

BIOPHYSICAL RESPONSES to COLORED ENVIRONMENTS to  
inform NATURAL HEALING practices in ARCHITECTURE.

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**Abstract**

*The built environments we occupy regularly have a strong and lasting impact on our mental, physical, emotional, and spiritual health. This leads to the question of: what role can architecture play in facilitating healing environments through the building design? This design project narrows in on a specific alternative medicinal method called chromotherapy, or color therapy, and shows how it can be applied in the design world. To further advance the research, a psychological research experiment was conducted on human subjects to record the correlation between colored environments and biophysical senses. The biophysical senses that were stimulated in the experiment were further analyzed in a correlational research study to determine which colors mitigate which illness. The results will then be implemented in architecture to create healing spaces through design.*

**Keywords**

Chromotherapy, biophysical sense, healing environment, color, energy, light, alternative medicine, healing

## 1.1 Background | Introduction

The philosophical framework for this research is Positivism-Postpositivism because reality can be objectively described or measured. Positivism assumes that objectivity can be achieved through research and (in Postpositivism) it is presumed as a goal. Positivism is what inspired the modifications and accommodations made in the research process, thus adding the experimental and correlational strategies, both of which will be implemented in my research process. In areas of design that involve people's responses to a setting, this is the recommended tradition to follow for the best results. Experimental strategies create a real-life setting where the study focuses on physical variables. Correlational studies are seeking to describe the relationship between the key variables. There is a focus on patterns that are naturally occurring which are set to be measured by specific variables (Groat & Wang, 2013). These two strategies will work together in producing results that solidify the relationship between healing and colored environments.

There are four quality standards within a Postpositivist System of Inquiry: the truth value through internal validity, applicability through external validity, consistency through reliability, and neutrality through objectivity (Groat & Wang, 2013). It is highly important that the quality standards are met, to ensure accuracy in the final research results. The internal validity comes from truthful representations of the object of study. The external validity is achieved through the results being applicable to the larger world, once the results are analyzed. The research should be valuable to multiple people and contribute to our society. The consistency in measurements or findings of the experiment helps ensure how reliable the results are. It should be safe to assume that the same results would be produced if the study were to be conducted under the same conditions at a different time.

The experimental study will involve the use of an electroencephalogram (EEG) headset and software recording system. The headset consists of electrodes that digitally record the brain waves that are produced in response to stimuli. For accurate results, the experimental study takes place within a design booth to eliminate any unwanted, external stimulation. The EEG equipment is a vital part to this research as it can record and provide valid neurological information that responds to colored-light environments. The correlational study will discover a relationship between the data's analysis conclusion of the brain waves in response to color with specified alternative healing practices.

This interrelationship explores a cross-disciplinary study between architecture and neuroscience, and how together they can design better environments for our future. The experimental study analysis will provide substantial quantitative data to provide an intentional impact. If there is a connection, this validates the opportunity for designers to schematically implement colored lights to induce an intentional response. Humans naturally respond to the frequencies of colored lights; this biophysical response will take architecture from its established physical realm, to an entirely new perspective in the behavioral realm. The goal of this thesis research project is to validate the understanding of the natural connection formed between neurological responses and the properties of colored lights. This analogy can guide designers, medical professionals, and essentially any individual to creating a better future and way of living. This research will provide a reliable and natural way of healing and living in our everyday lives.

## **1.2 Background | Types of Medicine**

In our world of medicine today, there are three main types of medicine that are practiced: alternative medicine, modern medicine, and complementary medicine. It is important to note that there are several known interchangeable names for these medicinal methods, but for better understanding I will use only the previously mentioned names in this study. In addition to that, there are several fields within each of the three medicinal systems, some of which will be mentioned in later examples.

### **Alternative Medicine**

The oldest known medicinal system is alternative medicine, which was founded solely on theory and practice (NCCAM, 2002). This method is a natural practice that uses techniques relating to exercise, diet, and counseling to treat patients. Most practices in this realm are noninvasive and use energies rather than substances to treat illnesses and diseases. The main disadvantage to the alternative medicinal system is that most methods take time to see results, and that is not something everyone has. It is important to be cautious of these methods because of the misconception of something that's natural means that it is safe because this is not always true. There are herbs and plants that are toxic and poisonous, for example poison ivy or tobacco.

### **Modern Medicine**

Modern medicine is younger than alternative medicine but was quickly accepted into the traditions of the western world. Modern medicine is practiced and executed by medical doctors or doctors of osteopathy, and often uses chemical treatments in the form of pills and medicine to treat patients with illness or disease. This system of medicine is more science based and backed on supporting evidence. The major con to modern medicine is the fact that there is seemingly a pill, or substance for basically everything. The downfall of this comes in the fact that the pills are meant to be taken repeatedly which means that these solutions are far from solutions, but rather a temporary fix for an otherwise permanent problem.

### **Complementary Medicine**

The last medicinal system is a hybrid of the two preceding medicinal systems mentioned. Alternative and conventional practices can be implemented simultaneously because they often complement each other when used appropriately (NCCAM, 2002). I think that a lot of people use this method more often than they might realize. An example of this is someone who takes prescription pain medication daily, but also goes to the chiropractor weekly.

In my research I am focusing intently on one specific stem of alternative medicine, although when I test this in a design application, I hope that it will be used as part of the complementary medicinal system to further advance the results. Chromotherapy, or color therapy, is an alternative method of healing that uses colors and lights to bring the body back to homeostasis, or balance. When the body falls out of its normal balance is when diseases and illnesses start to develop in the body, mind, and soul. By balancing the energy that flows throughout our body with the frequency of colors, the probability of forming a disease or illness will diminish. Over time, the problem has been in finding a scientific link between the colors and illnesses for a quantitative study of substance.

## 1.2 Background | History of Chromotherapy

Everyone practices chromotherapy theoretically every day, without even realizing it. Without it, we would be dead along with every other living organism. Sunlight is a practice of chromotherapy, arguably the most important color, and simply basking in its rays can do so much for our health. Sunlight is vital to all walks of life, and the strongest color on the spectrum as it contains every color within its rays. This is familiar to most individuals, especially those living in cold and dark climates as they realize how vital the sunlight is to our bodies when the skin starts to turn waxy and gray in color.

Chromotherapy is an alternative medicinal method that has been practiced for several thousands of years to date. There are instances that date back to ancient texts discovered in China, Greece, India, and Egypt although nothing of medical or historical implications were fully documented (Garala, 2009). Aside from colored light, there is a long history based on colors individually, without the additional use of light. While I think there is some important facts worth noting behind the properties of colors themselves, light is ultimately the healing factor.

The first instances of chromotherapy are indicated in the Grecian temples where they started with pure sunlight and slowly discovered a significance in the use of individual colors, too. There are geographical remnants and evidence of healing in recovered recordings that suggest the light and color practices were used in addition to the use of opiates. Opiates were ingested to deepen the patients sleep and hallucinations, thought to bring them closer to the gods/healing. The earliest cases are fascinating for many reasons, the first being the depth of knowledge they already obtained before teaching this practice. The priests and priestesses understood the importance of the intricate layers of healing and took on the responsibility of accumulating this knowledge and practice, as well as relating it. This meant to practice other methods such as healthy eating, exercise, hydrotherapy, aromatherapy, in a simultaneous way to deepen the healing properties (Roseman-Halsband, 2018).

There is evidence of color diagnosis and medical protocols found in the bible of Traditional Chinese Medicine, a book written over 2000 years ago, with information that is still relevant today. The Chinese people found inspiration and curiosity in nature as they knew there was a significance in the colors they were observing, growing all around. Herbs and vegetables were a significant variable in their healing methods, either to be ingested or applied directly on the skin (Roseman-Halsband, 2018). They were close in their theory as plants survive off sunlight and photosynthesis.

In Egypt there was another color practice called gem healing, which required gemstones of certain colors to be ground up and placed in water that is then charged by the sun's electricity (Roseman-Halsband, 2018). As time evolved, there were flaws found in this practice as some gemstones and minerals are found to be toxic, or even deadly. There is evidence of colored rooms in the Egyptian temples, in the Roman hospitals and mental institutions, and more recently in daily practices in America and Europe since the late 18th Century.

Doctor Edwin Babbitt formulated his own protocol after he extensively studied other cases executed physicians, that were mostly practiced naturally, at home through colored windowpanes. That was before electricity was created, which is a fascinating aspect given the advancement of knowledge in

topics of chemistry and color to create a viable method of healing such as chromotherapy. Babbitt's protocol was more objective and methodical as it required patients to complete a series of strict tasks.

In more recent times, chromotherapy has been implemented in various ways in healthcare facilities and wellness centers. There have been several instances where light is incorporated into yoga and meditation practices, as well as in saunas and flotation spas to bring the patients to a deeper level of healing by mixing complementary, alternative medicinal methods. Through this research I hope to discover a reliable method as on track with Babbitt's studies and theories to conclude with sound results.

### 1.3 Background | Key Definitions

The following section defines key terms to provide a deeper, comprehensive understanding of the material to be discussed in this article.

Alternative Medicine: Practices methods of health and healing that do not rely on drugs or surgery for treatments (Trivieri & Anderson, 2002).

Modern Medicine: Practices methods of health and healing that rely on drugs or surgery for treatments (Trivieri & Anderson, 2002).

Complementary Medicine: Practices methods of health and healing that use methods from alternative medicine and conventional medicine practices, simultaneously (NCCAM, 2002).

Chromotherapy: An alternative method of healing that uses the frequency of colors and lights to bring the body back to homeostasis.

Biophysical: A branch of science that studies the biological reactions/problems to physical principles.

Healing: To make whole or healthy again.

As rudimentary as this one might sound, it is important to note that *healing* does not necessarily mean going back to normal, or what once was. It can also mean coming to peace with something entirely new- and with that, it is not to be confused with the term *curing*.

Electroencephalogram (EEG): A test that measures brain activity through electrical currents.

### 2.1 Discussion of Methodology | Overview

The purpose of this research project is to validate the understanding of the natural connection formed between neurological responses and the properties of colored lights. The spaces we occupy everyday

have a lasting impact on our overall health and well-being, so it is important to me as a designer, to use my knowledge to design places of healing. This process can be manipulated throughout our built environments with this prior knowledge of connection between neurological responses and frequencies of colored light. Implementing these established connections in our design work will bring a perception of substance back to the design world. If designers have a goal to provoke a specific neurological response, architecture will take on a whole new meaning of relevance and influence.

This research project studies human subjects, data analysis, and correlational strategies in fulfillment. The human subject study consists of immersing each participant in a bath of colored lights, while an EEG headset records the responsive brain activity into the software. Data collected from the study will contribute in providing elements of quantitative data. Consideration of the human responses in addition to the quantitative data collected will provide a way of effectively determining how architecture can aide in the healing process from sickness and disease. Analyzing the brain activity in response to color frequencies will open a new world of design and healing. The collaboration of these aspects will allow validation of the study as a predominant form of scientific investigation.

### 2.1.1 Experimental Research | Design Booth

The main research strategy I am practicing is the experimental method. This requires training for working with human subjects and an approval from the Institutional Review Board (IRB). Once both were acquired, I was able to start the design and construction of a design booth. The purpose of the booth is to eliminate any unwanted stimulation that might affect the participant during the study. Eliminating as much external stimulation will provide a neutral environment to gather the most accurate results.

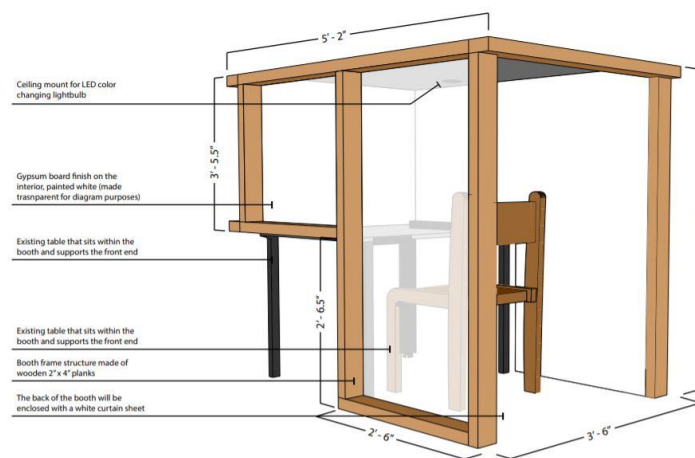


Figure 1 | Design Booth modeled in Sketchup

The design booth, diagrammed in *figure 1*, is constructed of a wooden 2x4 frame and finished with 1/2" gypsum board. The booth stands at approximately 6-feet in height and 3.5-feet in width. The booth was constructed and located in our second-floor studio of renaissance hall. The booth is partially supported by a table in the front, which will also provide comfort for the participants as they can sit and rest during the study. Inside, the booth is laced with sheer white cloth to

conceal the edges of the gypsum board and wood. The study will need to be actively monitored, so the back is fixed with an adjustable, sheer curtain.

The colored lights were emanated from a pair of LED light bulbs, labeled Smart LED Light Bulbs by *Twoon*. These bulbs were selected because of their high 100-Wattage power, and their ability to connect to a smart device wirelessly. The bulbs were mounted towards the front of the booth, on opposite sides as shown in figure 1. I connected the lightbulb devices over Wi-Fi to my smartphone via the SmartLife application, which allowed me to easily control the colors for the duration of the study.

### 2.1.2 Experimental Research | Color Analyzation

During the study, I showed a series of five colored lights as follows, in a consistent but no certain order: Red, Yellow, Blue with White, White, Blue. These colors were selected after extensive research on the properties of colors, the relationship of colors, and the basic inner workings of physics.

The relations of colors are often regarded upon a color wheel, which is what Babbitt expanded from with his harmony and contrast chart, shown in figure 2.6 (Babbitt & Birren 1967). This is the easiest way to understand how the primary colors can be made into secondary colors which is highly important. The relationship of colors is surface level compared to understanding how and why the colors appear the way they do.

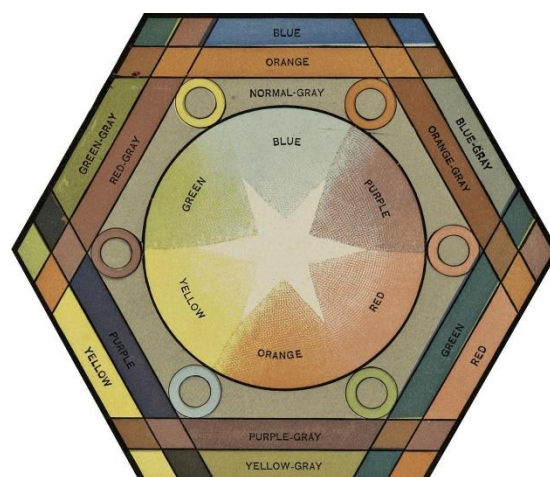


Figure 2 | *Chromatic Harmony of Gradation and Contrast*. Reprinted from *The Principles of Light & Color*. By, Edwin Babbitt. 1876.

An interest in the properties of colors, like most other physical things, stems from the knowledge of science. First, to understand the concepts of physics and matter is essential. The concept that energy and matter are dual expressions of the universe, a theory discovered by Einstein. Matter ( $m$ ) that is accelerated by the speed of light ( $c^2$ ) becomes dematerialized energy ( $E$ ) (Azeemi & Raza, 2005). What this means is that any materials of substance found in nature is energy. The colors we see are simply wavelengths and oscillations, but once these are combined with a source of light, the energy conducive to healing is produced to be applied to the impaired organs or bodily systems. Since every organ within is made of matter, it is safe to conclude that each organ has an energy that vibrates at its own rate. The objective is to match a vibration of colored light with that of the healthy organ to bring it back into harmony if it has fallen out (Klotsche 1992).

The law of polarity is essential as it explains the reasoning behind why there cannot be a negative without a positive. This becomes relevant in all aspects of science in the three-dimensional world (Klotsche 1992). This translates back to the basis of chromotherapy when the (2) polarities with our (2) bodies- ethereal and physical, are interchanged. Figure 3 shows a visual representation of this for a clear understanding of the way color frequencies move and translate, to bring the body into a harmonic balance for the best functionality. The two bodies can also relate to Einstein's formula, previously

mentioned, of  $E = mc^2$  where the spiritual body (E) equals the physical body (m) times light ( $c^2$ ) (Klotsche 1992).

POLARITIES		
Expression	Corresponding Opposites (poles)	
	Physically Receptive (sedative, minus pole)	Physically Reactive (stimulative, plus pole)
<b>Color</b>	Blue (fast waves)	Red (slow waves)
<b>Magnetism</b>	North-seeking pole	South-seeking pole
<b>Electricity</b>	Electric negative	Electric positive
<b>Bioelectricity</b>	Bioelectric positive	Bioelectric negative
<b>Gender</b>	Female	Male
<b>pH Value</b>	Sedation by alkalinity (pH above 7)	Stimulation by acidity (pH under 7)
<b>Chinese symbolism</b>	Yin	Yang
<b>Element</b>	Oxygen	Hydrogen
<b>Music</b>	Slow rhythm	Fast rhythm

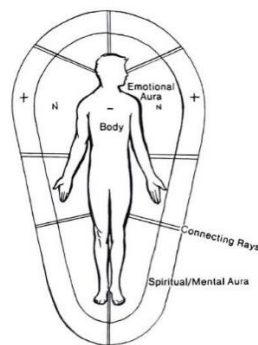


Figure 3 | Ideal aura/body polarity. Reprinted from Color Medicine. By Charles Klotsche.1992.

Each color contains different healing properties of their own. Theoretically, this would indicate that the primary colors (red, yellow, blue) are the most powerful, as every color beyond can be made with them. Light is the true rise of color. This is proved true when thinking of the rudimentary prism, shown in figure 4. The prism emanates every color of the spectrum within, when cast upon with sunlight, making pure sunlight the strongest color of all (Klotsche 1992).

The prism casts 7 colors; Red, Orange, Yellow, Green, Blue, Indigo, Violet- each containing its own unique wavelength, or vibration. When colors such as red, orange, and yellow, “feel” warm, it is because they literally are. These colors are more absorptive and move in slower, larger wavelengths. This is also true of the cool colors; blue, indigo, and violet, as they are reflective and move in faster, smaller wavelengths (Klotsche 1992). See figure 5 for a visual representation.

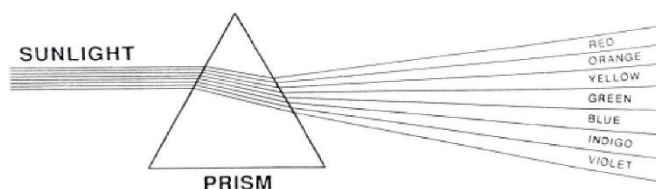


Figure 4 | Refraction and Dispersion of the Prism. Reprinted from Color Medicine. By Charles Klotsche.1992.

Once these theories were applied to specific organs and areas of the body, a noticeable pattern that seemingly reciprocates that of the seven chakras was noticed. The upper body resonates with the ‘warm’ colors, the bottom with the ‘cool’ colors, and green as neutral (Klotsche 1992). Described in this section is each color shown in the

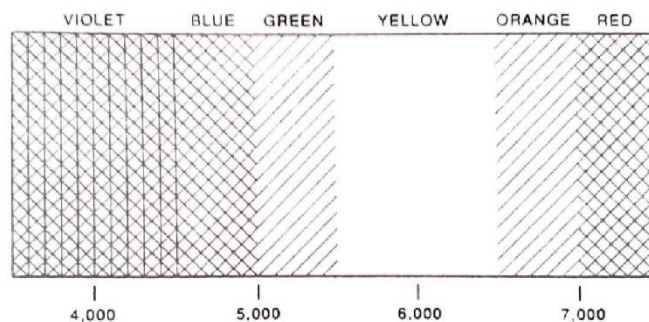


Figure 5 | The Visible Spectrum. Reprinted from Color Medicine. By Charles Klotsche.1992.



experiment with corresponding healing properties it produces.

The colors I showed to the study participants were viewed in no certain order, but consistent as the following:

#### *RED Light*

Red is commonly used as a stimulant and detoxifying agent. It resonates with blood, therefore affecting the circulation of the body. The nervous system and liver are especially affected by red. Falling on the far end of the spectrum, red is a powerful color and to be used with caution as it can easily over stimulate the body and have a negative effect on the mood.

#### *YELLOW Light*

Yellow is often regarded for its strong effects on the sensory and motor nervous systems. Yellow helps tone muscles and improves the digestive system. The intestines, pancreas, and digestive fluids are stimulated by this color, making it an effective laxative.

#### *BLUE Light*

Blue relieves pain and irritation with its calming vibrations. Its soothing properties help in providing deeper sleep. Blue decreases inflammation, general pains, and nervousness in the body. Too much blue can have a negative effect on the mood.

#### *WHITE Light*

Without sunlight, we would cease to exist along with all other living organisms. White sunlight literally gives us the energy of life. Too much sunlight can be over stimulating, especially to the brain and exposed skin.

#### *BLUE Light x WHITE Light*

Combining the electrical power of blue with the healing power of natural light creates a rousing, animating effect. They almost counteract each other to not let one get more powerful than the other, while still emanating their effective properties.

### **2.1.3 Experimental Research | Electroencephalogram Equipment and Software**

The electroencephalogram equipment and software were found online and purchased from Open Source Brain-Computer Interfaces (OpenBCI). This product started out as a Kickstarter idea and expanded from its success. The headset and electrodes are 3D printed products that work directly with the cyton board. The cyton board is attached to the headset and contains 16 biopotential input channels and wireless communication Bluetooth. The biopotential input channels are where the electrodes connect to the board for recording. The cyton board connects wirelessly to the ganglion dongle which is inserted in my laptop as the sessions are running and recording through the OpenBCI program. When the program is running, there is a layout option where you can customize the system control panel to view graphs and charts you want during the session. The system control panel digitally produces the brainwave activity in terms of frequencies and amplitudes that is being gathered. *Figure 6* is a screenshot of the system control panel layout that I used while performing the experimental study.

There are six options of charts to use in the system control panel, but I used the four that were most essential to my research: time series chart, fast Fourier transform plot, head plot, and band power. I did not use the accelerometer and networking charts, as they were not necessary to actively monitor.



Figure 6 | OpenBCI System Control Panel. 2019.

The time series chart shown in the top left window of *figure 5*, streams each of the 8 channels (for corresponding 8 electrodes) over a window I set to run 10 seconds, where it produces the currents in Ohms. While testing, this was the window I monitored closely as it is an easy indicator if the electrodes are reading properly. Before the participants entered the booth, I performed an impedance check on each channel to ensure it was reading the signal correctly, and not picking up excess signals.

The head plot frame located in the bottom left window of *figure 6*, shows an overview of the head with each electrode in its corresponding position. This helped link the 8 electrodes to their proper locations on the brain when adjusting the headgear. A detailed understanding of the inner workings of the brain was essential to conducting the study. This crucial information is further analyzed in a following section. Even more importantly, the head plot shows the polarity of the signal received from the electrodes. It is a good indicator of the rate of the voltage that is being measured.

The right side of the system control panel consists of two frames: the fast Fourier transform (FFT) plot and band power. They essentially relay the same information as the band power shows Hertz of the 5 major brain waves and the FFT plot shows the corresponding information, but instead, in the form of frequencies on a graph.

### 2.1.4 Experimental Research | Brain Waves

The major brain waves are an important aspect to analyze as they are naturally occurring and provide information regarding level of consciousness and awareness. The bands are listed below, in the order of their frequency range with a description of their attributes as determined in analyzation of the article by Zuzana Koudelkova & Martin Strmiska (Koudelkova & Strmiska 2018):

*Delta waves | 0.5-4 Hz*

Created with the lowest frequency, these slow waves are produced during sleep, or in a deep, meditative state. This frequency recharges the immune system and provides natural healing that restores our bodies. In extreme cases when Delta waves are lacking, one will experience insomnia or brain injury.

Delta wave disruption risks:

- Sleep disorders
- Parkinson's disease
- Schizophrenia
- Type II diabetes
- Fibromyalgia
- Alcoholism
- Epilepsy
- Depression
- Anxiety
- Obsessive compulsive disorder
- Attention-deficit/hyperactivity

(Inui et al., 1994) (Pilon, Zadra, Joncas, & Montplaisir, 2006) (Alfimova & Uvarova, 2008) (Inui et al., 2009) (Colrain, Turlington, & Baker, 2009)

*Theta waves | 4-8 Hz*

These brain waves are produced during moderate sleep or a conscious of daydreaming. Vibrating at such a low frequency, this is where our intuitive thoughts form and automatic tasks are executed.

Theta wave disruption risks:

- Heart disease
- Stroke
- Type II diabetes
- Obesity/weight gain
- Depression
- Alzheimer's/dementia
- Epilepsy

(Kecklund & Axelsson, 2016) (Tatum, Kaplan & Jallon, 2009)

*Alpha waves | 8-13 Hz*

In the middle of the band, alpha waves are a neutral oscillation that occupy the cortex, occipital lobes, and thalamic portions of the brain. It links our subconscious thoughts to our conscious thoughts, which provides a calming sensation.

Alpha wave disruption risks:

- Major depression
- Chronic fatigue disorder

(Mani et al., 2009)

### *Beta waves | 13-30 Hz*

This oscillation occupies a much wider range as it is often acquired during a higher level of consciousness, when one is awake. These waves are produced when a task is being executed with alert concentration. When one is focusing on a task or making a decision, these waves are produced.

### *Gamma waves | 30-100 Hz*

These brain waves are produced during conscious attention. In the brain, these waves are produced in the thalamus, but extend to other regions in search of activity. The thalamus is important for learning and processing.

Gamma wave disruption risks:

- Schizophrenia
- Behavioral hyperactivity
- Prepulse inhibition deficit

(PSYCHIATRIC SYMPTOMS, 2009)

The brain waves occur in certain areas of the brain, which helps in placing the electrodes accordingly on the head, using the EEG headset, as further explained in the following section.

## **2.1.5 Experimental Research | Brain Lobes and Electrode Positioning**

For the study, each participant is asked to wear the EEG headset on their head, which consists of (8) dry electrodes that are made adjustable for each person. The electrodes are a vital piece of equipment as they are stimulated by active nerve cells, so it is important for them to touch the scalp directly for accurate results. The nerve cells produce electrical signals which are transmitted by the electrodes in the form of brain waves, which are then transferred to the system control panel in the form of charts and graphs. With a concise understanding of the brain waves (Canavero 2015), I was able to locate the electrodes on the scalp. *Figure 7* provides a visual overview of the electrode sites on the scalp that are abbreviated as follows:

- F = Frontal
- Fp = Frontopolar
- T = Temporal
- C = Central
- P = Parietal
- O = Occipital
- A = Auricular

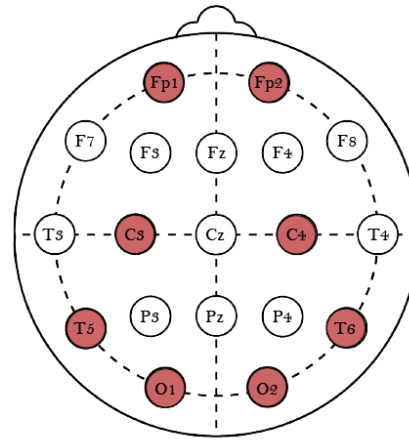


Figure 7 | Modified from Electrode locations of International 10-20 system for EEG recording. Wikipedia (2010). Copyright Public Domain.

There are 16 sites of for electrodes with an additional 3 centrally located sites that read z, for zero, which provide extra stability, with no electrode connection. The systematic understanding of the brain chart, in terms of an alpha-numeric order, will provide a simple way to connect where electrode activity is stimulated. This is made possible with the understanding of the brain maps in *figure 8* and *figure 9*, which provide an overview of what activity occurs in the corresponding brain region. This foresight will help in forming connections during the study.

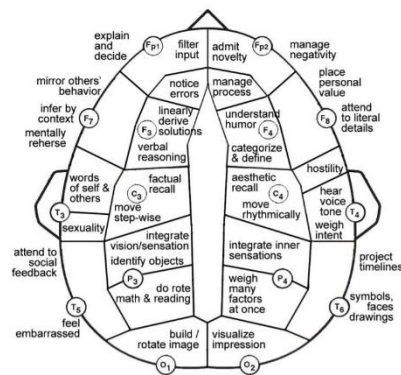


Figure 8 | The Brain Map. Neuroscience of Personality. By, Dario Nardi. 2009.

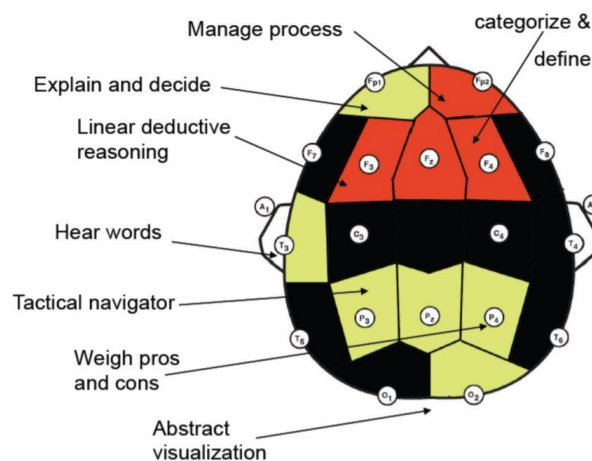


Figure 9 | The Brain Map overview. Neuroscience of Personality. By, Dario Nardi. 2009.

### 2.1.5 Experimental Research | Executing the Study

The study was executed over the duration of two weeks and tested 30 individual participants. Each participant filled out a corresponding survey questionnaire and study consent form that outlined the procedures and safety precautions for the study. Once the forms were completed, the EEG headset was mounted on the head and adjusted as needed. Before beginning each experiment, I performed a test and impedance check to ensure each electrode was working and reading properly. As they adjusted to a comfortable position in the booth, I explained what was about to occur and added the corresponding alpha-numeric code to their survey sheet for later analysis. During the study, the OpenBCI program was running on my laptop as I controlled the smart lightbulbs from my phone. Each colored light was emanated for approximately 90 seconds for a thorough analysis. Once the testing was complete, the participant removed the headset and that ended the session.

### 3.1 Research Results | Software Applications

Once all this information and data from the study are collected, it is time to analyze them and understand what they mean. In understanding them, I can answer the premise of the thesis on whether it is possible to provide healing agents with colored light in architecture. If the results of the study show similar in the form of their waves upon a graph, it is safe to presume that healing can be implemented through architecture. If the results are vastly differing, it can be assumed that chromotherapy is not a viable method of alternative healing.

The OpenBCI software recorded the data in a numerical code, which was saved into folders under the corresponding file name, produced by the software. Each session began with a 'session code' that I logged on the corresponding survey sheet. Using a numerical code protects the participants privacy while also keeping the sessions in order. Within each folder is the five data records as text files, one for each colored light shown.

The data was edited and analyzed using *Microsoft Excel*, *Igor Pro*, and *ScopeDSP*. They were chosen based off race/ethnicity, age, and design experience for a conclusive range of data. Choosing data from participants that are of similar groups will have a better chance of producing similar results. If the results are similar that means the thesis premise can be proven true.

The data produced by the OpenBCI software saves in numerical form as a text file. To convert this information into a wave or graph, I needed to first convert the text files to an excel spreadsheet. In the excel spreadsheet, I cleaned up the files so all that was remaining was the time stamp and data from the 8 electrodes. Once the files were extracted and edited, I loaded the waves into *Igor Pro* which is a wave metrics software that reads and analyzes any form of wavelength.

### 3.2 Research Results | Data Analysis

In *Igor*, I analyzed each file by using the lomb periodogram method. This methodology is a production of frequency estimation based off the least squares implemented. The least squares are an approximate solution of overestimated systems, which occur when there is more known variable than unknown. This allows a smooth oscillation to be produced for analysis.

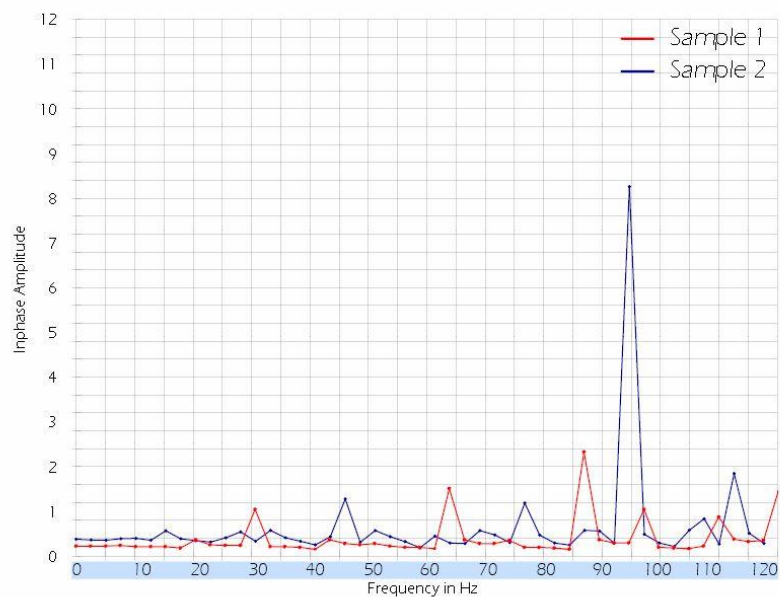
I analyzed 4 of the 8 electrodes: the 2 frontal (1 and 2) which decide and process information, and the 2 occipital (7 and 8) which abstract visualization, the remaining 4 are irrelevant to this portion of the study. For each electrode, within each color, for each individual participant, I created a lomb periodogram in *Igor*, and saved it as a test file. I opened these edited text files in *ScopeDSP* to produce a better graph that shows more detailed points for a thorough analysis. For a conclusive analysis, I compared the data within specific groups, and I chose the participants at random. I compared the results by overlaying the graphs for each electrode (1, 2, 7, 8), from 3 colors (red, blue, white), produced by each person, between the 2 random participants.

### 3.2.1 Data Analysis | Random Sampling

Color: Blue

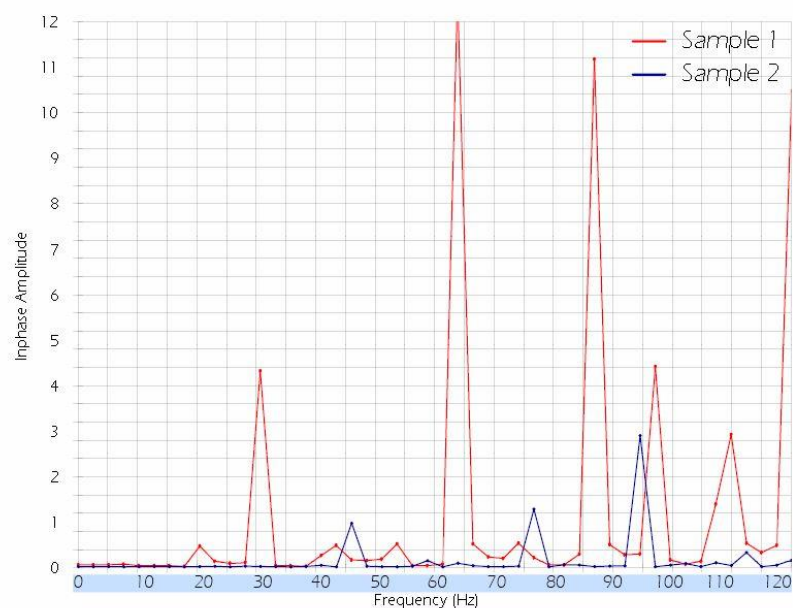
#### Electrode 1 - Left Frontal

The two samples in this electrode read very similar results. The large spike around 90 Hz is an interfering wave that is not to be included for analysis.



#### Electrode 2 - Right Frontal

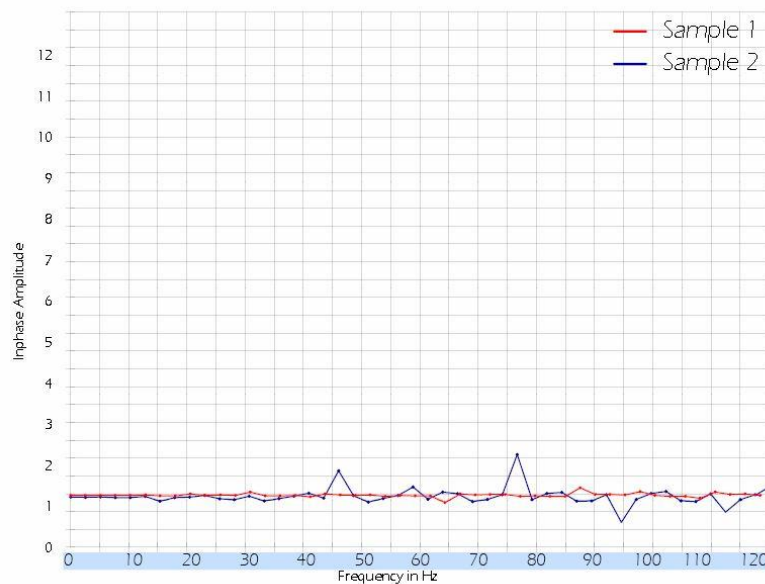
This wave picked up a few more interfering signals than the last. The other spikes, especially in the 100 Hz range of Gamma there is substantial activity. Beta waves around 30 Hz is the frequency in which stress can be released as it is an ideal meditative range.





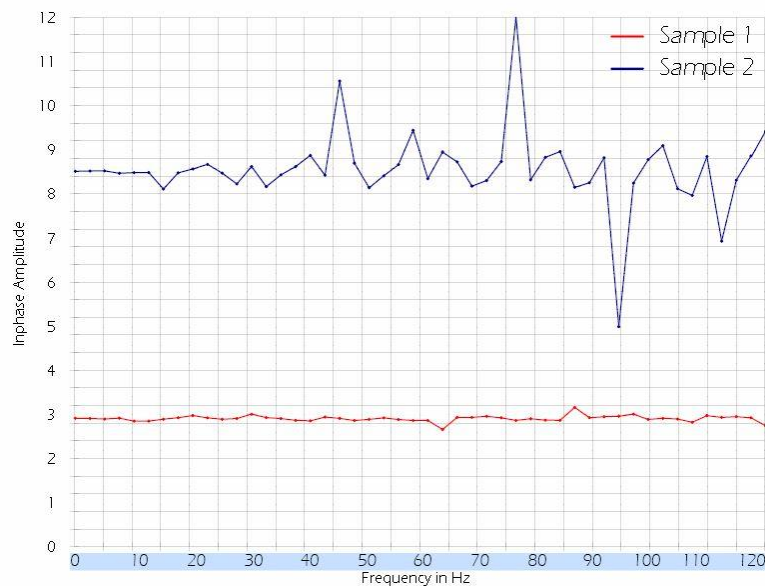
### Electrode 7 - Left Occipital

These waves show very similar results as well. Sample 2 experienced a few major spikes, one worth noting is around 45 because the range of 40-60 Hz is related to producing anxiety releasing effects. This corresponds with the previously explained effects of the blue colored light.



### Electrode 8 - Right Occipital

These waves were very different, and it is possible sample 2 read incorrectly. Sample 1 is similar to the waves read by electrode 7, which is important to note. Although sample 2 read at a higher amplitude, it spiked within the same frequency ranges as electrode 7 of sample 2.

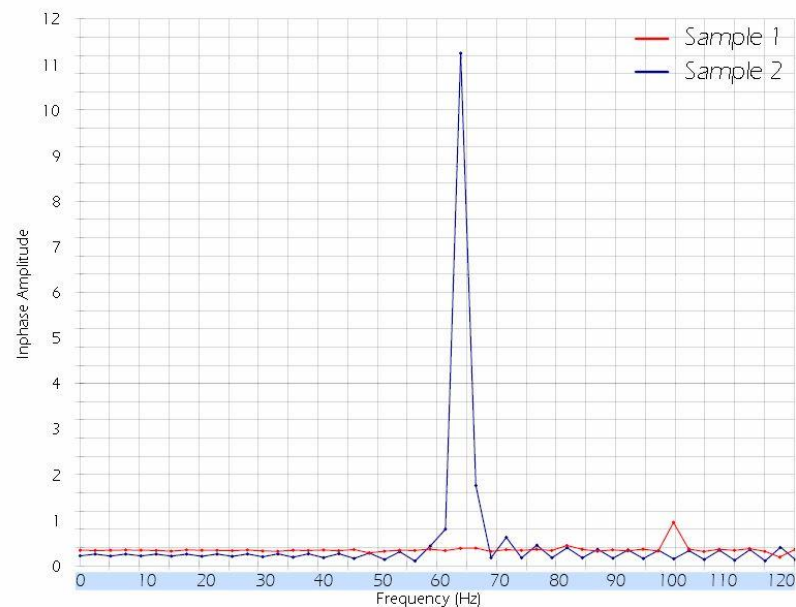


Color: Red

### Electrode 1 - Left Frontal

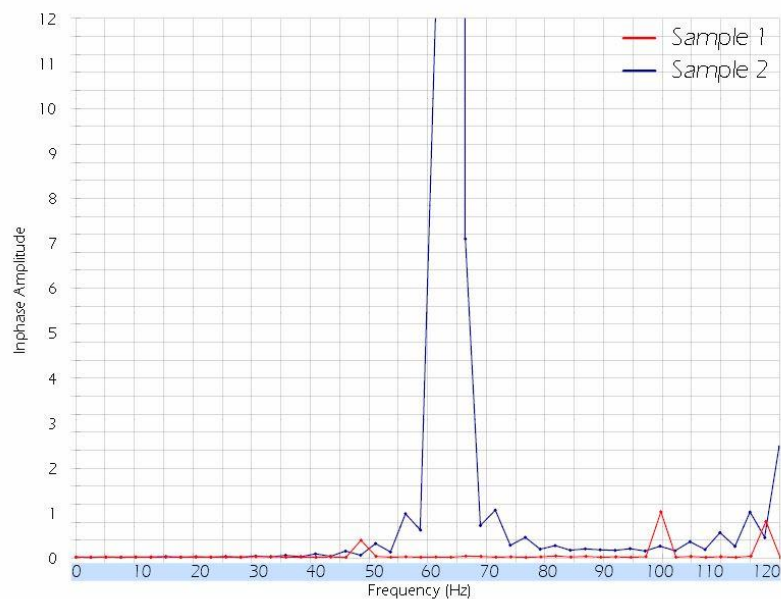
These random samples almost mirror each other with their movements. Sample 2 experiences a few significant Gamma spikes from 55-75 Hz. The very large one around 75 Hz is an interfering signal while the spikes surrounding it are related to the emotional spectrum, and feelings of physical vigor. In yoga, it is known to stimulate Kundalini. This is very significant as it coincides with research information found in *Color*

*Medicine*. Kundalini is energy stored in the base of the spine, the root chakra, the red chakra. The spike sample 1 produced at 100 Hz is possibly an interference, as brain produce waves at 100Hz maximum.



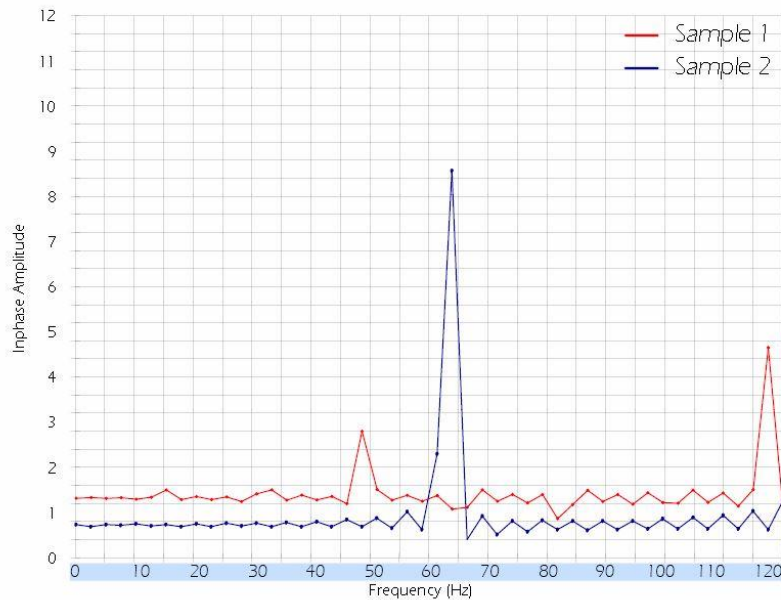
### Electrode 2 - Right Frontal

These graphs are very similar to the left frontal lobe, including the same interfering waves, too. Sample one experience a spike at 60 Hz, which follows the same stimulants as described in Electrode 1. The physical vigor, Kundalini, and the emotional spectrum.



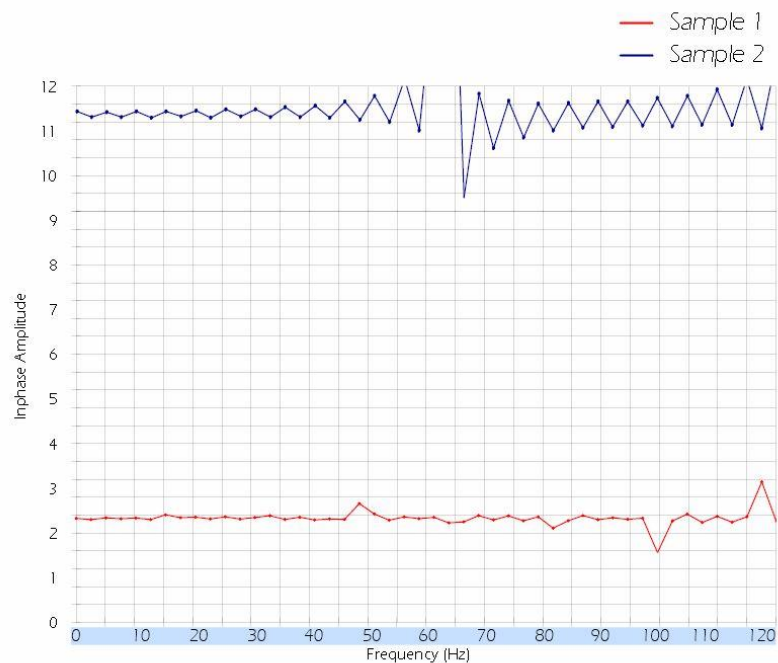
### Electrode 7 - Left Occipital

Although these occipital electrodes read at greater amplitudes, they are similar to each other within this electrode, as well as to the frontal lobes. Sample 1 experiences a small spike at 15 Hz which means that one is awake and alert. Sample 2 produced very similar waves compared to its left frontal lobe.



### Electrode 8 - Right Occipital

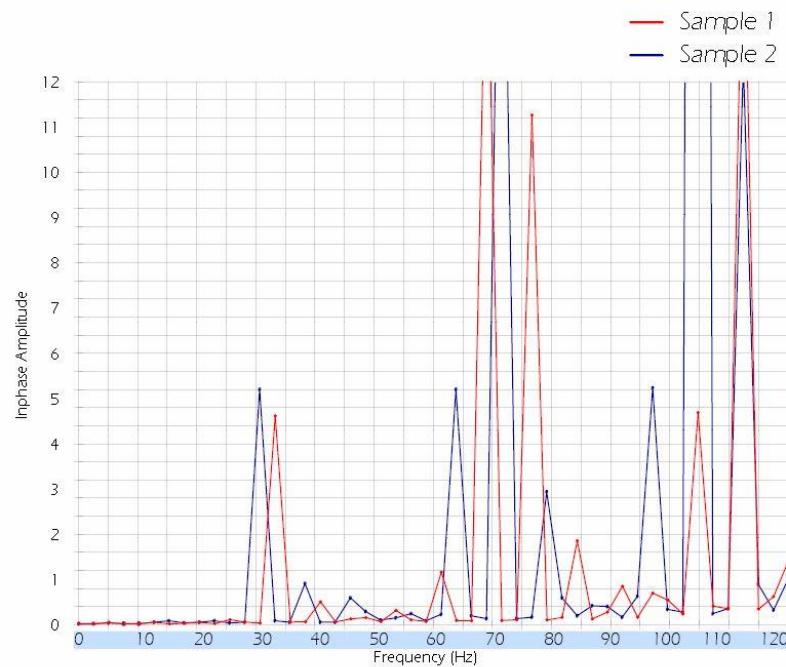
Both read at questionably high amplitudes. Although sample 1 shows more accurate, it is still high. It is similar to the left occipital wave, showing a similar spike at 50 Hz. Sample 2 is not further analyzed here.



Color: White

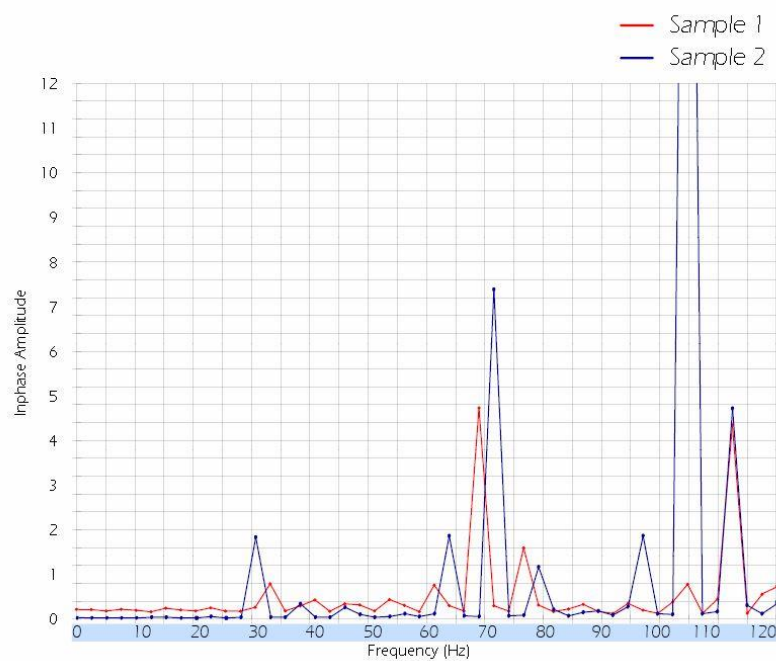
#### Electrode 1 - Left Frontal

This color evoked several significant spikes in the Beta and Gamma ranges, which is substantial evidence regarding the power of white light. The 2 samples almost mirrored each other in results. A spike at 30 Hz is the release of a growth hormone which increases muscle growth and helps in recovering from injury. They both consistently spike from 40 Hz to 60 Hz which is the frequency in which beta-endorphins are released that curate an anxiety-relieving effect.



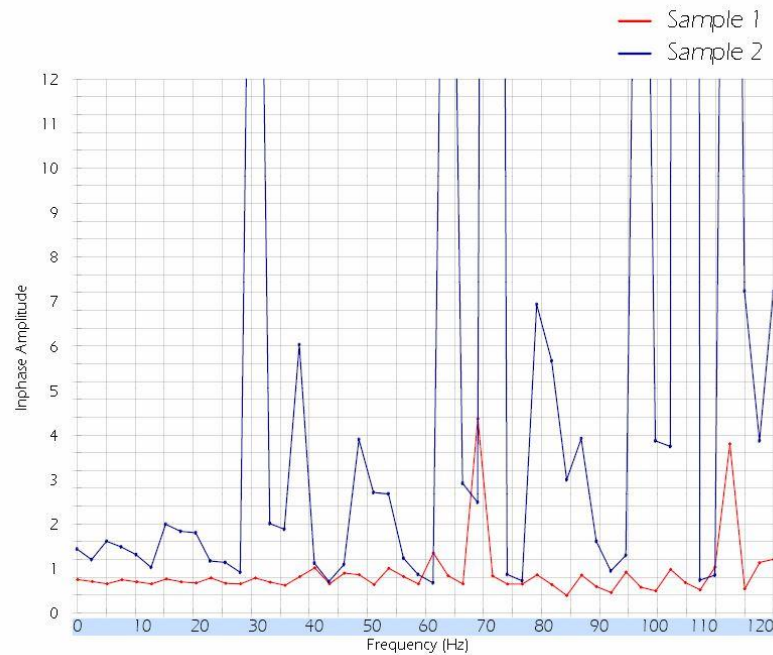
#### Electrode 2 - Right Frontal

In the right side, there are fewer spikes and less amplified. The ones that do read are very significant as they reciprocate the left frontal.



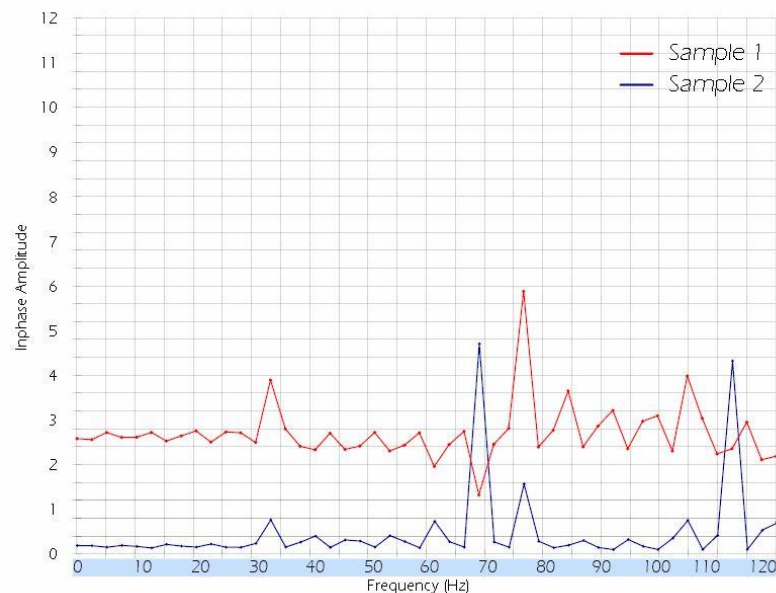
### Electrode 7 - Left Occipital

It is possible sample 2 was reading incorrectly. The amplitudes are very high, although when they are not, they are rigid. They are produced somewhat in the same areas, except this one also spikes at 50 Hz, indicating the earlier explained notion of Kundalini. Sample 1 of the left occipital is identical to the sample 1 right frontal. The spikes are somewhat in a pattern.



### Electrode 8 - Right Occipital

Although the amplitude is somewhat different, the spike ranges are almost identical. The meanings have all been previously discussed in similar cases.



## 4.1 Conclusion | Discussion of Results

Given the amount of time we spend in our built environments, and the overall mental and physical state of humans, it is no surprise the substantial influence they have on each other. If there was a way to physically heal from the spaces, we occupy it could impact the lives of so many people. Finding a solid

plan to manipulate the frequency of colored lights to harmonize with diseased parts through colored lights can be the method of success.

The graphs produced from the colored light experiment seem to be consistent within each category. The results produced can be clearly related back to and further analyzed from the information outlined regarding the brain waves and their corresponding influence on the chromotherapy basis outlined in *Color Medicine* and *The Principles of Light & Color*. The results produced obvious connections that prove that colored light can be implemented as an alternative healing method in architectural design and other medical practices.

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