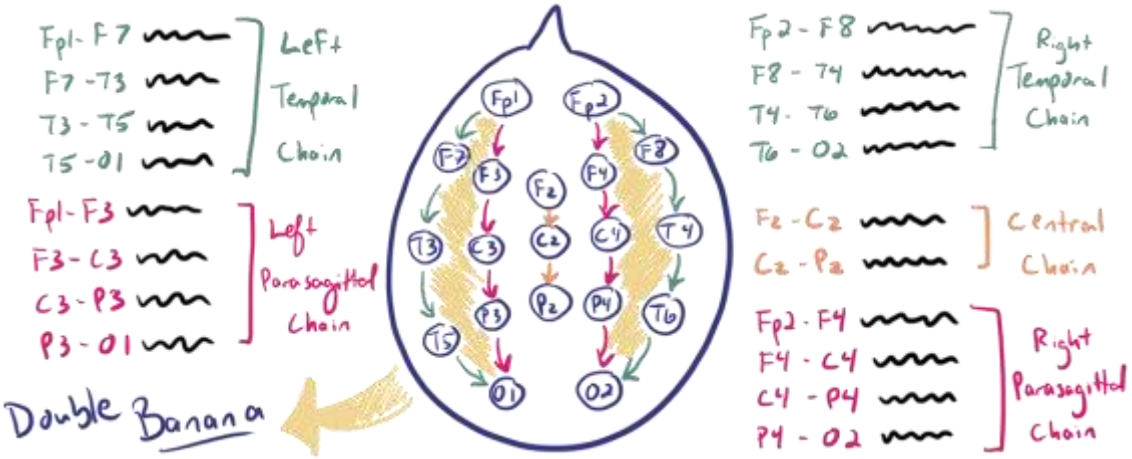


Figure 8:- The bipolar montage or double banana [46].

In each chain, an electrode's voltage is compared to the electrode behind it, so, in bipolar if the first electrode in the drawing line is more positive than the second one, we get a positive, downward deflection; if the second electrode is more positive, we get a negative, upward deflection [46].

For example, as in figure 9, if Fp2 has a voltage of -5 and F8 has a voltage of -20, the Fp2-F8 drawing would show (-5) - (-20) = +15 mV. (Down)
if T4 = -40 mV and T6 = -10 mV, so the T4-T6 drawing would show (-40) – (-10) = -30 mV (Up)

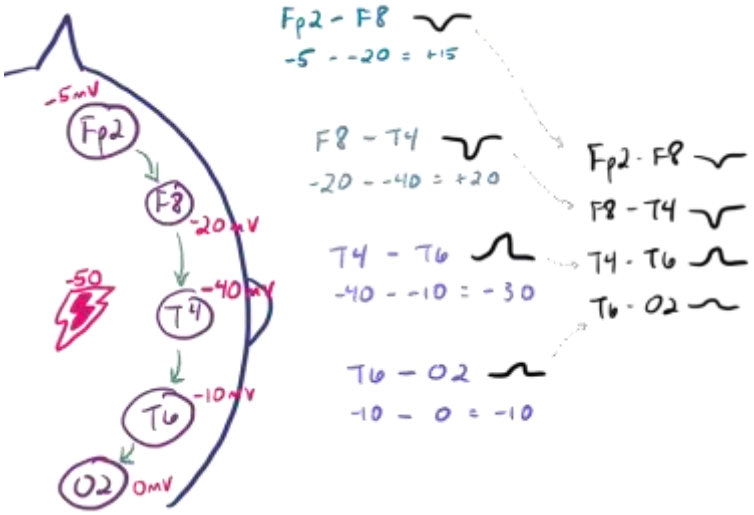


Figure 9:- Shows the voltage of electrodes that compared to the electrode behind and how it is drawn [46].

This same technique is used to give rise to all the tracings in all the chains.

Other type is Circumferential Montage, in which the electrodes are connected not in an anterior to posterior chain but in a circle around the head, as in figure 10, it does not include much of the middle regions / parasagittal electrodes, it only to clarify particular discharges.Nowadays, we aren't limited to a single montage, modern EEG software allows to change montages quickly and easily during the reading process [48].In both figures 11 and 12, shown the output of the EEG montage recording.In both figures 11 and 12, shown a samples of the final output of recording montage.

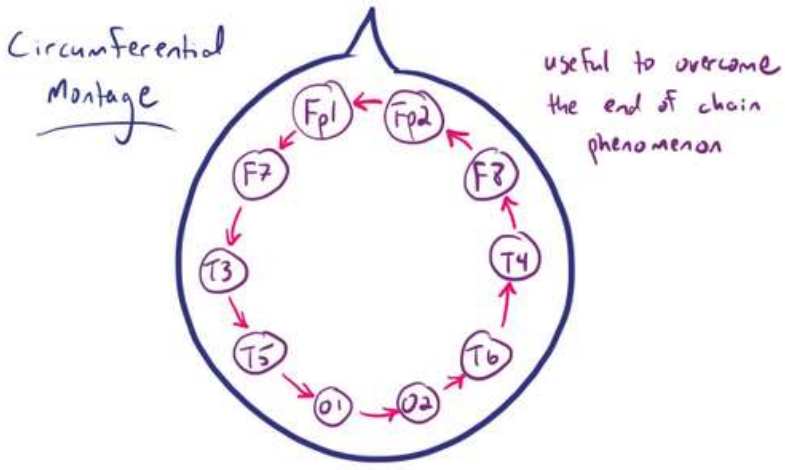


Figure 10:- The Circumferential Montage [46].

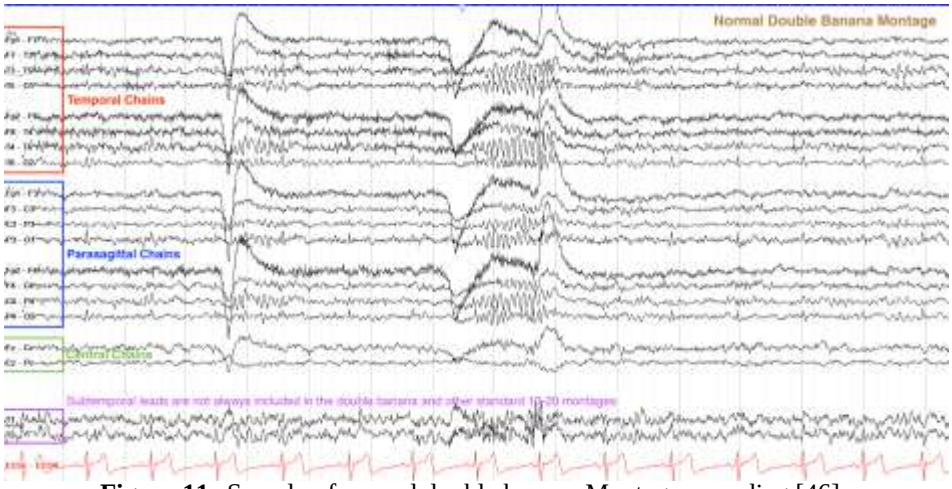


Figure 11:-Sample of normal double banana Montage recording [46].

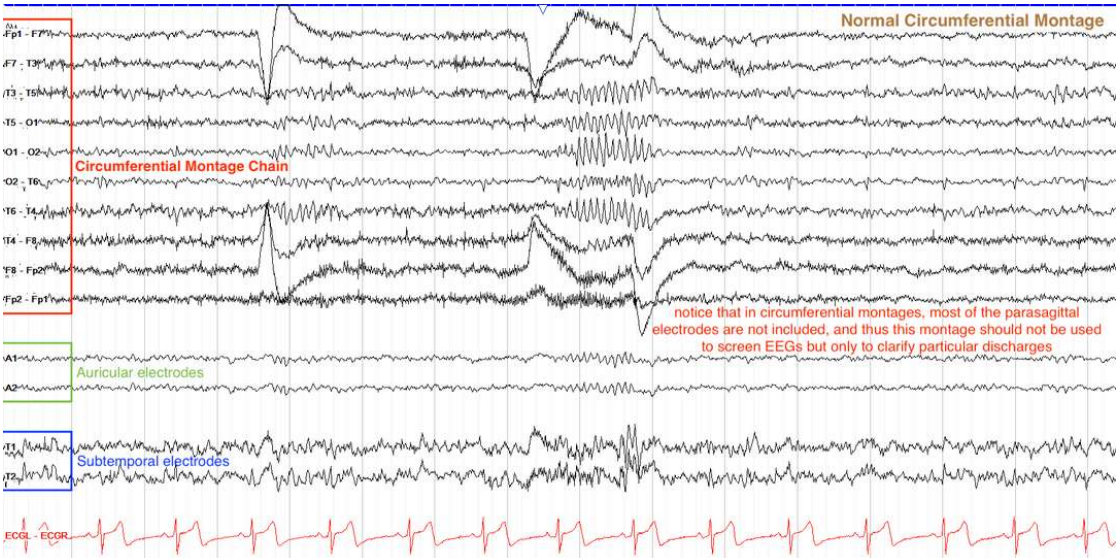


Figure 12:- The Circumferential Montage recording [46].

The EEG and Architecture

Some examples will be presented of the results of researchs in which the electroencephalography (EEG) device was integrated and used to know the impact of architectural spaces on users, and what was figured out.

Study 1:

In one of the studies about the effects of different architectural elements on users' relaxation/arousal reply by measuring the EEG, by creating a simulate room in virtual reality (V.R), three architectural elements are varied in the VR space (aspect ratio of space, ceiling height, and window ratio), and analyze the ratio of alpha to beta waves to determine the stimulation changes,

firstly, the study created the Visual Stimuli in VR Space by applied a fixed internal area of 13 to the private room represented through the VR device by referring to the room sizes in M Postpartum Care Center in Busan [25], the window was placed on the wall facing the entrance door, and the VR space was created using Revit Architecture, and drew the floor plan, elevation, and ceiling plan before making the basic 3D model, the basic 3D model imported into Twinmotion, to produce 3D images with 360 angles to be implemented on the VR device, the daylight coming through the window, and in total, 30 360 angles 3D images producted for the VR space of the room of experiment. this is an important part in clarifying that it has become possible and easy to change spaces in a virtual reality that simulates the real ones with spaces, shapes and proportions, and to play with data and architectural elements to reach

the most appropriate and most comfortable for users. The study ran Experiment Center 4.0 to import the 30 preset visual stimuli, and inserted the description of the experiment, the black screen between stimuli, and the white screen for measuring the background EEG, 19 channels has been used to collect the EEG data, then analyzed the EEG data from 8 lobes, prefrontal (Fp1 and Fp2), frontal (F3 and F4), parietal (P3 and P4), and occipital lobes (O1 and O2). The subjects' EEG signals received from the 19 channels underwent the 16 bit AD (Analog-Digital) converter at 300 Hz sampling frequency, and was stored on the computer in the frequency passband of 0.003~150 Hz [25].

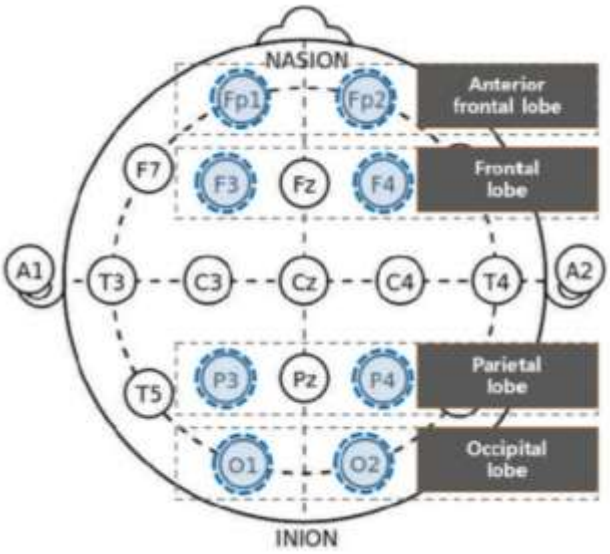


Figure 13:- Brain waves measuring area [25].

By the Statistical Analysis the result was, after the experience in the VR space, the lobes of the brain in the EEG recording (F4 and P3 EEG channels) showed statistically significant differences in the relaxation-arousal responses, both brain's regions are important to the visual spatial processing and known to be involved in the tasks of processing the space, or the environment when users using the VR spaces, as P is denotes the parietal lobe in the brain. The ratio of space may possibly exert a positive or negative result on users' physiologically, can be known by the space impact the changes in the brain waves (alpha and beta), which is measured by EEG.

This study is distinguished in that it succeeded in showing (actually) the difference of the effect of architectural elements on users who have prior experience towards a specific place, and between the change of these architectural elements for the same place, but in virtual reality.On the other hand, it succeeded in combining the use of both the virtual reality programs and the electroencephalographic EEG device, both on users, and getting a statistical results. This will facilitate in the future the architectural design process and save a lot of time and effort spent on studies of user questionnaires and survey, as it used to be done previously.Research on this topic still needs a lot of research in many different aspects, such as studying the effect of spaces and architectural elements in educational buildings, sports areas, hospital, residential buildings, etc., as well as the effect of light, ventilation, colors, and others.

Study2:
In this study, an experimental method has been applied to the analysis of contemplative landscape to be compared to non-contemplative landscapes, by twelve 3D fixed-angle videos recorded with a SonyTM HDR-TD30 camcorder (20 s long), representing landscape images, six contemplative landscape and six non-contemplative landscapes, all were shown while EEG was recorded.

According to the International Position System 10–20, The EEG data were collected using an eight-channel electroencephalographic EEG amplifier, Enobio model with dry electrodes, placed on a neoprene headcap. The device is wireless (operating with Bluetooth) with a Li-Ion battery, and connected to a laptop through the NIC 1.2 software. The electrodes were read at the AF7, AF8, Fz, T7, Cz, T8, P3, and P4 in this case is referenced to an electrode placed at the right mastoid (RM). The electrode is always located according to the areas of interest. Whereas, AF= Anterior-frontal, F= Frontal, T= Temporal, P= Parital

The 3D shutter glasses were used in the study without interfering with the cap, cables, or electrodes. The glasses were connected to the PC and received the infrared signal by the IR 3D emitter. So, two devices are used, EEG and 3D shutter glasses [16].

The study focused on beta power in the right temporal lobe and frontal beta power, as the right temporal areas of the brain are responsible for visual attention, visual information interpretation and memory of pictures, visual scenes, and familiar faces.

Regarding frontal beta power, the reseachers found higher values of beta power on the baseline and no differences between landscapes. Considering the temporal beta power asymmetry, the finding suggests a general activation of the right temporal areas of the brain while watching both contemplative landscape and non-contemplative landscape scenes when compared to the baseline [16].

Also indicated that exposure to landscapes shifts the brain from voluntary or directed attention (which includes all the tasks requiring mental effort, and induces mental fatigue in people). By switching to involuntary attention, and the pattern of brain activity elicited by viewing landscapes has been linked to the mechanism of involuntary attention.

The results found increased power in the beta frequency band of the right temporal brain regions in the viewings of contemplative landscapes compared to non-contemplative landscapes.So, the contemplative landscapes capture more visual, stimuli-driven attention from the viewers and can be linked with switching attention systems, which is compatible with a stress reduction mechanism.Using EEG was not limited to built-up spaces only, In this study, the effect of landscapes on the human brain was studied as one of the elements of the built environment as well. The methodology was well done and showed that the use of three-dimensional shutter glasses does not conflict with the electroencephalography device, which demonstrates the ease of using more than one device with the electroencephalographic device, as in case study 1 in using VR devices.

So, in this study the sequence of results was as follows in figure 14, how started and end up to:

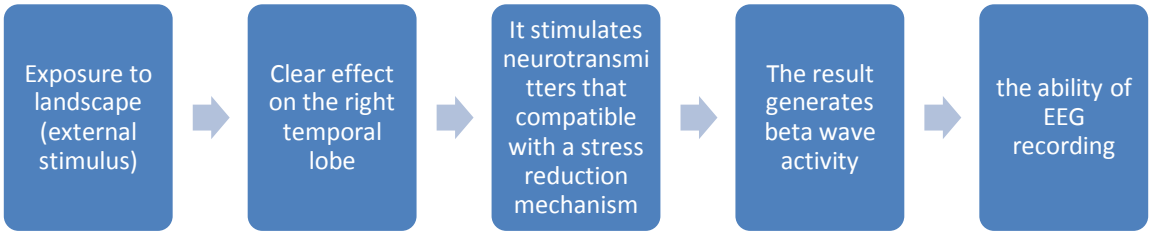


Figure 14:- Arranging the sequence of reading the EEGsince of seeing the stimulus landscape (the author).

Study3:
This study try to show the effect of buildings associated with religious beliefs on the human brain, by measuring the brain waves. The experiment was carried out in both Sultan Hassan and St. Sergius groups in Egypt, a strong correlations were found between frequency and the Theta/Beta ratios in both conditions.As mentioned in the study
-The increase Theta/Beta ratio increases tension and hyper activity
-The decrease in Theta/Beta ratio increases relaxation.
-The increase in Alpha brainwave increases relaxation level a person feels.

To determine the relationship between brain statuses of users using EEG, a test was calculated for the Theta to Beta ratios, Alpha peak, and peak frequency values. The same statistics were used for comparing the brain performance of those subjects before and after being subjected to the selected buildings [21].

Pro-Comp 5 EEG portable device was used in the recording step (a device used for diagnosis of brain waves disorder) with a 4-channel Data acquisition system, A/D conversion of 24 bits, sampling frequency of 256 Hz, inbuilt filter setting options and selfcalibration mechanism. SS2L leads having electrodes were connected to channel 1 of Pro-Comp 5 EEG portable device via BIOGRAPH software. Three electrodes were placed on the subjects scalp.

The first electrode was placed on the ear lobe (ground), second on the occipital lobe (negative) and the third on the parietal lobe (positive).

The analysis showed that is 63.64% of the subjects showed an increase while 36.36% of the participants showed a decrease in alpha activity, the amplitude of theta/beta ratio showed a decrease, which accounts for 72.7% while 27.3% showed an increase. Thus, increases in the alpha and decrease in theta/beta parameters showed the suggestive of relaxation and calm awareness after staying for 20 minutes inside the building [21].

The effect through the use and experience of buildings associated with religious beliefs lead to suggestive of relaxation.

The relaxation is helping people with high blood pressure, helps the body fight against chronic diseases, like arthritis, and cardiovascular diseases. It may also increase the lung capacity [21].
So, in this study the sequence of results was as follows in figure 15, how started and end up to:

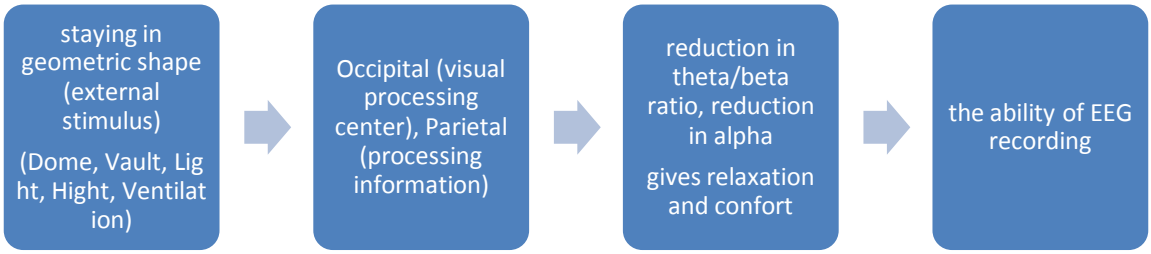


Figure 15:- Arranging the sequence of reading the EEG since of staying in the timeless (the author).

Conclusion:-

People have different physiological reactions in a different environments, so, measuring of brain activity is an effective way of evaluate the physiological perception of spaces, environment, or other objects. EEG technology has been applied to different fields, including environmental perception, it is also helped us more to know and understand emotion, object structure, color, textures of objects and spaces impact on us.
The electroencephalogram (EEG) recording method is distinguished from other methods such as Magnetic resonance imaging (MRI) in knowing the functions of the brain, in that it is a simple device that is easy to use for the participants or volunteers in the experiments.

Electroencephalography (EEG) is also distinguished for the field of architecture, in facilitating the possibility of touching the results of the building's impact on the behavior of users through knowledge of the aroused and active brain waves, so studies on the design of spaces became statistically readable, unlike previous studies, which measured users' physiological behaviors and reactions to architectural space elements in a way that seems primitive or dependent on survey and observation only.

It is also possible, during the use of the EEG, to insert other devices and modern technologies, such as virtual reality (V.R), or heart rate monitors, and others, in this way, the scope of the studies expands in reading and understanding people's reactions and behaviours towards architectural spaces.

It is noted that beta was the common wave in reading for the three study cases, and beta is the wave in which the brain is in a state of alertness, attention and decision-making. Its ratio was compared with another wave, theta/beta or alpha/beta, and this leads us to know the extent the degree of relaxation, well-being and a sense of comfort that the brain has reached due to the space.

Reference:-

1. Andre´a de Paiva, Richard Jedon, 2019, Short- and long-term effects of architecture on the brain: Toward theoretical formalization, Frontiers of Architectural Research https://doi.org/10.1016/j.foar.2019.07.004

2. Eslam Elbaiuomy, Ibrahim Hegazy, Sherif Sheta, 2018, The impact of architectural spaces' geometric forms and construction materials on the users' brainwaves and consciousness status, International Journal of Low-Carbon Technologies, DOI: 10.1093/ijlct/ctx018
3. D. Rock, 2010, Your brain at work: Strategies for overcoming distraction, regaining focus, and working smarter all day long, Journal of Behavioral Optometry, search.proquest.com
4. Young Lim Lee & Yungil Lee, 2020, Developing an autonomous psychological behaviour of virtual user to atypical architectural geometry, Building Research and Information, DOI: 10.1080/09613218.2020.1786348
5. N. Khaleghimoghaddam, H.A. Bala, G.Ozmen et al., Neuroscience and architecture: What does the brain tell to an emotional experience of architecture via a functional MR study?, Frontiers of Architectural Research, https://doi.org/10.1016/ j.foar.2022.02.007
6. D. Simeone, Y. E. Kalay, D. Schaumann, S. Wan Hong, 2013, Modelling and Simulating Use Processes in Buildings, conference paper, Simulation, Prediction and Evaluation - Volume 2 - Computation and Performance - eCAADe 31 | 59-68
7. Aurora Saidi, 2019, ARCHITECTURE VS NEUROSCIENCE: THE INTERPRETATION OF RESEARCH RESULTS IN NEUROSCIENCE TO SUPPORT PHENOMENOLOGICAL ISSUES IN ARCHITECTURE, Igra ustvarjalnosti - Creativity Game DOI: 10.15292/IU-CG.2019.07.033-037
8. H. Ghamari, N. Golshany , P. Naghibi Rad and F. Behzadi, 2021, Neuroarchitecture Assessment: An Overview and Bibliometric Analysis, Eur. J. Investig. Health Psychol. Educ. 2021, 11, 1362–1387. https://doi.org/10.3390/ejihpe11040099
9. N. Ibrahimi, Ani Çuedari, F. Nepravishta, 2019, NEURO-ARCHITECTURE AND PLACEMAKING THE RELATIONSHIP BETWEEN THE BUILT ENVIRONMENT AND BRAIN, IFAU 2017, Tirana. ISBN 978-88-6542-679-1 Pg 217-222
10. Z. Koudelková, M. Strmiska, R. Jašek, 2018, Analysis of brain waves according to their frequency, INTERNATIONAL JOURNAL OF BIOLOGY AND BIOMEDICAL ENGINEERING Volume 12. ISSN: 1998-4510 Pg 202-207
11. Dina Ezzat Ahmed, Prof. Dr. Shaimaa Kamel, Prof. Dr. Laila Khodeir, 2021, Exploring the contribution of Neuroarchitecture in learning environments design "A review", INTERNATIONAL JOURNAL OF ARCHITECTURAL ENGINEERING AND URBAN RESEARCH, ISSN: 2785-9673 VOLUME 4, ISSUE 1, 2021, 67– 94.
12. Martin Billinger, Clemens Brunner and Gernot R Muller-Putz, 2013, Single-trial connectivity estimation for classification of motor imagery data, J. Neural Eng. doi:10.1088/1741-2560/10/4/046006
13. Jenny J. Roe, Peter A. Aspinall, Panagiotis Mavros, Richard Coyne, 2013, Engaging the brain: The impact of natural versus urban scenes using novel EEG methods in an experimental setting, Environmental Sciences. DOI: 10.12988/es.2013.3109
14. Zihuan Zhang, Zao Li and Zhe Guo, 2022, EEG‑based spatial elements optimisation design method, Zhang et al.Architectural Intelligence (2022) 1:17 https://doi.org/10.1007/s44223-022-00017-6
15. Yuting Wang, Shujian Wang and Ming Xu, 2022, Landscape Perception Identification and Classification Based on Electroencephalogram (EEG) Features, Int. J. Environ. Res. Public Health 2022, 19, 629. https://doi.org/ 10.3390/ijerph19020629
16. Olszewska-Guizzo AA, Paiva TO and Barbosa F (2018) Effects of 3D Contemplative Landscape Videos on Brain Activity in a Passive Exposure EEG Experiment. Front. Psychiatry 9:317. doi: 10.3389/fpsyt.2018.00317
17. Ai Yoto, Tetsuo Katsuura, Koichi Iwanaga and Yoshihiro Shimomura, 2007, Effects of Object Color Stimuli on Human Brain Activities in Perception and Attention Referred to EEG Alpha Band Response, Journal of PHYSIOLOGICAL ANTHROPOLOGY. DOI: 10.2114/jpa2.26.373 · Source: PubMed
18. Papale P, Chiesi L, Rampinini AC, Pietrini P and Ricciardi E (2016) When Neuroscience 'Touches' Architecture: From Hapticity to a Supramodal Functioning of the Human Brain. Front. Psychol. 7:866. doi: 10.3389/fpsyg.2016.00866
19. HawasliAH,KimD,LedbetterNM, Dahiya S,BarbourDLand Leuthardt EC(2016)Influenceof White andGrayMatterConnections on EndogenousHumanCortical Oscillations. Front. Hum.Neurosci.10:330. doi: 10.3389/fnhum.2016.00330
20. Buskila Y, Bellot-Saez A and Morley JW (2019) Generating Brain Waves, the Power of Astrocytes. Front. Neurosci. 13:1125. doi: 10.3389/fnins.2019.01125
21. Sally Essawy, Basil Kamel, Mohamed Elsawy, 2014, TIMELESS BUILDINGS AND THE HUMAN BRAIN: The Effect of Spiritual Spaces on Human Brain Waves, Archnet-IJAR, Volume 8 – Issue 1 - March 2014 - (133-142) – Section: Original Research Articles

22. Juhani Pallasmaa, Harry Francis Mallgrave and Michael Arbib, 2013, Architecture and Neuroscience, a Tapio Wirkkala - Rut Bryk Design Reader, ISBN: 978-0-615-93618-5
23. Zamzuri Idris, Mustapha Muzaimi, Rahman Izaini Ghani, Badrisyah Idris, Regunath Kandasamy, Jafri M. Abdullah, 2014, Principles, Anatomical Origin and Applications of Brainwaves: A Review, Our Experience and Hypothesis Related to Microgravity and the Question on Soul, Journal of Biomedical Science and Engineering Vol.7 No.8(2014), Article ID:47331,11 pages DOI:10.4236/jbise.2014.78046
24. Mina Kheirkhah, Philipp Baumbach, Lutz Leistritz, Otto W. Witte, Martin Walter, Jessica R. Gilbert, Carlos A. Zarate Jr., and Carsten M. Klingner, 2021, The Right Hemisphere Is Responsible for the Greatest Differences in Human Brain Response to High-Arousing Emotional versus Neutral Stimuli: A MEG Study, Brain Sciences are provided courtesy of Multidisciplinary Digital Publishing Institute (MDPI) doi: 10.3390/brainsci11080960
25. Sanghee Kim, Hyejin Park, and Seungyeon Choo, 2021, Effects of Changes to Architectural Elements on Human Relaxation-Arousal Responses: Based on VR and EEG, Int J Environ Res Public Health, doi: 10.3390/ijerph18084305
26. Song, C.; Ikei, H.; Kagawa, T.; Miyazaki, Y. Effect of Viewing Real Forest Landscapes on Brain Activity. Sustainability 2020, 12, 6601. https://doi.org/10.3390/su12166601
27. Chauhan P, Rathawa A, Jethawa K, Mehra S. The Anatomy of the Cerebral Cortex. In: Pluta R, editor. Cerebral Ischemia. Brisbane (AU): Exon Publications; 2021. Online first Sep 02. Doi: https://doi.org/10.36255 /exonpublications .cerebralischemia.2021.cerebralcortex
28. THOMAS FISHER, ASSOC. AIA, 2016, How Neuroscience Can Influence Architecture, https://www.architectmagazine.com/practice/how-neuroscience-can-influence-architecture_o
29. Kayt Sukel, 2019, Neuroanatomy: The Basics, Dana Foundation,https://dana.org/article/neuroanatomy-the-basics/
30. Kathryn Hulick, 2016, Explainer: How to read brain activity,science news exploreshttps://www.snexplores.org/article/explainer-how-read-brain-activity
31. Oksana Andreiuk, 2019, What it's like to have a brain in permanent flow state — a qEEG report, Published in Canadian Biohacker, https://medium.com/canadianbiohacker/what-its-like-to-have-a-brain-in-permanent-flow-state-a-qeeg-report-c34595d2eb77
32. FAIRLEY J., 2018, Neuroarchitecture: The new frontier in architecture, Roca Gallery Sharing Knowledge on Architecture and Design, http://www.rocagallery.com/the-built-environments-new-frontier
33. https://anfarch.org/
34. What is the function of the various brainwaves?, 1997, SCIENTIFIC AMERICAN, https://www.scientificamerican.com/article/what-is-the-function-of-t-1997-12-22/
35. Understanding brain waves, Neurofeedback Alliance | The science of neurofeedback, https://neurofeedbackalliance.org/understanding-brain-waves/
36. How Brainwave Entrainment With EquiSync Can Change Your Life, EOC Institute, https://eocinstitute.org/meditation/brainwave_charts_brainwave_patterns/?mind_power&gclid=Cj0KCQjwxMmhBhDJARIsANFGOSuDsHOH6cLB2bH-4ZrVLNaRnCBA0vGSbywIWAdL7Gns0mlK6t0TlXsaAhc6EALw_wcB#/
37. Electroencephalogram (EEG), Cleveland Clinic, https://my.clevelandclinic.org/health/diagnostics/9656-electroencephalogram-eeg
38. Types of Brain Waves: How Delta, Theta, Alpha, Beta and Gamma Brain Waves Impact Your Days, Blossom a mental wellness company, https://drinkblossom.com/pages/types-of-brain-waves-how-delta-theta-alpha-beta-and-gamma-brain-waves-impact-your-days
39. Left and Right Hemisphere of the Brain, 2022, THE HUMAN MEMORY, https://human-memory.net/left-and-right-hemisphere-of-the-brain/
40. https://pressbooks.online.ucf.edu/lumenpsychology/chapter/reading-parts-of-the-brain/#:~:text=The%20frontal%20lobe%20is%20involved,is%20essential%20for%20language%20production.
41. Britton JW, Frey LC, Hopp JLet al., 2016, Electroencephalography (EEG): An Introductory Text and Atlas of Normal and Abnormal Findings in Adults, Children, and Infants [Internet]. National Library of Medicine, national center for biotechnology information,https://www.ncbi.nlm.nih.gov/books/NBK390353/
42. https://en.wikipedia.org/wiki/Occipital_lobe#:~:text=The%20occipital%20lobe%20is%20the,called%20V1%20(visual%20one).
43. Brain Basics: Know Your Brain, Form Approved OMB# 0925-0648 Exp. Date 06/2024, National Institute of Neurological Disorders and Stroke, https://www.ninds.nih.gov/health-information/public-education/brain-basics/brain-basics-know-your-brain

44. The midbrain, The University of Queensland Australia, Queensland Brain Institute, https://qbi.uq.edu.au/brain/brain-anatomy/midbrain#:~:text=There%20are%20three%20main%20parts,tegmentum%2C%20and%20the%20cerebral%20peduncles.
45. LOBES OF THE BRAIN, University of Central Florida,https://pressbooks.online.ucf.edu/lumenpsychology/chapter/reading-parts-of-the-brain/#:~:text=The%20frontal%20lobe%20is%20involved,is%20essential%20for%20language%20production
46. https://www.learningeeg.com/montages-and-technical-components
47. Electroencephalogram (EEG), Page last reviewed: 05 January 2022, NHS, https://www.nhs.uk/conditions/electroencephalogram/#:~:text=An%20electroencephalogram%20(EEG)%20is%20a,looked%20at%20by%20a%20doctor.
48. https://en.wikipedia.org/wiki/Electroencephalography#:~:text=In%20conventional%20scalp%20EEG%2C%20the,attached%20to%20an%20individual%20wire.
49. FREQUENCY WAVES, 2021, ADHA, https://curvex.dk/blog/frequency-waves/
50. What are neurotransmitters?, The University of Queensland Australia, Queensland Brain Institute,https://qbi.uq.edu.au/brain/brain-functions/what-are-neurotransmitters
51. Neurotransmitters, cleveland clinic, https://my.clevelandclinic.org/health/articles/22513-neurotransmitters#:~:text=What%20are%20neurotransmitters%3F,muscle%20cell%20or%20a%20gland.
52. Cerebral Cortex, cleveland clinic, https://my.clevelandclinic.org/health/articles/23073-cerebral-cortex#:~:text=The%20folds%20consist%20of%20many,of%20your%20brain's%20total%20mass.
53. Jeremy Moeller, 2014, An introduction to EEG for students in the health professions, including medical students, neurology residents, and students of EEG technology, https://www.youtube.com/watch?v=XMizSSOejg0&t=1s
54. Yohan Delton, 2014, Practice electrode placement with international 10-20 system for neurofeedback. Grateful for Siegfried and Sue Othmer,.https://www.youtube.com/watch?v=lSrCAHj0t-E
55. Olivia Guy Evans, February 8, 2023, Gyri And Sulci Of The Brain, simplypsychology, https://www.simplypsychology.org/gyri-and-sulci-of-the-brain.html.