The Investigation of EEG Responses for Design Tasks Using Traditional and Digital Tools

Gaius Josiah D. Arroyo
ARCH 771
Dr. Ganapathy Mahalingam

North Dakota State University

00. Table of Contents

01. Abstract

With the emergence of computers and modern technology, the way professionals do architecture has drastically change over the recent decades and schools have been faced with the task of how they want to guide the next generation of architects. Will the use of technology be taught as a fundamental skill? Or do the traditional techniques take precedent? This has raised the question of how digital technology has affected the minds of architecture students – and more specifically – in the area of design thinking. This research report will take a preliminary look at the neural responses in the brain when using traditional tools and digital tools. The goal of this research project is to compare the brain's activity when using traditional tools versus digital tools. The document will go over the process of collecting electroencephalogram (EEG) data from human participants while they were using traditional and digital tools. This was made possible using the Ultracortex Headset from OpenBCI. Afterwards, the raw data was analyzed using a statistical analysis program called Igor Pro. Within the program, the waves data was transformed into Lomb Periodograms and then were compared using the Wilcoxon test and the T-test. Finally, those results were organized onto an Excel Spreadsheet.

02. Introduction

Framing the Problem

Architecture is a long-standing profession that has been practiced for thousands of years. Within the past hundred years, architecture has been rapidly changing evolving as new technology is being developed and brought to the market. Technology itself is relatively new and has been changing all sorts of professions and the way we do things. With this change, professions have had to quickly adapt technology into their everyday operations, which in turn leads to people having to learn how to properly utilize this new tool. Architecture has a long history of how things have been done but as technology speedily evolves, so too does the profession. Hand drawing and modeling has been a cornerstone for architecture and within a couple decades, technology has made leaps and bounds in the way architectural drawings are made and how designs are conceptualized. As a side effect, architecture academia has had to make a decision on how to go about adopting and implementing the use of technology into their curriculum. Some schools opt to stick with the traditional means of architecture, only allowing their students to use hand drawing and physical modeling. Other have tried to adapt technology into the curriculum and allow the use of CAD programs, laser cutters, 3D printers and other digital technologies. Within architecture academia, there has always been some debate on the role traditional techniques and digital techniques play in the minds of architects. However, little research has been done on how the two actually work in the mind of an architect.

Goals of the Research

This research project is a preliminary start to investigating the differences in the brain when using traditional tools versus digital tools. The goal is to see whether or not there is a major difference in the way the brain functions when using traditional tools versus digital tools. These finding will be a start to shining a light on whether or not using traditional or digital tools have a major difference in neural responses in the brain.

Key Definitions

Traditional

In this paper, will typically define tools or techniques that architects would have used before the introduction of digital computers/technology.

Digital

In this paper, will typically define tools or techniques that architects would use with a computer after their introduction to the profession.

EEG (electroencephalogram)

“An electroencephalogram (EEG) is a test that measures electrical activity in the brain using small, metal discs (electrodes) attached to the scalp. Brain cells communicate via electrical impulses and are active all the time, even during asleep. This activity shows up as wavy lines on an EEG recording.” (EEG (Electroencephalogram) - Mayo Clinic, n.d.)

Lomb Periodogram

“The Lomb–Scargle periodogram (Lomb 1976; Scargle1982) is a well-known algorithm for detecting and characterizing periodicity in unevenly sampled time-series and has seen particularly wide use within the astronomy community.” (VanderPlas, 2018)

03. Methodology

This research project involved experimental research. Since the goal was to find out if there were differences in brain function between traditional and digital tools, human subject research was involved. This would require the certification to conduct human subject research. So before any research began, completing this certification was a must. After that, the design of the research study started and so too did the recruitment process for participants. Additionally, the use of a brain computer interface (BCI) was involved. So learning to use that device and learning to analyze the data it outputs was also done in this study.

To achieve the goal of this study, human participants were asked to perform tasks involving traditional and digital tools while having a BCI (brain-computer interface) device on their heads, reading their EEG (electroencephalogram) responses. Proper certification for human subject research was done before performing this experiment.

The Brain

This research is specifically analyzing the activity in the brain. Through the use of a BCI device we can see a person's EEG responses.

As describe early in the introduction, the adoption of technology in architecture is still relatively new, so the idea of how traditional tools and digital tools affect a person's ability to design has only been analyzed through the production of peoples' work with no real empirical data to back up any claims. This is where EEG comes in. Being able to record the brain activity of a person while performing these tasks allow for a numerical study to be done on those results. This gives us a more solid answer to be able to compare the results of the two activities.

In this test, electrodes will be connected to the participant's frontal lobe, parietal lobe, and occipital lobe. The specific locations of these electrodes can be seen by the highlight dots in Figure 1.

Ultracortex Mark IV
Node Locations (35 total)

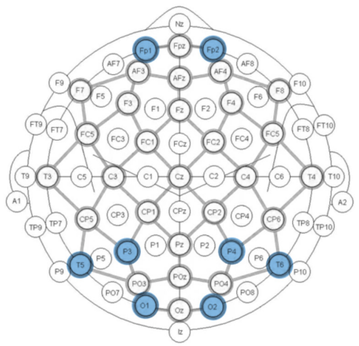


Figure 1 | Node Locations

Figure 2 | Ultracortex From OpenBCI

Setup and Prep

As for the hardware used, this research project utilized the Ultracortex EEG Headset from OpenBCI, as seen in Figure 2. Along with it came the OpenBCI GUI software that allows the computer to graphically show the activity in the brain in real time. This software also records the raw data into comma delimitated text files. Learning to use this tool was essential to the project. Afterwards the use of a data analysis program was used to read and analyze the data.

A testing area was required to perform the tasks the participants were asked to do. This area would allow for the participants to perform the tasks comfortably. In order to reduce as much interference as possible, a small divider was made to designate the testing area and block the side peripheral view of the participant. Consideration for electronic interference was taken to minimize interference in the recording of the data. However, due to the location of the testing area, some interference still may have been present. Additionally, while the peripheral sight of the participant was blocked, noise from the environment was not blocked. This was done out of convenience and comfort for the participant. The headset wouldn't allow the use of noise canceling headphones, and earplugs could be unnatural to the participants normal working environment. The headset alone would be enough of a new stimulus to get used to.

Figure 3 | Picture of Dividers

03. Methodology (cont.)

Tasks

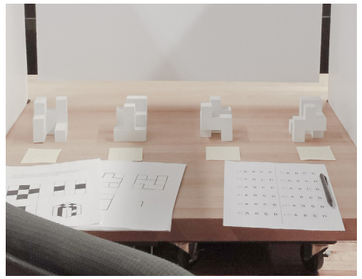


Figure 4 | Task 1 - Traditional

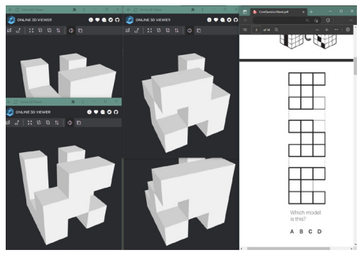


Figure 5 | Task 1 - Digital

Figure 6 | Task 2 - Traditional

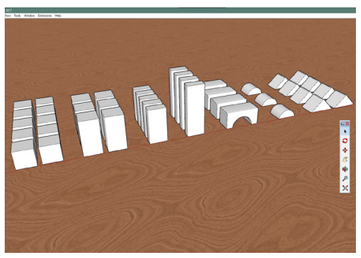


Figure 7 | Task 2 - Digital

The tests performed in this study needed to be carefully considered in order to properly compare the differences between the use of traditional and digital tools. Furthermore, the task between traditional tools and digital tools needs to be designed in a way that is similar enough to be consider an equal representation of the two mediums. Basically, the two tasks need to be the same using their respective tools.

After coming up with several ideas for tasks, my professor, a classmate, and I were discussing the tasks and the viability of them. Some tasks made more sense that others and, in the end, the chosen tasks were adjusted to make executing the easier. There were two tasks chosen per medium. The first task was based on observation and the second task was based on their ability to recreating a given image.

The ability to read a 2D image and translate that to 3D is an essential skill for an architect. This first task was designed around that concept. Participants are given a set of orthographic drawings, and they are tasked with figuring out which block corresponds to that drawing. Both the traditional and digital task had this premise. Both traditional and digital tasks had four blocks with 12 sets of drawings. Physical models and paper answer sheets were given to the participant for the traditional task. Digital models and a PDF answer sheet on a laptop was given to the participant for the digital task. They had 10 minutes to complete the task.

Unfortunately the second task ultimately was omitted from analysis because of time constraints but documentation for that task will still be provided. This task involved the participants recreating a 3D model using blocks with only one image as a reference. A supply of blocks was provided for the participant and the reference image was a structure that was created using the same supply of blocks. The participant was tasked to recreate as many images as they could in 10 minutes. Data was gathered for this task, but in the end, was omitted from analysis due to the inconsistent organization of the raw data and time constraints.

Igor Pro 9

In order to analyze and understand the data better, Igor Pro was used to analyze the raw data. Looking at the waves data alone would not have been possible for me to understand and analyze. OpenBCI outputs two comma delimited files after the recording has been stopped. This file contains the numerical value of the wave. Using Igor Pro we can organize that data into a different form. Using the Lomb Periodogram, the data is going to be organized into frequencies of 150. This allows the for the data to be organized in a way that allows us to see the occurrences happening in the brain waves. After the data from each electrode has been transformed into a Lomb periodogram, the Wilcoxon test and T-test will be performed between the traditional and digital electrode counterpart. These two tests will determine whether or not the two samples are statistically similar.

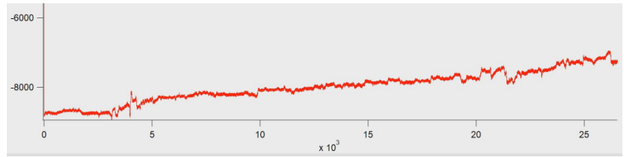


Figure 8 | RAW Wave

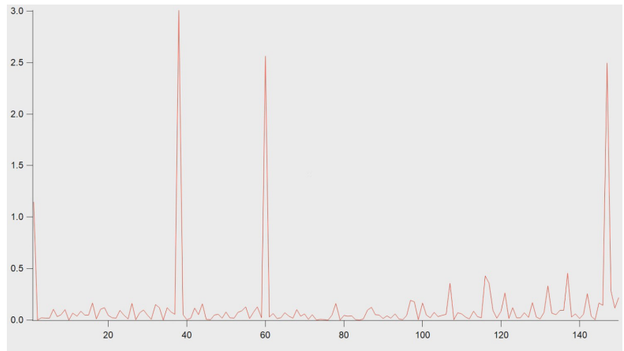


Figure 9 | Lomb Periodogram

04. Results of the Research

Table 1 | Example Test Result

Electrode	Wilcoxon	T-test
Fp1	CR	A
Fp2	R	R
P3	CR	A
P4	R	A
T5	R	R
T6	R	R
O1	R	R
O2	CR	A

Note. CR = Cannot Reject; R = Reject; A = Accept.

Table 1 is an example of how the results from the Wilcoxon and T-test were organized. Each participant had 8 electrodes recording the EEG responses.

Table 2 | Grand Totals of the Tests

Wilcoxon		T-Test	
Sum of CR	Sum of R	Sum of A	Sum of R
46	34	65	15
Percentages			
58%	43%	81%	19%

Note. CR = Cannot Reject; R = Reject; A = Accept.

The tables are organized in to show the results of the Wilcoxon test and the T-test. After that, the data from the tables were separated and organized based on the electrode's position. Percentages have been calculated based on the data in the given chart.

Further calculations were made based on the electrodes and which part of the brain those electrodes were reading. Doing so allows us to see if certain parts of the brain were similar between different participants. Observations can then be made based on the specific lobe.

Table 3 | Frontal Lobe Totals

Wilcoxon		T-Test	
Sum of CR	Sum of R	Sum of A	Sum of R
11	9	15	5
Percentages			
55%	45%	75%	25%

Note. CR = Cannot Reject; R = Reject; A = Accept.

Table 4 | Parietal Lobe Totals

Wilcoxon		T-Test	
Sum of CR	Sum of R	Sum of A	Sum of R
9	11	16	4
Percentages			
45%	55%	80%	20%

Note. CR = Cannot Reject; R = Reject; A = Accept.

Table 5 | Occipital/Temporal Lobe Totals

Wilcoxon		T-Test	
Sum of CR	Sum of R	Sum of A	Sum of R
26	14	34	6
Percentages			
65%	35%	85%	15%

Note. CR = Cannot Reject; R = Reject; A = Accept.

These totals were calculated based on the location of the electrode. This allows us to see how a specific lobe functioned between all the participants. From here observations can be made about how the tasks compare based on a specific lobes activity. The function of that lobe could bring more insight to comparisons that are being made.

04. Results of the Research (cont.)

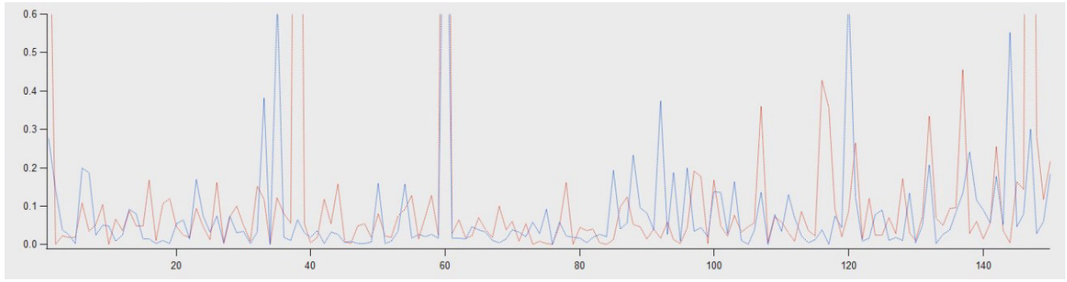
Table 6 | Individual Electrode Totals

Electrode	Wilcoxon		T-Test	
	Sum of CR	Sum of R	Sum of A	Sum of R
Fp1	7	3	9	1
Fp2	4	6	6	4
P3	4	6	8	2
P4	6	4	8	2
T5	6	4	9	1
T6	7	3	8	2
O1	6	4	8	2
O2	7	3	9	1

Note. CR = Cannot Reject; R = Reject; A = Accept.

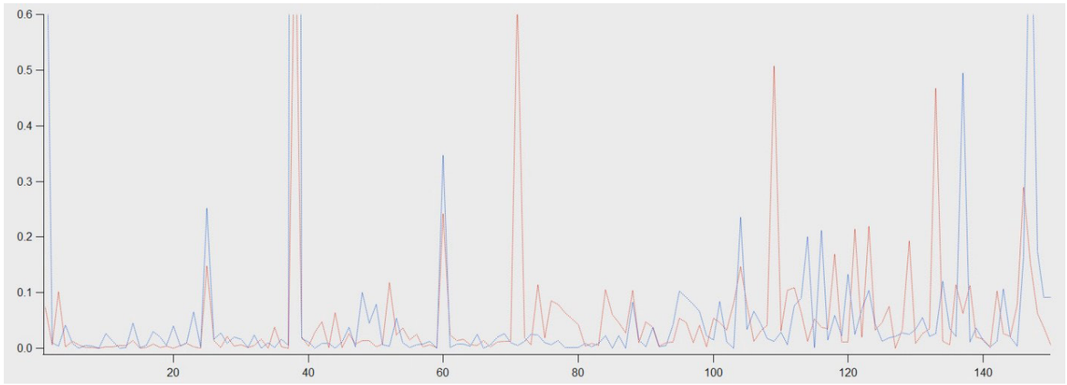
Table 6 goes over the totals of the results across the individual electrodes.

Figures 10-13 are graphs showing what it looks like if the Lomb Periodograms tested cannot reject and rejected. The traditional and digital periodograms have been superimposed on each. A dotted line is also used to try to improve visibility of each line. These are not the waves that are outputted by OpenBCI.



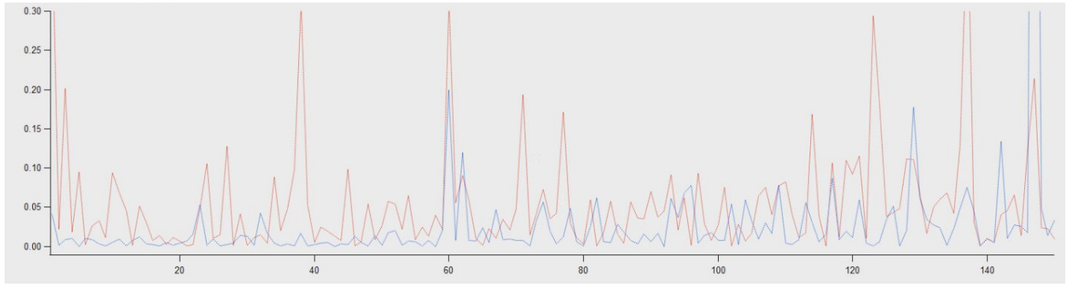
Note. Blue = Digital; Red = Traditional

Figure 10 | Lomb Periodogram that Resulted in CR for Wilcoxon



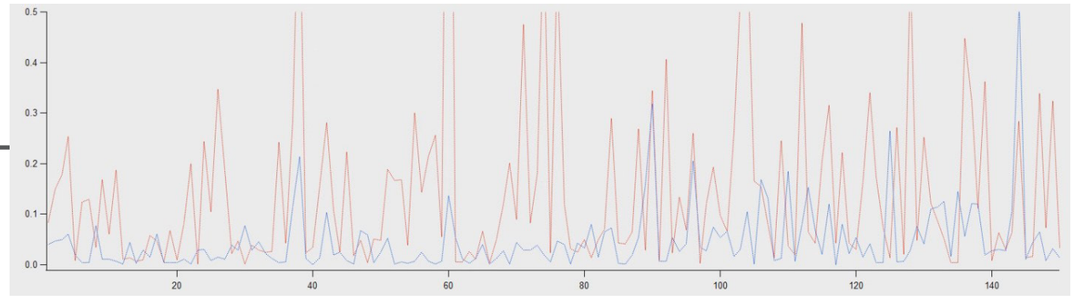
Note. Blue = Digital; Red = Traditional

Figure 11 | Lomb Periodogram that Resulted in CR for Wilcoxon



Note. Blue = Digital; Red = Traditional

Figure 12 | Lomb Periodogram that Resulted in R for Wilcoxon



Note. Blue = Digital; Red = Traditional

Figure 13 | Lomb Periodogram that Resulted in R for Wilcoxon

05. Conclusion

Looking at the results of the Wilcoxon test, there is a slight favor that traditional and digital tools and techniques have similar neural responses in the brain. This test does not show a conclusive result. Even so, These results are very close and most of the results have a slight lean towards the brain activity being similar. However, the T-tests resulted in an overwhelming favor for the brain activity being similar between traditional and digital tests.

My personal hypothesis was that the brain activity was going to be very different. But based on the data that resulted from the research, I can not say with full certainty that the neural activity in the brain is completely different when working with traditional and digital tools and techniques.

I do believe that further testing would help give a more conclusive answer. Sadly the second task was not very well organized in a way that would smoothly allow me to analyze the data like the first task. That was due to an oversight in design of the task and the way the data was recorded.

This research project is only a small piece to a very large puzzle. The tasks used to perform this only engage a certain part of the brain. More complex tasks could be designed to more specifically test how the brain functions in certain architectural scenarios.

06. References

EEG (electroencephalogram)—Mayo Clinic. (n.d.). Retrieved December 9, 2022, from https://www.mayoclinic.org/tests-procedures/eeg/about/pac-20393875

Ultracortex “Mark IV” EEG Headset. (n.d.). [Photograph of Ultracortex Device next to its box]. OpenBCI Online Store. Retrieved December 10, 2022, from https://shop.openbci.com/products/ultracortex-mark-iv

Ultracortex “Mark IV” EEG Headset. (n.d.). Ultracortex Mark IV Node Locations (35 total) [diagram]. OpenBCI Online Store. Retrieved December 10, 2022, from https://shop.openbci.com/products/ultracortex-mark-iv

VanderPlas, J. T. (2018). Understanding the Lomb–Scargle Periodogram. The Astrophysical Journal Supplement Series, 236(1), 16. https://doi.org/10.3847/1538-4365/aab766