

PSYCHOLOGY & DESIGN

The Biophysical Connection between Architectural Design and Psychological Health.

CONTENTS

4

INTRODUCTION

ABSTRACT
INTRODUCTION
MIND BODY CONNECTIONS WEB
TERMINOLOGY

10

HISTORY

HISTORY: HEALTHY HOMES INITIATIVE
HISTORY: WELL LIVING LAB
RELEVANCE

18

METHODOLOGY

BRAIN LOBES
ELECTRODE POSITIONING
THE BRAIN WAVES
STUDY REQUIREMENTS

26

RESULTS

RESEARCH RESULTS
LOMB PERIODOGRAM | BAR GRAPH ENCLOSED SPACES
LOMB PERIODOGRAM | BAR GRAPH GREENSPACE
LOMB PERIODOGRAM | BAR GRAPH OPEN SPACES

36

CONCLUSION

CONCLUDING FACTS
REFERENCES



A B S T R A C T

This purpose of this thesis is to emphasize the importance of the biophysical connection between the human psyche and the environment. In theory, these elements can coexist to manipulate the relationship between design and emotion. This emotional response to the built environment creates a biophysical relationship between humans and their environment, in return, creating an everlasting experience.

Architecture is a realm of design that guides the user on their journey through physical limitation. This limitation can be manipulated to induce an emotional narrative influencing what each occupant does, experiences and remembers. This opportunity to promote an emotional response is the realm of design that needs to be considered when establishing a theory of connectivity between the human neurological state and the built environment.

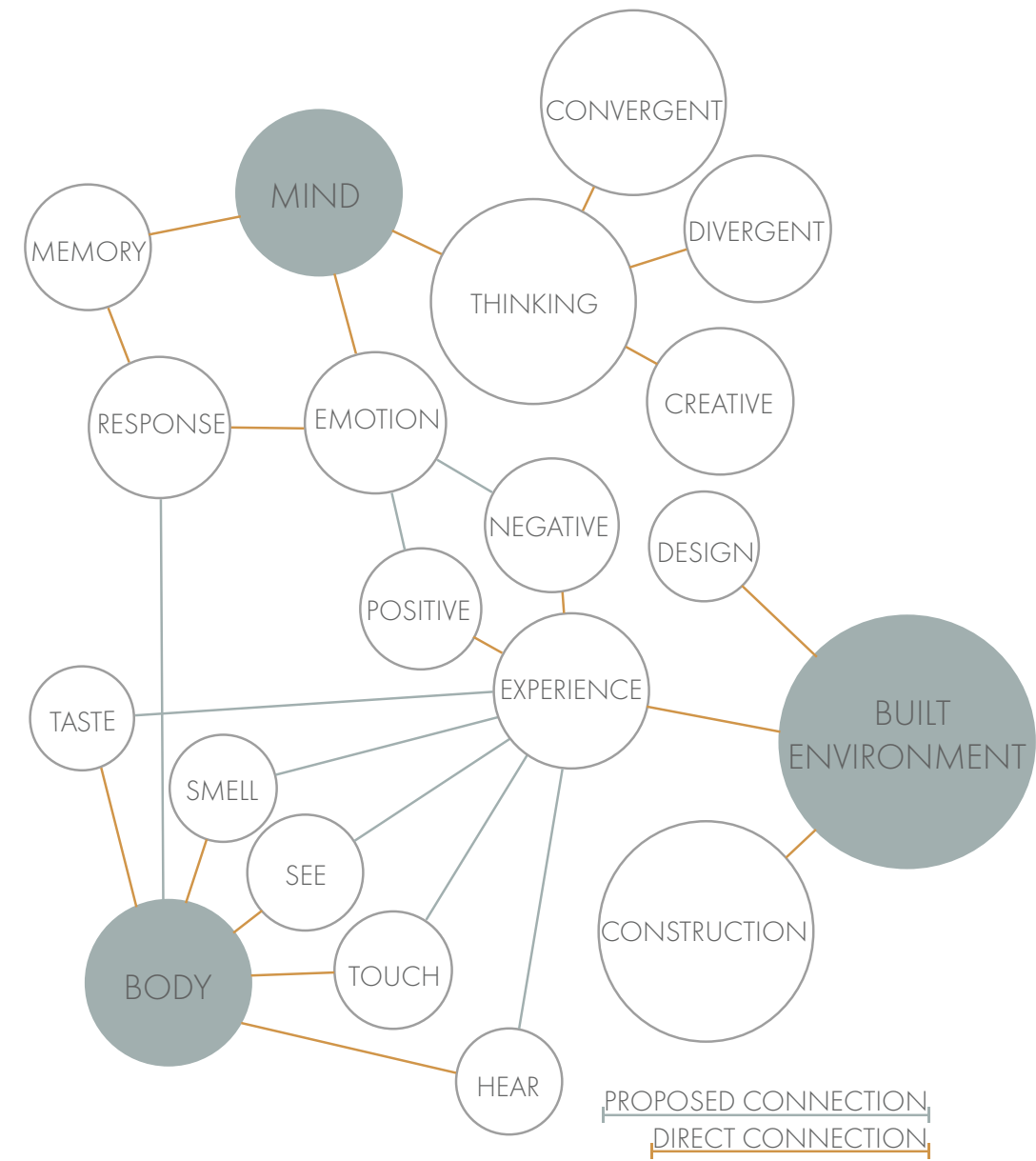
PSYCHOLOGY

I N T R O D U C T I O N

This correlative relationship dives into a cross-disciplinary study between architecture and neuroscience; entertaining how the combination of the two can manipulate design thinking for the strategic planning of future environments. The EEG study will provide me with enough quantitative data to analyze and imply a subconscious influence. If a connection is formed, this recognizes that there is an opportunity for us as designers to schematically incorporate design elements to evoke an intentional response. Humans subconsciously analyze and respond to the built environment; this biophysical response extends the hand of architecture from the physical realm to the behavioral realm.

P R O J E C T | G O A L S

The essential goal of this research project is to interpret the physiological connection between the design environment and the neurological response of those experiencing the environment. This connection can guide us as designers to further legitimize the necessity of the design industry by means of influencing design of environments that positively impacts human health, productivity and overall well-being.



The system of inquiry that governs this research project is phenomenology with subliminal references toward grounded theory. Phenomenology is the connection between consciousness and stimulation experienced throughout architecture. This connection will be integrated through in depth consideration of literary articles, scientific articles and experimental studies.

The experimental study will involve the use of an electroencephalogram (EEG) recording system. This is a machine that records electrode stimulation, sending the results to a computer. The computer software allows reviewers to study abnormalities and variations in brainwaves in response to stimuli. The EEG machine is a necessity due to its ability to establish the legitimacy of the study by providing valid neurological information that is a response to a modeled environment. The study is guided by grounded theory ideology, which works to validate the collection of neurological data by initiating research based on data analysis and inductive reasoning. In coordination, the use of these theories will aide to recognize that humans are neurologically stimulated, in a similar manner, by the built environment.

Consideration of this connection between neurological stimuli and design efforts introduces theories of connection between the built environment and our subconscious. Specific case studies investigate the Healthy Homes Initiative (HHI), brought forth by the U.S. Department of Housing and Urban Development. In conjunction to the HHI, I plan to gain understanding of the WELL living lab, started by the Mayo Clinic. Then a personal experiment will be implemented to further my understanding and test the effectiveness of an EEG machine. These elements will help me to gain a better understanding of the impact the built environment has on our biophysical experience.

“The built environment can impact occupants' comfort and satisfaction, mood, health and well-being, and performance. To optimize the built environment for occupants, we must begin to understand the interactive impact of environmental conditions on occupant outcomes” (Jamrozik P.197).

neuroscience (n):

- the field of study encompassing the various scientific disciplines dealing with the structure, development, function, chemistry, pharmacology, and pathology of the nervous system

electroencephalogram (n):

- a graphic record produced by an electroencephalograph. Abbreviation: EEG

brain waves (n):

- electrical potentials or impulses given off by brain tissue.

subconscious (adj): (n):

- existing or operating in the mind beneath or beyond consciousness
- the totality of mental processes of which the individual is not aware; unreportable mental activities

environment (n):

- the aggregate of surrounding things, conditions, or influences; surroundings; milieu

psychology (n):

- the science of the mind or of mental states and processes.
- the science of human and animal behavior

correlation(n):

- mutual relation of two or more things, parts, etc.
- Statistics. the degree to which two or more attributes or measurements on the same group of elements show a tendency to vary together.

emotion (n):

- an affective state of consciousness in which joy, sorrow, fear, hate, or the like, is experienced, as distinguished from cognitive and volitional states of consciousness.

H I S T O R Y

"the collaboration between architecture and neuroscience could lead to a better understanding of human nature, and to a better understanding of how people perceive their environment" (Karandinou & Turner).



HEALTHY HOMES INITIATIVE

Our homes have a profound impact on our physical and mental health, so everyone should experience this simple commodity. The Healthy Homes Initiative (HHI) program was founded in 1993, due to the lack of government initiative towards the implementation of environmental and physical health conditions within the home. To this day, the HHI has worked to protect families from the inadequacies within their own homes by providing examples of how to protect a home from toxins while also developing grant programs to enable low income families to live in a hospitable environment. This society has done scientific research to guide their understanding of the direct impact our homes can have on our mental, social, and physical well-being.

The Housing and Urban Development home page states, "in response to a Congressional Directive over concerns about child environmental health, the US Department of Housing and Urban Development (HUD) launched its Healthy Homes Initiative (HHI) to protect children and their families from housing-related health and safety hazards." This initiative was set to advocate the importance of healthy home standards to the public, due to the immense physical and mental toll inadequate housing can take on residents, especially children. The company has proved itself necessary and successful throughout the years by funding \$14.6 million towards the initiative, annually. To date, the 101 Healthy Homes Demonstration and Healthy Homes Technical Studies grants have been awarded to HUD providing them with approximately \$81 million. This company can be deemed a reputable resource due to its success and continual necessity. We will always need adequate homes and we will always need architects who can manipulate these healthy living standards through design.

The company, Healthy Homes Impact, recognizes the necessity for health standards within the built environment. HHI is working to better buildings that are completed, but residential environments can envelop these ideas within the beginning phases of design. This will drastically reduce the waste and cost throughout the building's operating life. The HHI initiates an understanding of the way homes are supposed to be designed in response to health. In response, design can be guided by the organizations standards and implement these tactics into the building during the design development phase, lowering construction costs and implementing better health within the home.

HEALTHY HOMES INITIATIVE: IMPACT ON MENTAL HEALTH

The HHI recognize, "substandard housing affects multiple dimensions of health. There is evidence that, in part, poor housing conditions contribute to increasing exposure to biological (e.g., allergens), chemical (e.g., lead) and physical (e.g., thermal stress) hazards, which directly affect physiological and biochemical processes." Another stressor that directly influences residents who live in low-income areas is concern of their rental property and fear of homelessness, causing an increase in psychological stressors.

Design standards can also cause psychological stress through biological conditions causing a connection between biological response and mental health. The US Department of Housing and Urban Development guides further exploration of this common circumstance. For example, poor insulation can lead to excessive noises, in return initiating sleep deprivation. Inefficient indoor temperature can be associated with irritability and social intolerance. Damp, moldy and cold interior temperatures can induce anxiety and depression, and crowding can be associated with psychological distress among women. In children, homelessness and living in temporary housing may lead to social isolation due to the reluctance of occupants to invite guests over to their home. Just as the design of a high-rise building lacks the social spaces to initiate social interaction among residents. Residents who experience these daily issues within substandard housing would psychologically benefit from improved design within their living environments.

This organization works to better the lives of the occupants within these residential areas to better their physical health, mental well-being and socioeconomic standing by means of design strategy.



THE WELL LIVING LAB

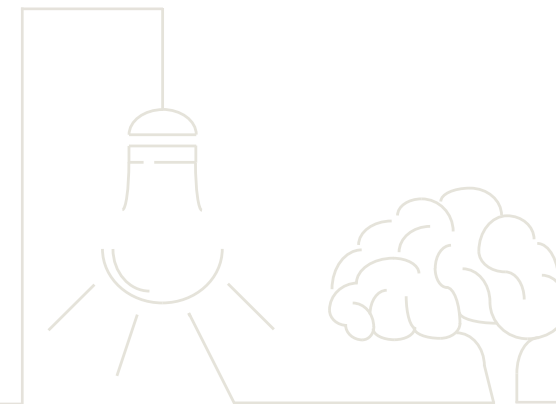
While the Healthy Homes Initiative is looking at how our homes influence our health, the WELL living lab in Rochester, MN focuses on how the office space does. They do this by researching neurological simulation, within the living lab, to determine what variables improve cognitive function and lower stress levels. This lab was first announced on September 9, 2014 through Mayo Clinic, allowing researchers to develop an understanding of how exactly environmental variables influence our mental health.

To test this hypothesis, they manipulate variables such as: temperature, noise, scents, lighting and floorplan design. Following the variable manipulation, a correlational study is established to consider each occupant's overall health, stress levels, ability to sleep, comfort and work performance levels in response to the environmental change. Study 1 researched, "the effect of sound, light, and temperature on employees in an open office environment." Thorough analysis of the experience led the WELL living lab to conclude, "the combination of cold temperatures, noise, and lack of window views and natural light caused employees to feel the most distress." (Study 1. P.2) This connection between the environmental elements and the employees caused them to feel unhappy and less energetic, and elements such as the ability to see outside improved the mood of the occupants. This study provides us with the information necessary to conclude that building variables induce a biological response within occupants, in return influencing their mental health in a positive or negative way.

Study 2 focuses on, "The impact of Scent Diffusers on Indoor Air Quality." Indoor air quality is an element that is also studied within the Healthy Homes Initiative because it is so important for human health. High concentration of volatile organic compounds (VOC) and particle matter within the air impact people with asthma and chemical sensitivities. So, as concluded in the study, it is important to maintain ventilation levels throughout the building in sequence with the device that is releasing the scent. This will maintain the levels of particulate pollution as well as VOC levels. Since occupants are physically affected by the air quality within a space, it is important to balance the levels of VOC's and particulates as they can induce a positive or negative effect on the health of the occupant.

Study 3 tests the, "Impact of office lighting on cognitive performance and sleep." This study justifies the importance of lighting within the home and the office space considering we spend about 90 percent of our time within these spaces. Lighting influences our productivity levels alongside influencing our health, mood, behavior and comfort levels. The study proved that blue-enriched LED light influences better productivity levels, better task switching performance, and better sleep at night. This study proved the benefits of blue-enriched LED light, yet also justifies the need for daylighting due to daylight's natural ability to improve alertness throughout the day. The efforts of studying this information support my research in recognition of the impact daylighting can have on biological responses.

These three living lab studies provide a source of quantitative analysis that directly regard the built environment and its physiological influence over the occupant's overall health, stress levels, ability to sleep, comfort and work performance levels. Scientific studies and journal articles work to conclude that human performance levels and productivity indeed are correlated to the office environment. With that in mind, it is important to take this information and apply it in the context of design. These studies present research that proves: having the thermostat set at 71 F, limiting distracting sounds, providing access to natural light with a window view, using blue-enriched LED lighting and implementing balanced levels of VOC's and particle matter, benefit the biological response of the occupant, in return influencing their mental health in a positive manner.



RELEVANCE

RESEARCH EXPERIMENT RELEVANCE:

The EEG recording system is responsible for recording the electrical activity within the brain, it does not work to formulate an emphasis on feelings or emotions. So how can this research experiment be correlated back to the human subject's experience in relation to the built environment?

- The experiment will calculate quantitative data, allowing the researcher to process the information and study correlations between the participants' brainwave activity and the environment they are experiencing.
- It can work to bring attention to the similarities between participants' reaction to a specific built environment.
- The lobes of the brain that are simulated signify how the participant experienced the visual environment.

Concluding these three points will guide the research study towards a works to initiate a connection between our neurological responses to architectural design with intent to induce a positive user experience throughout the built environment. The combination of these research techniques will aide in the recognition that there is a stable correlation between neuroscience and architecture. This correlation can work to emphasize the importance of the architectural practice throughout the built environment. Furthermore, research studies can work to conclude, "the collaboration between architecture and neuroscience could lead to a better understanding of human nature, and to a better understanding of how people perceive their environment." 1

METHODOLOGY

In the field of architectural design, it is important to recognize the connections between our neurological state and the built environment. This connection can be manipulated throughout the built environment by designing to induce a specific neurological response. If architects enter the schematic design phase with the desire to provoke a specific neurological response, the design world would benefit in terms of relevance and influence. Achievement of this connection will bring an awareness of significance back to the designed environment.

This research report studies human subjects, data, and case study analysis. With most attention towards the human subject's study. This study immersed each participant into a visual environment with intentions of translating brainwave activity into quantitative data. The data is collected through a brain-computer interface (BCI) grade EEG machine that is situated on their head and tightened into place. Data is then collected from the system control panel downloaded from the BCI website. Deliberation of the human response through the quantitative data provides means of effectively determining what the built environment can do to neurologically stimulate human beings. The goal of this experiment is to engage a theory of connectivity between the human neurological state and the built environment. Charting what is occurring within the mind when someone is experiencing an environment will allow us to access this theory.

B R A I N | L O B E S

The EEG machine is situated on the head of the participant and the electrodes are tightened into place. These electrodes are stimulated by activated nerve cells within the brain that produce electrical signals to resonate through the electrodes in the form of brain waves. The EEG machine works to pick up these brain waves and amplify the signal through a system control panel. The system control panel represents, through graphs and charts, the brainwave electrode activity in terms of frequency and amplitude. The chart also has a diagram that plots the sections of the head to show where, within the brain, this electrode activity is occurring. Within the head plot there are a series of numbers ranging from 1 to 8, each of these numbers refer to an electrode site, overlying a lobe of the brain. The Epilepsy Foundation directly states, alphabetical abbreviations to identify the lobe or area of the brain which each electrode records are labeled as:

- F = FRONTAL
- Fp = FRONTOPOLAR
- T = TEMPORAL
- C = CENTRAL
- P = PARIETAL
- O = OCCIPITAL
- A = AURICULAR

Further narrowing of localized brain waves is achieved using given numbers with even numbers identifying electrode positions residing on the right side of the head, and odd numbers on the left side. A z (zero) represents an electrode placed on the midline of the head. This ability to chart the brain in an alphabetical and numerical sequence simplifies our ability to chart where the electrode activity is stimulated. Figure 1.3 is a functional map of the brain describing the positioning of each lobe and what activity generally occurs within that lobe of the brain. This figure will work to aid us in understanding the correlations between the EEG head plot and our neurologically triggered responses.

E L E C T R O D E | P O S I T I O N I N G

According to "10/20 System Positioning", "The international 10-20 electrode system is based on the relationship between the location of an electrode and the underlying area of the cerebral cortex. The numbers 10 and 20 refer to the fact that the distances between adjacent electrodes are either 10% or 20% of the total front-back or left-right distance of the skull." The placement of the electrodes is significantly important regarding the study's legitimacy. Beginning with the 10/20 system, then adding extra positions between the existing system is a way to utilize more electrode locations. Within this study the electrodes were placed in the Fp1, Fp2, P3, P4, T5, O1, O2, and T6 locations.

The electrode formation was chosen, due to the capacity for electrode connection ports on the EEG recording machine. Electrodes Fp1 and Fp2 are connected to the frontopolar cortex (FPC). "The FPC is the large region in the anterior portion of the brain that plays a significant role in complex behavior such as multitasking, decision making, abstract reasoning, episodic memory retrieval and detailed recollection." The following facts regarding each lobe of the brain is directly influenced by the article, "Anatomy of the Brain" analyzed by the American Association of Neurological Surgeons. The electrodes P3 and P4 were specifically chosen due to their positioning on the parietal lobes. These lobes simultaneously interpret all signals received from other portions of the brain such as, vision, hearing, motor, sensory and memory. Electrode's O1 and O2 are in direct correlation with the occipital lobes within the brain. The lobes are focus towards the posterior end of the brain, and they enable humans to experience and process visual stimulation. Influencing how humans experience and interpret light, shapes, colors, and basic forms of visual stimulation. The occipital lobes were strategically chosen due to their direct influence over visual experience. The T5 and T6 electrodes are covering the temporal lobes. These lobes are located on each side of the brain residing at ear level. The area on the right side is involved in visual memory and aids in recognition of objects and faces. The area on the left side of the brain is involved in verbal memory and aids in understanding and memorization of language. The rear of the temporal lobes enables humans to interpret other people's emotions and reactions.

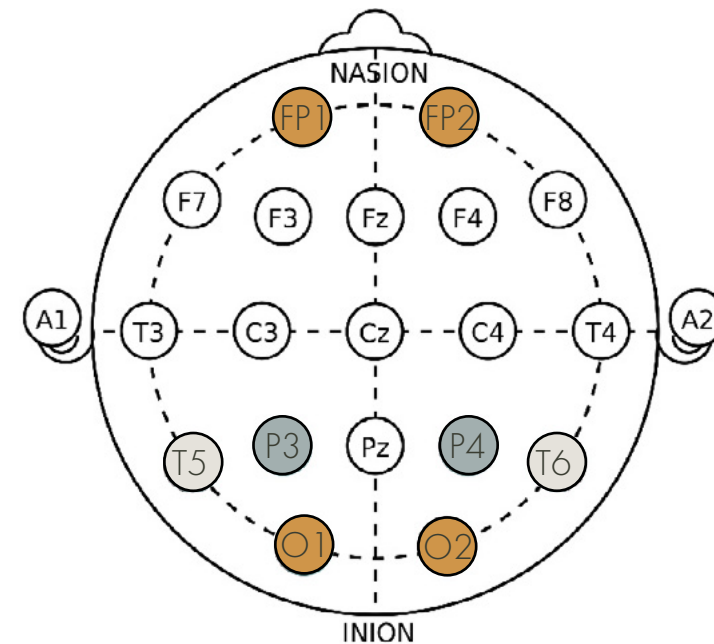


FIGURE 1.2 | Electrode Locations

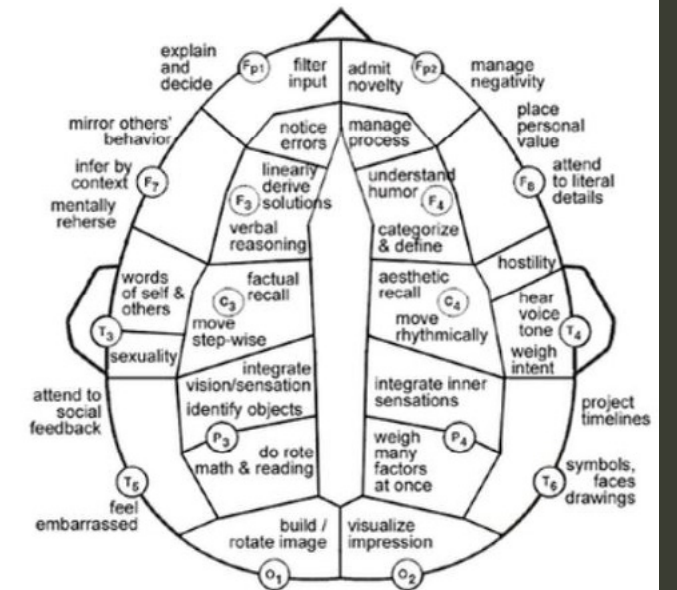


FIGURE 1.3 | The Brain Map

B R A I N | W A V E S

The EEG system puts together a diagram that examines the electrical brainwaves from the brain. In order to differentiate the name and frequency of each brainwave, they have been put into categories. The five most common EEG bands and their frequencies are:

- Gamma: 30-100+ Hz
- Beta: 12-30 Hz
- Alpha: 8-12 Hz
- Theta: 4-8 Hz
- Delta: 0-4 Hz

The analysis of these wave forms can guide research toward the process of how humans think. Specific neurological oscillations are linked to emotional experiences throughout the human consciousness. Continued analysis of this conscious experience will provide correlational data that is needed to connect brainwave stimulation to the participants experience. The following facts regarding the EEG bands are directly influenced by the article, "Introduction to the Identification of Brain Waves Based on their Frequency" analyzed by Koudelkova and Strmiska.

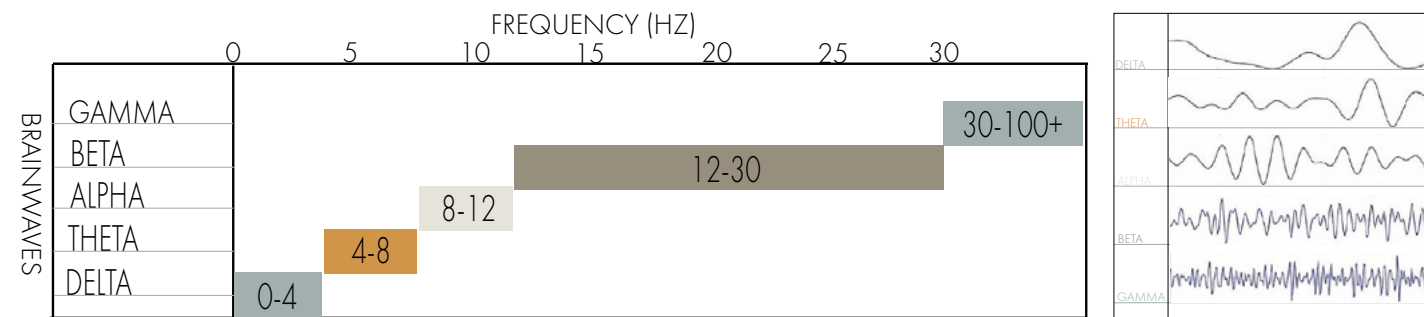


FIGURE 1.4 | Five Major Brain Waves.

GAMMA waves impact learning, cognitive function and information processing. The high frequency brainwave regulates at 30 Hz to 100Hz and are considered important for binding our senses regarding perception and understanding new learning material. The gamma waves within individuals who are mentally handicapped or have learning disabilities tend to be lower. Having the appropriate amount of gamma wave frequency aides in the binding of senses, the power of cognition, and information processes. It also aides in ability to reach the level of REM sleep, which "stimulate the brain regions used in learning".

BETA waves are commonly tested while the participant is awake. This is because the low amplitude brain wave is most visible during logical and analytical reasoning. The moderate frequency range throughout the beta wave is 12Hz to 30Hz. If the participant experiences beta wave frequencies within this range they are considered focused, with optimal memory and problem consciousness. Too high of frequencies within beta waves may signify the participant is unable to relax and experiences high amounts of stress. Too little beta waves may signify that the participant has ADHD, depression, or poor cognition.

ALPHA waves work to connect conscious thinking and the subconscious mind. The moderate frequency range throughout the alpha wave is 8Hz to 12Hz. If the participant is within this frequency range, they are considered relaxed. If the participant experiences too much alpha wave stimulation they may daydream, be unable to focus, or be too relaxed. If the participant does not have enough stimulation, they may have high anxiety levels, high stress levels, experience insomnia, or suffer from OCD.

THETA waves allow us to experience deep emotions, perform automatic tasks and are involved in sleep and daydreaming. The adequate frequency range for theta waves is 4 to 8Hz, this optimal frequency can aide in creativity, emotional connections, feelings of intuition, and ability to relax. A person who experienced too many theta waves may develop depression and have impulsive thoughts. If someone does not experience enough stimulation in this brain wave category, they may experience anxiety, stress and poor emotional awareness.

DELTA waves the slowest brainwaves at a frequency range of 0Hz to 4Hz, this is because they are experienced during meditation and deep sleep. The optimal frequency can benefit the immune system, aide in natural healing and provide restorative deep sleep. If a person experiences too little delta waves, they may experience insomnia, which leads to the inability to rejuvenate the body or revitalize the brain. If a person experiences too high of a frequency they may be experiencing a brain injury, severe ADHD or learning problems. Studying each brain wave singularly provides recognition of the cognitive function each brain wave aides in. Processing this information establishes a connection between brain wave stimulation and the emotional experience of the participant.

S T U D Y | R E Q U I R E M E N T S

The study is to be held at Renaissance Hall, within the second-floor studio space, as this is the allocated space to practice experiments. This room proves adequate, due to the ability to place the booth against a corner. This will allow the booth to remain secluded, yet still in a space filled with other students. There will be a total of 30 participants tested, as this is a quality sample size for a scientific journal.

The participant will initially be given a demographics report to fill out, this report allows us to record the participants age, sex, race and design experience. It is important to consider whether the participant is a designer or not as the mind of a designer may react to design situations differently than a non-design student. After they filled out the demographics report, they moved on to sign a form of consent and understanding of the study. Once these forms were filled out, we situated the EEG machine onto the participants head and secured it into place. The subject is then tested with the machine in place to determine correct positioning and connection of each electrode, it is important that each electrode is fully connected and computing all 8 channels of brainwaves.

Next, the participants were asked to enter the booth and face the projection screen. The booth is constructed out of 2x4's, gypsum board, and cloth. A visual representation of the 2x4's structure is featured in Figure 1.5. The booth was approximately 6'0" x 4'2" x 5' in dimension. This allowed each occupant the adequate amount of room to sit within the space. The proximity of the side walls influences a sense of containment and seclusion in hopes of proper focus on the projection on the screen. The visual experience was projected on the front section of gypsum board, as shown in the diagram. This booth initiates a sense of focus and environmental change for the participants. The change in space from being within the room to being within the booth is necessary to provide the participant with a neutral environment that lacks stimulus other than that shown on the projected demonstration.

The slideshow demonstration was projected through a ViewSonic M1 smart portable projector. This projector was chosen due to its connectivity, contrast ratio, and built in kick stand. The set-up standards allow connection using WiFi or an HDMI cable. The projector has 16GB of internal storage so the images or videos that need to be projected can also be downloaded onto the projector for wireless display. The resolution is 854 x 480p allowing the display to be of HD content. The next step to this process was to expose the participant to the collage of images, while the results are being recorded. The collage was made up of a collection of six environmental conditions:

1. COLORFUL space
2. DAYLIGHTED space
3. CONCRETE space
4. GREEN space
5. ENCLOSED space
6. OPEN space

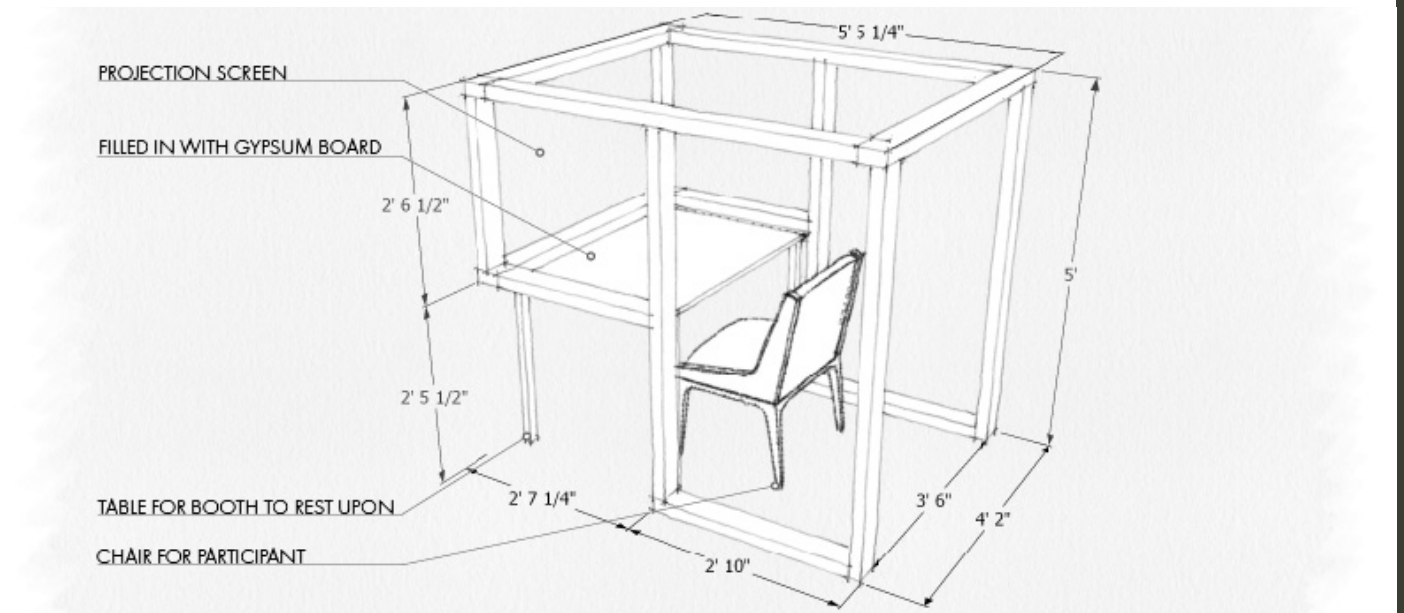


FIGURE 1.5 | Created with Sketchup

These environmental experiences were broken down into twenty images, the participant was exposed to each image for fifteen seconds. In total, the process took five minutes. The first four images are colorful buildings, the next three slides show spaces that are appropriately daylighted. The following three slides are of buildings made with concrete design only, these spaces can be used in comparison to the colorful designs. Four of the slides are of greenspaces within and around buildings, in hopes of ensuing recognition of the impact greenspace has on our subconscious. The next three regard enclosed spaces, the last three are of open spaces; studying the differentiated impact the two forms of space can have on the participant. The decision to use images rather than videos was strategically done because the participant needed to be focused on a specific element of design rather than exposed to a moving situation. This movement may stimulate a lobe of the brain that needs to remain stagnant for thorough analysis of the processed EEG data.

While the participant is experiencing each image of the presentation, the EEG is recording a fifteen second interval of brainwave data. The OpenBCI system works to chart the participant's neurocognitive experience throughout the visualized spaces, in return producing quantitative data in the form of an txt. file. This quantitative data will emphasize which part of the brain is stimulated throughout which built environment. Accumulation of this data aides in the establishment of the connection between our brain and the architectural compositions presented as visual stimuli.

R E S U L T S



Psychology and architecture are significantly connected, and the recognition of this connection will aid in the achievement of purposeful built environments that attribute to the community in a positive manner by means of influencing our psychological experience.

R E S E A R C H | R E S U L T S

Psychology and architecture are significantly connected, and the recognition of this connection will aide in the achievement of purposeful built environments that attribute to the community in a positive manner by means of influencing our psychological experience. This psychological experience was successfully documented using the EEG machine and the computers system control panel. The system control panel releases the data as a txt. file in a numerical sequence, as represented in Figure 1.6. This numerical sequence can then be brought into excel and examined to determine which electrode influences which column of information, as represented in Figure 1.7. In Figure 1.7, columns A-H represent the varying electrode positions, the numerical data throughout each of these columns show the graphical positioning of each brainwave. If plotted, this information is charted as a graph. To further analyze, the data was pulled into a signal processing program called IGOR Pro. This program is a scientific data analysis software that takes numerical information and turns it into a physical graph. This graph coordinates the information on a y-axis that is associated with time, and an x-axis that associates with amplitude, as shown in Figure 1.9-1.11.

Igor Pro was used to manipulate the data to find correlations, differences and similarities. This is beneficial to the project, as the goal is to correlate the participants' neurological experiences. Correlation of these brainwaves would suggest that a participant experienced the simulation similarly to another participant. Figures 1.9-1.11 are examples of the form of study that is diagrammed to test the hypothesis of correlation. If there is a correlation between the brainwaves of the participants, we can draw toward the conclusion that environmental factors do impact people in a similar manner, thus enabling designers to create spaces that uniformly impact the general population.

To research the information further, sampling of three participants within three categories was done. The participants and categories were chosen at random. The categories, chosen by random, were greenspaces, open space, and enclosed space. Figure 1.8 shows the images the participants were exposed to, when the brainwave frequencies were collected. Analysis of this information focused on waves 1,2,7 and 8, as these translate the brainwave frequency of the Frontal Parietal and the Occipital lobes.



G R E E N S P A C E E N C L O S E D | S P A C E O P E N | S P A C E

FIGURE 1.8 | Categories used in Correlative Study.

As established in the Methodology, the Frontal Parietal lobe retrieves episodic memory and the Occipital lobes allow humans to process visual stimulation. These lobes initiate connection between the brain and the visual stimulation, so they were chosen as the basis of the study.

Figures 1.9-1.11 are Lomb Periodograms overlapping the electrode experiences of three participants, while they were exposed to the same image. The overlapping of the graphs allows comparisons to be made. Specifically, Lomb periodograms are used as a spectral analysis tool allowing us to transform the time-series data into a frequency spectrum and plot the frequency spectrum of the data. The periodogram processes the information as the amplitude of the brainwave in microvolts to time. Throughout each periodogram, there is a spike of frequency at approximately 80 Hertz. Further research has led to the conclusion that widescreen monitors run at this frequency, allowing us to recognize this 80 Hz spike as an interference that can be disregarded in the conclusion. Figures 1.12-1.14 are bar graphs analyzed through the program ScopeDSP. ScopeDSP allowed the study to be analyzed at a higher level of detail, thus initiating breakdown as to exactly what point in frequency electrode spikes occurred. This connection to frequency levels will aide in the correlational study between frequency and bands.

In finalized form, the analyzed data will further the design process towards recognition of the biological connection between the environment and design. It will do this by providing quantitative data that fluctuates as the visual environments change. To benefit the design world, this connection needs to be manipulated, by systematically examining space versus the response in the EEG recording system, to guide the project's overall design.

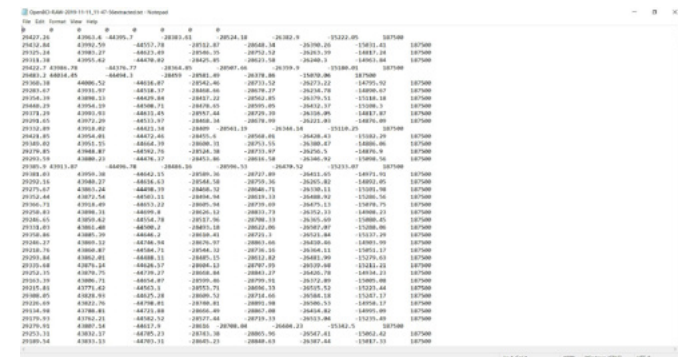


FIGURE 1.6 | OpenBCI Raw Data Format.

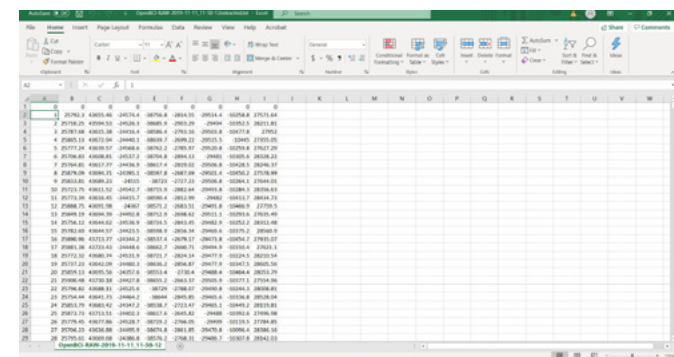


FIGURE 1.7 | OpenBCI Excel Data Format.

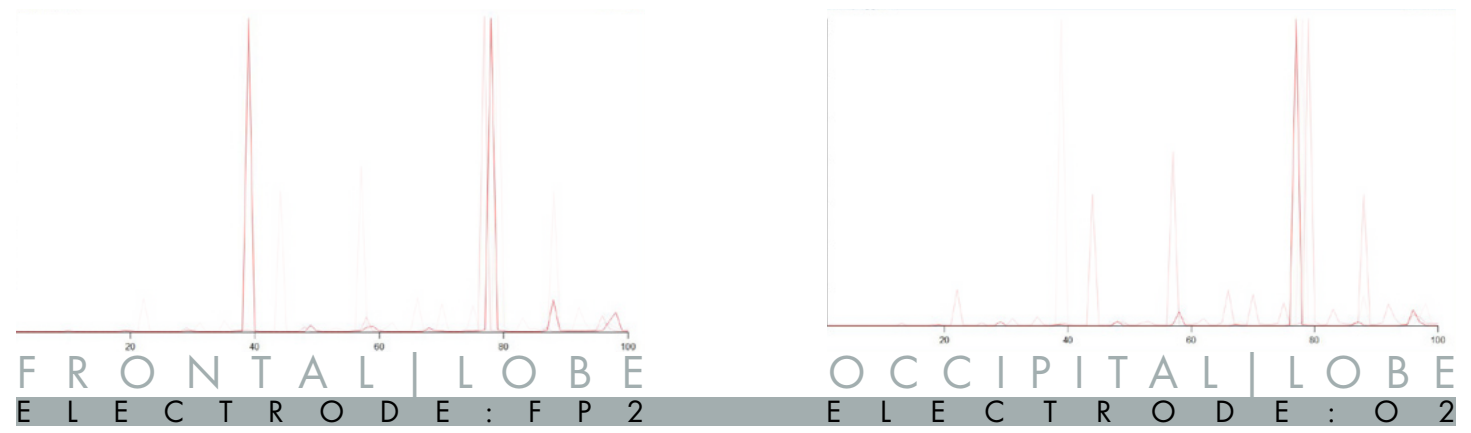
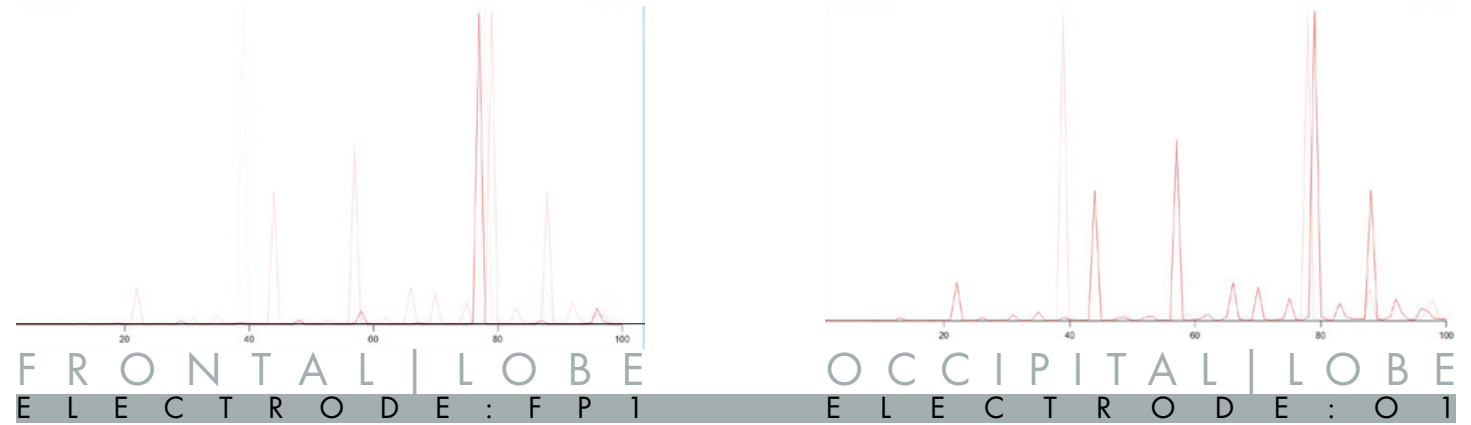


FIGURE 1.9 | IGOR Pro Data. Correlative Graphs of the Enclosed Spaces Study.

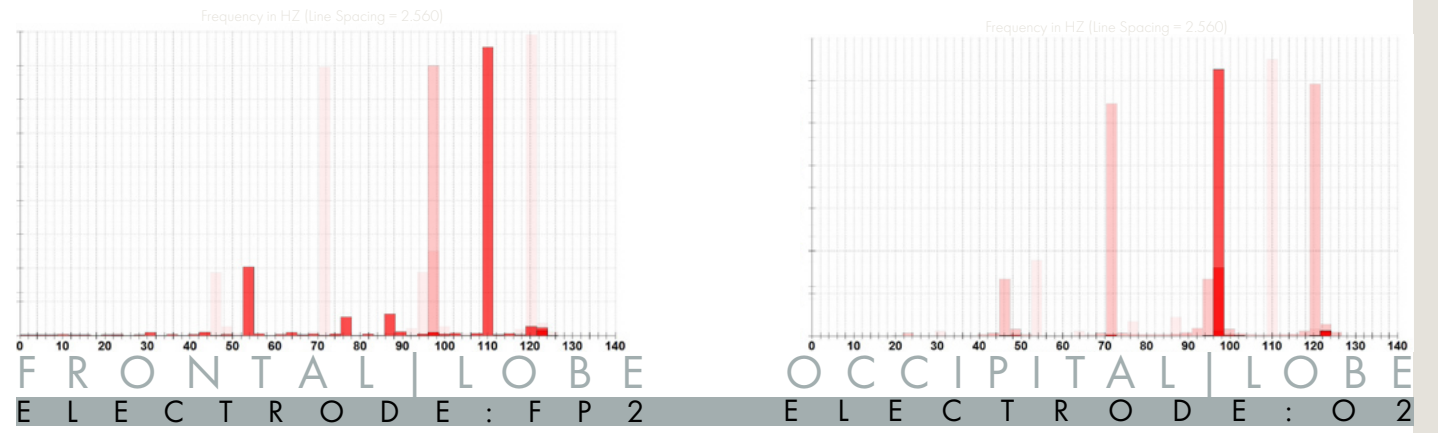
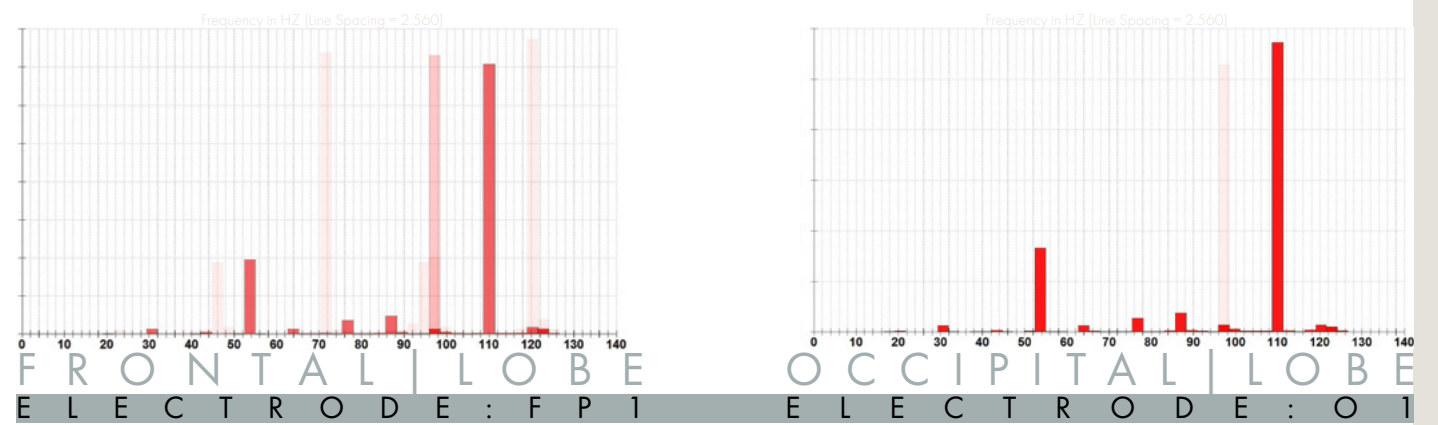


Figure 1.12. Scope DSP Data. Correlative Bar Graphs of the Enclosed Space Study

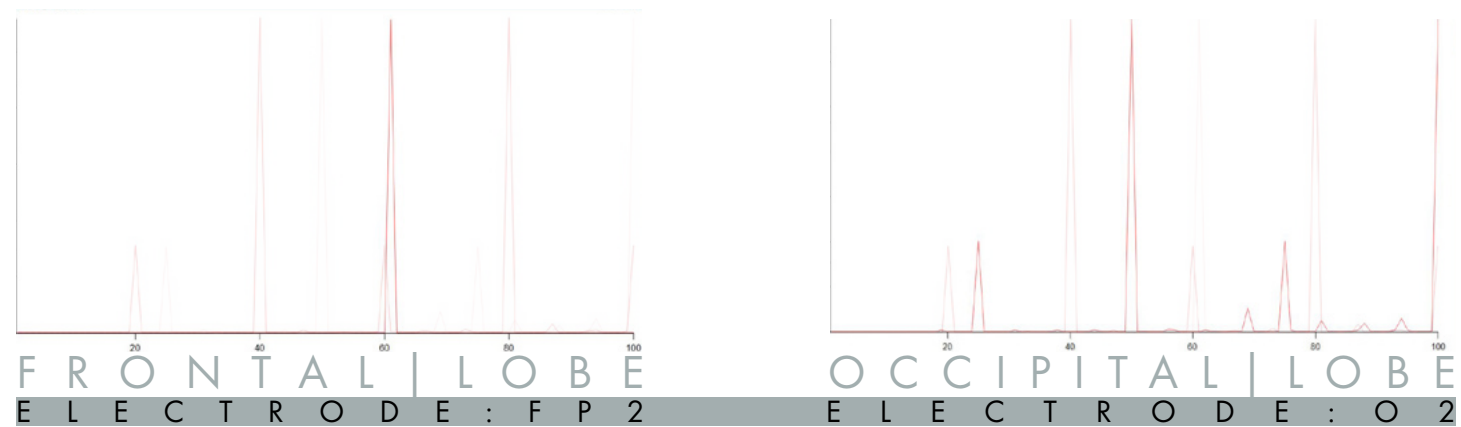
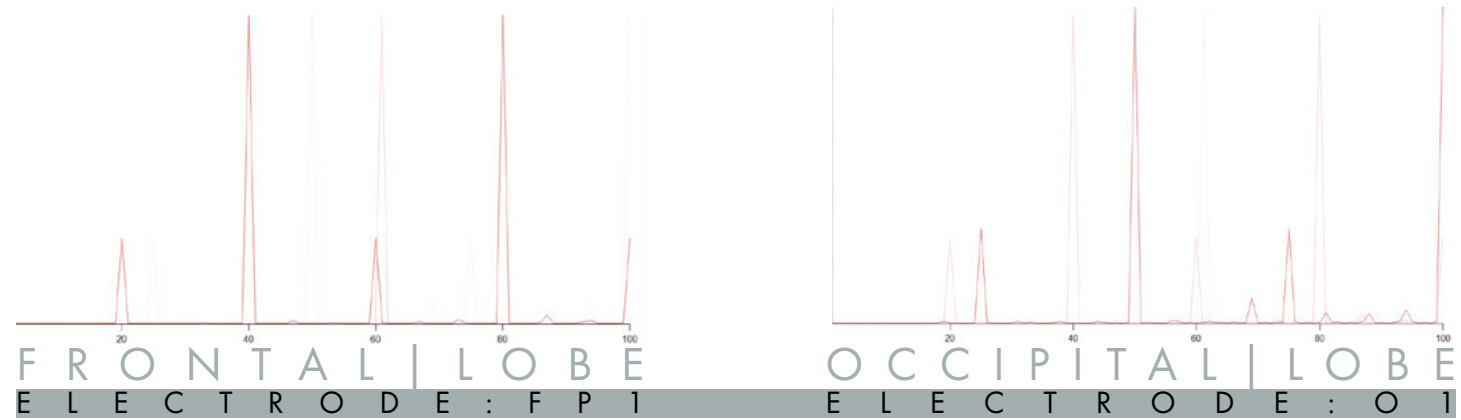


Figure 1.10. IGOR Pro Data. Correlative Graphs of the Green Space Study.

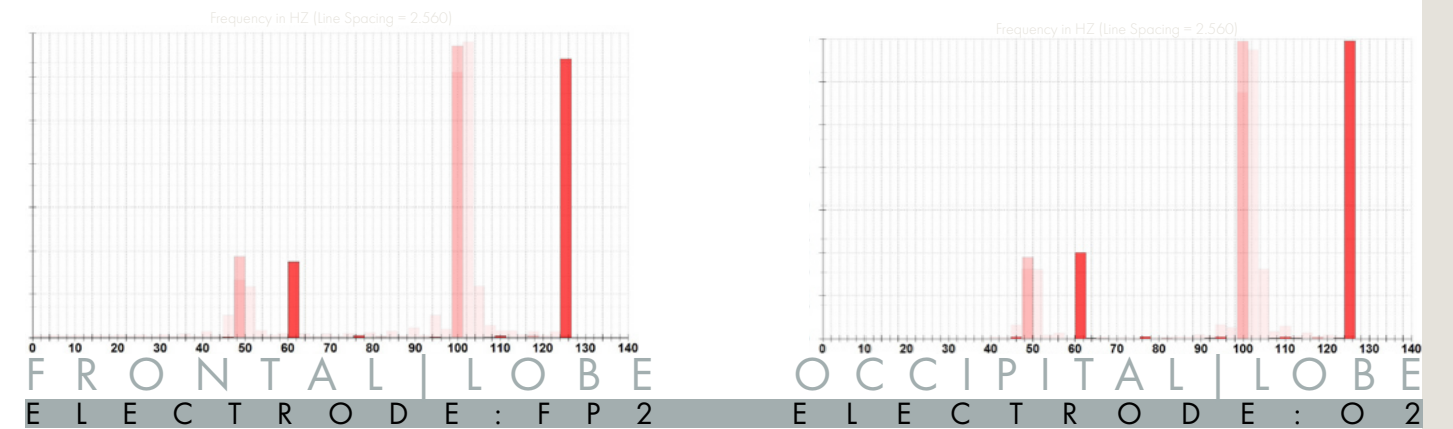
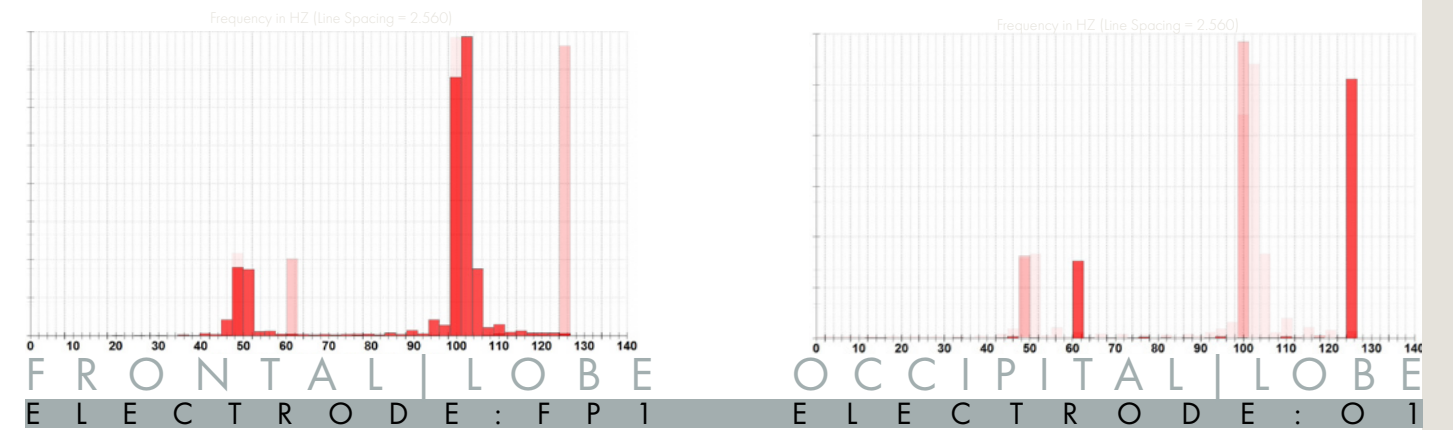


Figure 1.13. Scope DSP Data. Correlative Bar Graphs of the Greenspace StudyStudy

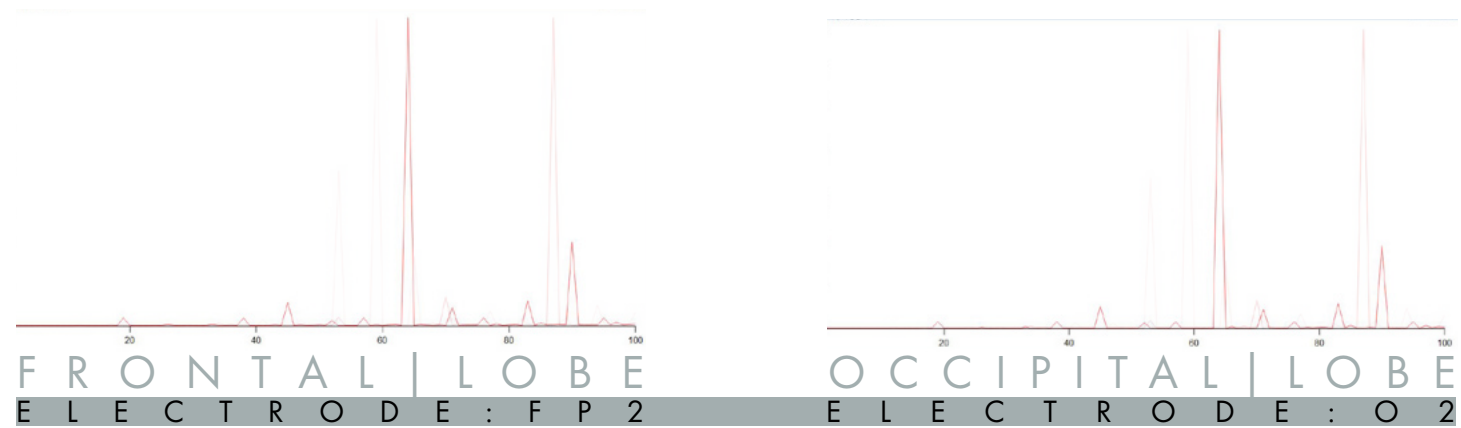
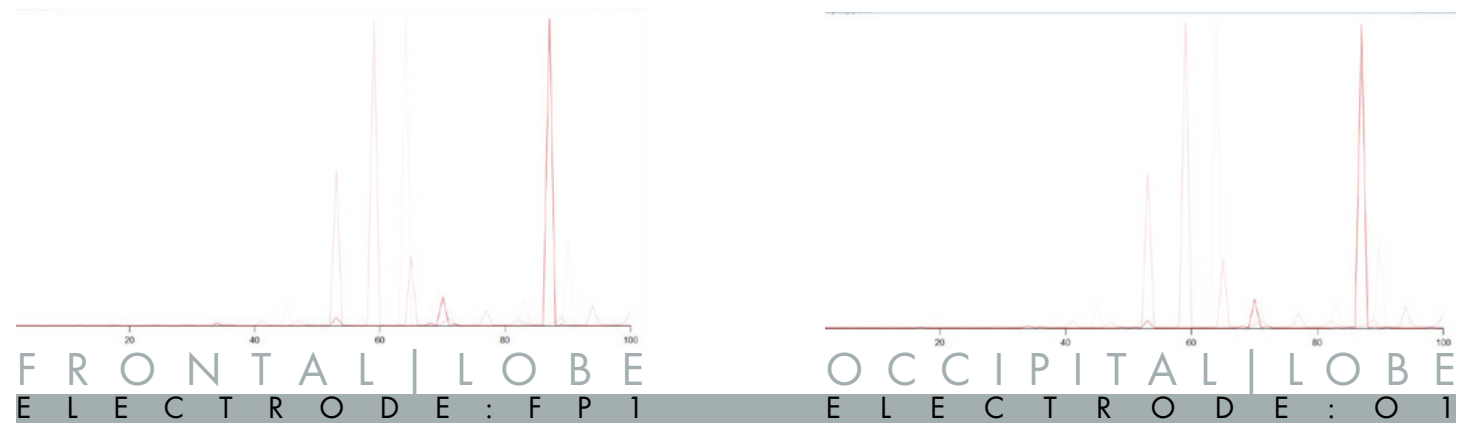


Figure 1.11. IGOR Pro Data. Correlative Graphs of the Open Space Study

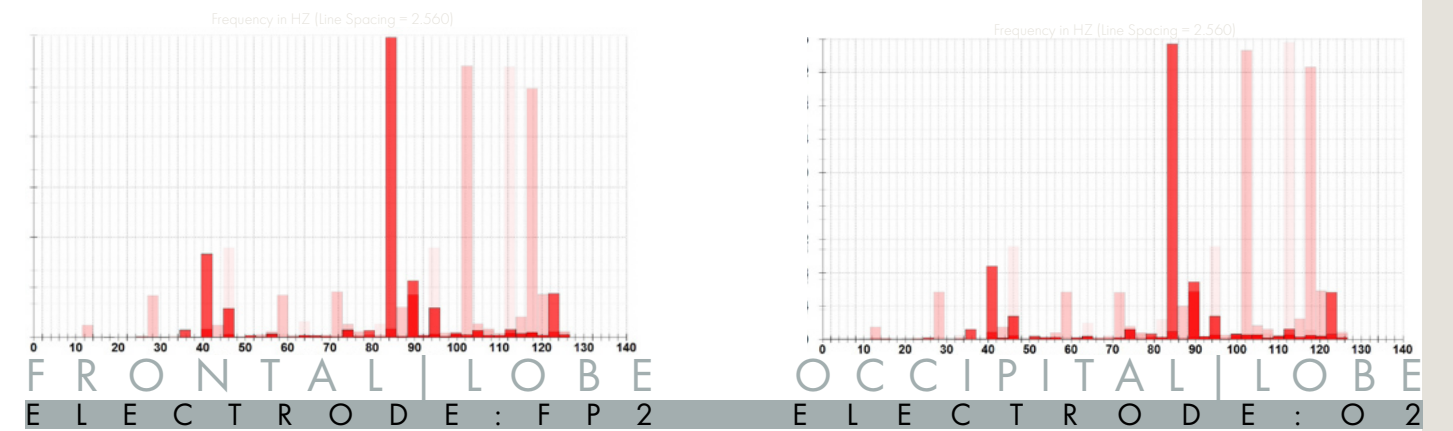
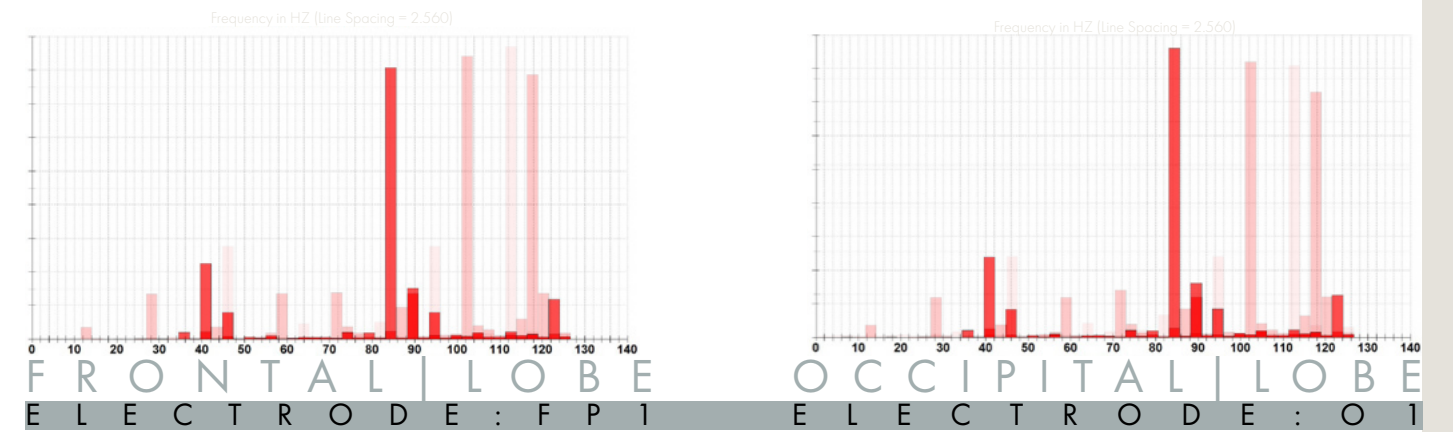


Figure 1.14. Scope DSP Data. Correlative Bar Graphs of the Open Space Study

CONCLUSION



"An architect can control human behavior with his design by understanding the way that a building's design can influence a person's behavior, thus, modifying the individual's mood and perception, whether the environment is natural or man-made." (Vats 1)

C O N C L U S I O N

There is an issue with the current state of the built environment. This issue stems from utter disregard of the significance of environmental design quality. "A good deal of cognition—some experts put it as high as 90 percent—is nonconscious. So, if you're not aware that something is affecting you, then society's failure to accord built environmental design the immense value that it deserves makes some sort of perverse sense." This outlook on the built environment stems from a neutral connection to the environment that does not allow us to truly experience or understand the positive impacts that effective design strategies can influence. Due to this overwhelming mindset, we have yet to achieve a world where design is given the opportunity to consistently influence our subconscious. Formulation of this research study will aide in my attempt to reiterate the influence design can have on our subconscious well-being.

Throughout the research in the signal processing software, IGOR Pro, it can be established that the brainwave activity of each participant was not similar on a raw data level. This dissimilarity occurred because the overall brainwave activity of each participant differed too much. The inability to create this relationship does not degrade the quality of this journal article, as human beings are innately dissimilar, and an exact brainwave match is nearly impossible. To continue the study, it can be done in a correlational manner. The correlational study recognizes three categories, as explained previously as greenspace, open space, and enclosed space. Three random participants within these sections of the study we chosen and the activity from electrodes 1,2,7 and 8 of those three participants were processed in a graphical manner. This processing allowed correlational research to be done on a visual level. The visual representations of correlational research reside as Figures 1.9-1.11 and 1.12-1.14. It is important to remember, the spike of frequency, at approximately 80 Hertz, is considered as external noise and it can be disregarded throughout each participant.

Beginning with the enclosed space study, it can be seen within Figure 1.12 that the overlapped frequencies of all three participants are correlated. In FP1 and FP2 there is a common spike at 55 Hz, 100 Hz, and 110 Hz. In O1 and O2 there is also a common spike at 55 Hz, 110 Hz and one at 120 Hz. Regarding the methodology section "Brainwaves" we can conclude that this means within the enclosed spaces, the FP1, FP2 as well as the O1, O2 lobes showed signal at a gamma level. This is a high frequency level that are used as a binding tool for our senses to process new information .

The greenspace study can be seen in Figure 1.13. The frequencies most prevalent spike at 48 Hz, 62 Hz, 100 Hz and 128 Hz. This is also within the gamma frequency range.

The open space study, as processed in Figure 1.14, shows frequencies that elevate at levels of 30Hz, 40 Hz, 100 Hz, 112 Hz, and 118 Hz. This range of frequencies tells me that the image may have induced more stimulation through the participant, whether that be because of the complex design of the space or the lack of simplicity throughout the photo. Nonetheless, this visual stimulation initiated both beta waves and gamma waves. Beta waves "are channeled during conscious states such as cognitive reasoning, calculation, reading, speaking or thinking" (Kruizinga, 2018).

The data sampled and processed shows that throughout the three studies of spaces that are recognized as enclosed space, greenspace and open space there is a correlation occurring at the gamma wave frequency and in the open space there is a correlation occurring at the beta wave frequency. This concludes that participants react similarly to their environment, in return concluding there is a theory of connectivity between the human neurological state and the built environment. Through literature research and an experiment using an electroencephalogram (EEG) recording system, the connection between architecture and neurological stimulation was established.

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