Interaction Design and Architecture(s) Journal - IxD&A, N.44, 2020, pp. 53 - 70

Early Design Stage Analysis with Brain Imaging Method

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Abstract. This study focuses on the early design phase in architectural design and aims to examine how participants transform their knowledge to make the initial decisions regarding design. A total of 100 volunteers, 50 architects and 50 non-architects, participated in the study. Architect and non-architect participants were to make mobile phone designs, while brain activities were being monitored during the research. All designs were rated by an independent group of 12 people. Supporting architectural education methods relating to the study; the aim is to make conclusions that help explain the early design stage and the overall design process which effects how the design ideas begin to take form. The study reveals the contribution of the early stages of design regarding architectural education and also that architects versus non-architects begin to create more meaningful designs during/at this stage.

Keywords: Early-design Stage, Architecture Education, Cognitive Design

1 Introduction

Architectural education is a model of education that moves with the complex and a "master-apprentice" type of relationship. Therefore, the actors (learner-teacher) in architecture education need to come together on a common ground and an optimal environment of dialogue should be established. Studies which examine architectural education within different aspects related to different cultures and approaches [1; 2] have indicated that one of the fundamental problems regarding education is the overall "teaching design." Kroemer et al., [3] having a different approach with a perspective based on this point of view, argues that designs should be accurate, functional and adapt in a way to make people's lives easier. In this sense, the "design" is viewed as an artistic and rational problem-solving art, where "humans" are in the center. Here we see the definition as a concept of rationality based on the system of values known from a material and technological field. It also refers to all the rational elements a product must have. The aesthetics can be defined as a level of approach to a high level of performance in the universal level of appreciation. On the other hand, relating to development demands, the definition of a "good design" has become a dynamic process; that goes outside of aesthetics and rationality. In other words, "correct design" is viewed as a "concept" and “expendable" in the global system of competition [4; 5]. Adding another perspective relating to "correct design," we can look at both basic problems and definitions [6; 7]. In other words, it can be interpreted as a way to disrupt memorization process as well as approaching the solutions by finding the meanings and reaching unusual results.

In design theories, the question of "what is right?" is a field of interest for the pedagogical architectural researchers based on education. However, the answer to the question about how it can "contribute the to the education system on architecture?" is that education is taught in different ways in many cultures and that every one of these methods is different. The early design phase takes place at the beginning of this investigation. The main decisions are made about the design within the early phase, for example the acquirement of information, the selection and association/conversion of appropriate information, the creation of alternative syntheses, and the formation of new design ideas [8]. Designers progress throughout the process (from the beginning designing stage to the final product stage) using the information they have. It will determine what information is used in the early part of the phase, in which ideas start to take shape. It is important, as it will clarify the ambiguous and unclear structure of the design problem. The point of this study was to show that complicated design paradigms were worth investigating in order to add dynamism to the different disciplines involved.

In addition, in this study, the early design focused on the cognitive processes. The beginning design phase is the most important part of abstraction / transformation [9; 10] because it will decide the entire concept of the design. During this phase, it is thought that the concepts of information acquired, analyzed and synthesized are used individually [11]. In the early stages of the design phase, the designer begins to produce various concepts based on his personal and professional knowledge [12] as well as his experience. All information about any design problems determines design knowledge. Designing information includes the knowledge of the designer and the information gained during the training process.

In this study, some hypotheses have been put forward regarding the early design phase of design:

H1:The early design phase does not continue in the same way for both architects and non-architects.

H2:Architects' designs are more likely to be “appreciated"” than others.

H3:Brain activities (cognitive activities) of people who studied architecture are also different than those who have not studied architecture.

The aims of this study were to:

•explore how participants in the early design phase transformed the knowledge they possessed to form the first design decisions,

• compare the design achievements of architectural educators (architects) with those who are not trained (non-architect),

• analyze the cognitive and emotional changes that occur during the design phase with the neuroimaging device.

2 Literature Review

Teaching the design and how to design is a phenomenon with contributions from different disciplines, besides architectural education, and different theories have been developed in this regard. One of these theories is "Neuro-cognitive learning," which classifies learning as a physiological event. Anderson [13], who takes the Hebbian approach theory, states that it is not possible to understand the nature of learning without understanding how the course works. The brain is the center of human intelligence, learning and motivation. If learning takes place within the brain, a living tissue, the structure of the brain after learning something must change [14; 15].

Naturally, there are different approaches that investigate how a design will transition in the "learning-teaching" duality. Kvan & Yunyan [16] examined the learning styles of Chinese architectural participants using the Experimental-Learning-Theory and found a statistically significant relationship between learning styles and academic performance while taking into account the studio performance. Roberts [17] investigated how a group of students can analyze cognitive styles with Riding's Cognitive-Styles-Analysis theory to show their approach to architectural design studios.

The architectural design process is a stage consisting of quite complex cognitive processes. Researchers who have studied these processes, such as Hamel [18], Simon and Role [19], describe the design process as an act of problem solving. Acer [20], however, describes design as an act of decision making. As a third approach, Researcher [21] suggests that design is an act of puzzle making. The most important common feature of all three approaches is that they interpret design as a process moving from abstract to concrete. The progression from abstract towards concrete begins with the early design phase. At the end of the early design phase, the design problem evolves to the first design schemes, leading to the first tangible product, which has the characteristics of the intermediate production of the overall design process.

The early design phase is one of the most appropriate examples of working with ill-defined problems [22]. At this stage, initial design alternatives are tried one by one. The excessive and ambiguous information as well as the variability of ideas affect the formation of design alternatives. Here, it is noteworthy that architecture education diverges from any other education. Zeisel [23] states that the participants in this science education work on problem-oriented solutions, while the participants in the design/art education work directly towards solutions.

In his study, Lawson [24] reported that the initial ideas and design decisions that emerged during the early design phase play an important role in the development of the designers' works. Cross [25;26], however, emphasizes the importance of the use of representation in order to have new insights using relevant information at this stage, noting that designers are able to move more easily between different layers in the early design phase.

Do et al. [27] put forward a similar argument and discusses the necessity of representations in creating and developing concepts. Suwa & Tversky [28] and Suwa et al. [29;30] state that representations cannot be seen as merely a drawing, but a method that embodies the ideas of the designer.

In her study investigating the process of searching for form in design, Goldschmidt [31] states that transferring mental images to paper is what denotes the relationship between a form and mental process. To prove that the transferring the mental images frequently to paper positively affects the creativity phenomenon, students' design processes were observed. As a result, it was determined that creating a large number of repetitive representations plays an active role in achieving creative solutions and facilitates shaping conceptual relationships. All these processes are believed to be related to the early design phase.

Significant and usable architectural encodings exist in the architectural representations produced during the early design phase. These representations are well-defined and can be distinguished from each other. For example, plan representation is an external representation that helps short-term memory in solving the design problem involving multiple relationships [32].

The early design phase is also considered in performance-based design [33] and energy efficient building designs [34] in addition to the basic design phase of architecture. In addition, augmented reality environments, one of the tools of modern architecture, are also used in design studios to work on design methodologies using early design phase data [35].

3 Procedure

The experiment was conducted in an office room located at the Architecture Department in 2017. The temperature and intensity of illumination were maintained at 23 °C and 500 lux, respectively.

3.1 Participants

One hundred healthy people (50%-male; 50%-female) with average (Mean ± SD) ages of 27.6±1.4 years; were selected for this trial. All participants were non-smokers and had no previous record of mental disorders. Participants were divided into 3 different groups:

- First group="architects"(50 people): The people who make up this group are those who have completed the 4 year education degree of architecture and received the title of architect.
- Second group="untrained in architecture education"(50 people): This group consists of people who have not received architectural education or an undergraduate diploma. All participants have at least graduated from high school.
- Third group="independent selectors-jury-“(12 people): This group consists of people who have not received education in architecture but they have undergraduate diplomas.

3.2 Apparatus

External interventions were not allowed except for 112 people participating in the experiment and researchers. In the experiment, an A4 drawing paper and a drawing pen were given to the participants and a mobile electroencephalogram (EEG) device was used to monitor the cognitive performance of the participants. In order to test participants in the same environment, they were asked to design on the same desk with the same pen and paper. In addition, during all stages of the experiment, the ambient temperature was fixed at 23 degrees and the ambient light was set to 500 lux.

For the study, an EEG device, which is an actively used method of analysis in modern architecture, was used for the study. Thanks to this device, it is possible to gain some insights about cognitive activities of individuals. EEG is a test used to evaluate the electrical activity in the brain. The participants' cognitive activities were being tested with the EEG. In this stage, it was observed which parts of the brain were active during the experiment. Blinking and muscle movements were cleared by the algorithm of Gratton et al., [36]. Only the participants' cognitive behavior during the experiment was focused on.

In this study, EEG signals were obtained by a simple electroencephalograph (Neuro Sky Mind Wave Mobile) and we obtained EEG at the only Fp1 defined by the International 10-20 system as Yamaguchi and Mitsukura [37]. Fp1 is located on the left frontal cortex. This device was chosen for this experiment because of the simple electroencephalograph, which gives subjects little to no burden because it measures only one point and the wireless data transmission system is suitable for experiments under the environmental setting. Therefore we acquired emotional information by measuring EEG signals using the device. Data was recorded at a 512 Hz frequency and an embedded algorithm of sliding windows Fourier transform has been performed. Towards the end of the phase, the actual analyzed signal was a spectrogram with a 1Hz frequency in the 0.1 to 50Hz band. EEG signal can also be categorized into five major frequency rhythms: Delta, Theta, Alpha, Beta and Gamma as Bhatti et al. [38]. All these present different mental conditions of the subject [39]. Alpha waves are evident in a relaxed position with eyes closed; Beta waves can be observed in frontal and central regions of the brain when a person is involved in mental or physical activities; Delta waves are associated with deep sleep in normal individuals; The gamma wave has a high frequency and small amplitude and is believed to unify conscious perception; Theta waves are associated with creative thinking and deep meditation [40].

4 Experimental Setup

In the first phase of the study, there was a lot of interest to design a "mobile phone" from both the first and second group. The reason why the mobile phones design was preferred in this experiment was that they are a device used by almost everyone nowadays. Therefore, the mobile phone is a tool that even people who are unfamiliar with the design can easily imagine. For this reason, it was believed that people who had not studied architecture would also have an idea about mobile phone design and the experiment was developed in consideration with mobile phone design.

The design criteria were "display, keys and on/off button." They were required to use these three different functions when designing their mobile phone. Each participant was given 600 seconds to create the design. A total of 100 people in the first two groups designed a total of 100 different types of mobile phones. In order to evaluate these designed phones, an evaluation jury consisting of a different group of 12 people was established. The flowchart is shown below in Figure 1.

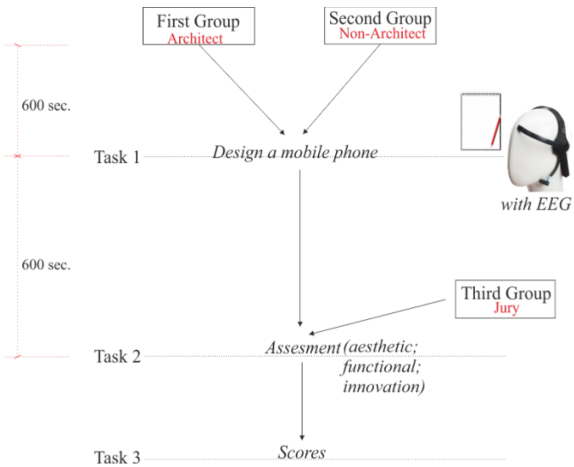

Fig. 1.. Flow chart of the experiment

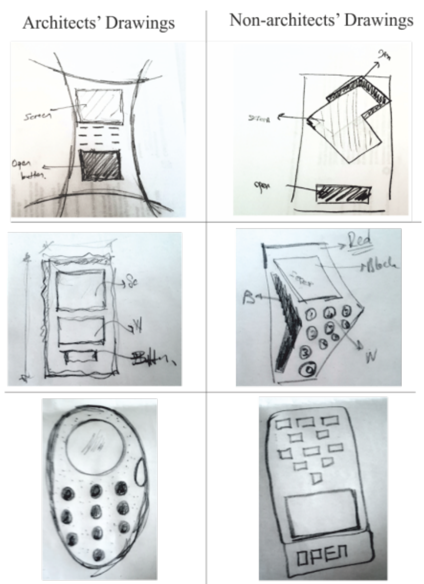

Fig. 2.. Examples of mobile phones designed by participants

After completing the first and second group design process, it was necessary for the third group of 12 jury members to evaluate all designs. Some examples from the designs of the participants are presented below in Figure 2.

As can be seen in Figure 2, the lines used by the group of architects are more prominent than the other group participants. However, different grading categories were given for the jury to evaluate on. The rating scale for the jury, was decided as 3 points for aesthetics; 3 points for functionality; and 4 points for innovation, a total of 10 points.

5 Analysis

Data were analyzed by an R-software to determine whether there was a normal distribution among the scores given by the jury members to all participants. This statistical analysis was performed by using R-software [41; 42]. A sample of the given notes and statistical values is shown in Table 1.

Table 1. Example of statistical values of jury scores

Jury	Avg. Score	Rank	Index	z-score
Jury-1	7.25	11	0.561224	0.154074
Jury-2	7.29	12	0.564626	0.1627080
Jury-3	6.88	5	0.5306122	0.0768089
Jury-4	7.13	10	0.5510204	0.1282398
Jury-5	6.79	3	0.5238095	0.0597171
Jury-6	6.96	8	0.5374154	0.0939230
Jury-7	7.00	9	0.5408163	0.1024905
Jury-8	6.83	4	0.5272118	0.0682615
Jury-9	6.67	1	0.5136054	0.0341104
Jury-10	6.71	2	0.5170070	0.0426426
Jury-11	6.88	5	0.5306120	0.0768096
Jury-12	6.92	7	0.5340147	0.0856369

Considering the ratings of the jury, it is noticed that the statistical distribution of 99% probability is normal. This shows that jury ratings are useful. The jury were not informed as to which of the participants were architects. Here, average scores indicate the average of the scores out of 10 given by the jury for 100 different designs. The average score given to 100 participants was 6.94. While the average score awarded to the group of architects (50 people) was 7.43; the average score of the non-architects (50 people) made up 6.47. On the other hand statistically analyse was shown in Table 2.

Table 2. Independent sample t test for architect and non-architect group

	N	Mean	Std. Deviation	Std. Error Mean
Group 1 (Non-Architect)	50	5,52	3,89575	1,0878
Group 2 (Architect)	50	6,94	2,40895	,76859

	Levene's Test for Equality of Variances		t test for Equality of Means					95% Confidence Interval of the difference	
	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Equal variances assumed	,946	,221	-2,455	124	,021	-,43124	,18794	-1,01478	-,08400
Equal variances not assumed			-2,564	104	,018	-,43124	,17849	-1,00015	-,10147

According to statistical analyses and table 2 shows that (sig. (2-tailed);,021<,05) there was a significant difference in the scores for architects' design (M=6,94; SD=2,40) and other participants (M=5,52; SD=3,89) design so H2 was confirmed.

In addition, a paired T-test was used to compare the mean values between EEG data, with a significance value of $P<0.05$, and the Wilcoxon-signed-rank test was used to analyze EEG data, with significance at $P<0.01$.

In EEG data, alpha and beta, reflecting the brain activity, increased every minute during the beginning part of the design comparing to the non-architects group. Compared to the mean values during the control viewing period, most of the high alpha mean values for both males and females were higher when staring (starting) the design of the mobile phone in the 1-min analysis (Figure 3).

High alpha value can often be said to increase focus [43]. Therefore, as shown in Figure 3, a significant decrease in focus/attention levels is observed, in women who are not architects, during the task. In addition, it can be said that the focus/attention levels of female architects do not decrease, even increase slightly, during the mobile phone design phase, so their attention remains stable. For males, however, there was a slight increase in non-focus both in male architects and in individuals who are architects.

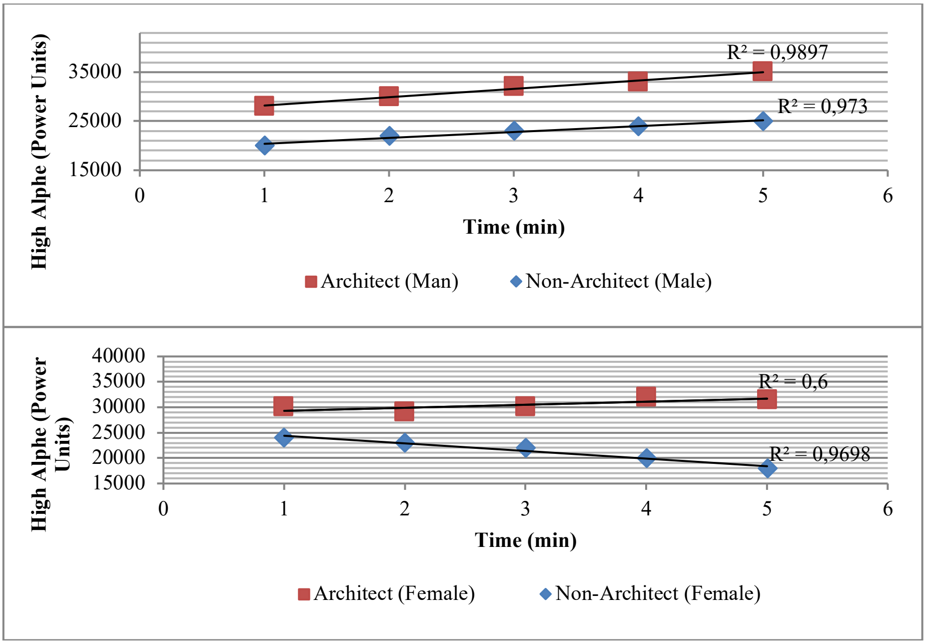

Fig. 3.. One-min averages and the overall mean high alpha (power units) values of EEG variability between males and females while staring (starting) the design and during the control phase.

During the 1-minute analysis, most of the high beta values shown in both males and females from the beginning of the design, architects had higher values than the non-architects. High beta activity may increase in cases of over-stimulation [44]. Thus, the sudden increase in stimulation levels in the group of architects at the beginning of the design, as they enter the early design phase, may indicate the importance of the "beginning of the design" and the high-level of cognitive activity in the early design phase. According to the paired T-test, these differences were significant ($P<0.05$) (males-architects, begin to design: 30447.4 ± 1189.6; non-architect, begin to design: 23410.4 ± 1374.4; female architects, begin to design: 31458.5 ± 704.5; female non-architects begin to design: 23100.9 ± 2478.8).

The brain can be divided into three parts, which are: the hindbrain, midbrain and forebrain [45]. However, the brain has fours lobes, which are the frontal, parietal, temporal, and occipital. The frontal lobe deals with concentration, planning, emotions and judgments; while the parietal lobe is responsible for sensation tied to the muscle and skin; temporal lobe handles short-term memory, and equilibrium and least the occipital lobe controls image recognition and perception [46; 47]. This study was focused on only the frontal lobe. The frontal cortex also deals with problem solving, comfort, pleasure, and dis-pleasures [48; 49]. During this period, EEGs were constantly being recorded by the EEG Headset Neuro-Sky Mind Wave [50]. This device records brainwaves from the forehead (the Fp1 position) (Figure 4).

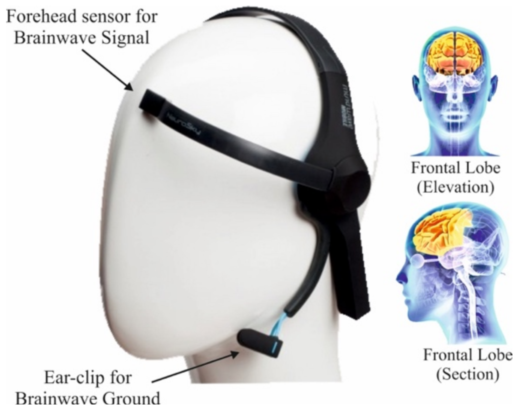

Fig. 4.. EEG Headset Neuro-Sky Mind Wave Fp1 position

The brainwaves (high alpha; high beta) lengths, which were collected during 1-min intervals at each location of the experiment, were compared within the 5 min average.

5.1 Initial / Early Design Stage Analysis

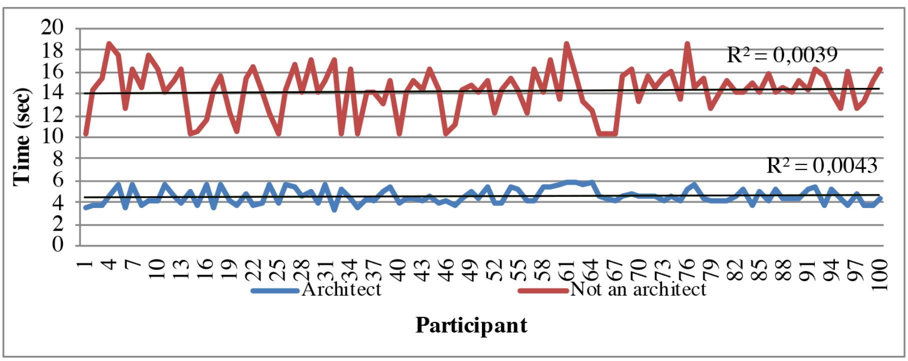

Fig. 5.. Time until 100 participants start designing

In the early design phase relating to analyzing, individual work is essential. It is at this stage that the information gathered during the information acquisition phase is analyzed according to the requirements of the design problem and the main design objectives are revealed. This phase is called 'phases within the beginning of the design' in the study. The time from the beginning of the design was accepted as from the moment when the participants took their items in hand until the time they finished the first drawing. It was also important to take into consideration the time spent by participants before starting to design and to include it. . The time spent by participants is shown below in Figure 5.

How participants' start-up phases of their design were also analysed by EEG. The average time spent by the participants in the architect group to start designing was 4.57 seconds; whereas the average non-architectural Figure 6 shows the brain activities of architects and non-architectural participant group was noted as 14.27 seconds. However, as shown in Figure 5, it is evident that the architecture group was more stable and they had a stable start-up time.

During the design phase, EEG entries were received from non-architecture participants. Frontal lobe activity, which is the anterior region of the brain, was observed in these records.

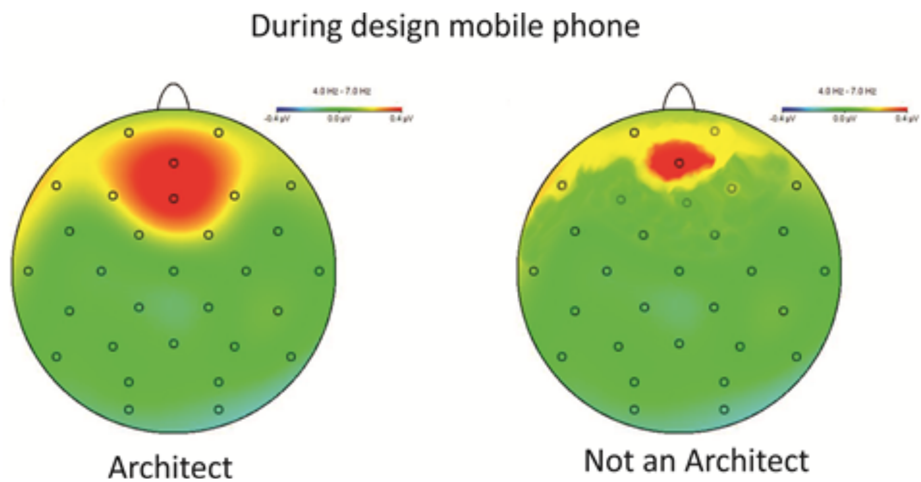

Fig. 6.. Frontal lobe activities of two volunteers participating in the experiment

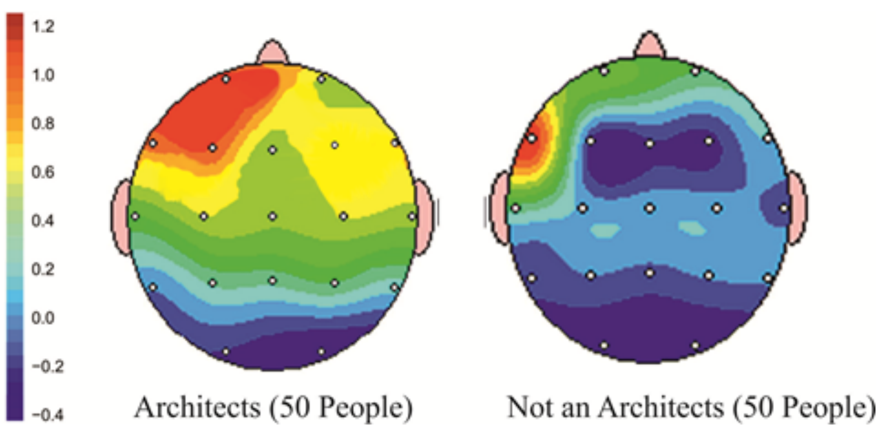

Fig. 7.. Overlaid appearances of all participants' frontal lobe activities

As clearly shown in Figure 6, the frontal lobe of the architect participant's brain is more active than the non-architecture participant. The frontal lobe is the lobe in the forehead region. It is the region of the brain where emotions are controlled; such as thinking, decision making and reasoning. At the same time, architects who spent a short time at the beginning of the design seem to have more active frontal lobes than non-architecture participants.

However, brain maps of 50 architects and 50 non-architects overlapped using the image processing method in order to obtain the result shown in Figure 7.

The brain images of a total of 100 participants in the experiment were compared as they designed the mobile phone. It was observed that the activities of the participants, who were architects, had noticeably more activity in the left anterior frontal lobe of the brain than the others

6 Discussion

Studies advocating interdisciplinary education in design education (51, 52) aim to adapt focus skills from different disciplines to the design process. The early design phase, one of the most important stages of this focus in design, was investigated in this study. The preliminary-design/early design process is most important because it seems to increase and motivate creativity. In addition, it is a phase where decisions are made that will form the main structure of the design after the principal decisions. In this process, the architect shapes the characteristics of the relationship between the function, size, character, image and space of the design in accordance with his/her own demands and the demands of the person who requested the design. This phase is also the most important process in discovering alternative design solutions and creating appropriate design concepts.

This study viewed the design task as a problem-solving activity and one that questions the state of design in the early process. The focus of the study was on the early design process and at this phase, the architects and non-architects attempted to explore the different ways in which they have transformed their own knowledge in order to make their first design decisions.

The current study is similar to some studies in the literature [12; 29; 53; 54] which reveal that experienced designers exhibit their own approaches in architectural design, while inexperienced designers try to make irregular/unstable architectural designs. Findings from this study's participants support the above claim. Architects are more determined by their ability to transfer design decisions. It is evident that the designs of the non-designers were often indecisive. The fact that the frontal lobe is activated here may also indicate more powerful decision making mechanisms. Rather than making a right or wrong decision, the presence of a decision making situation may reveal "determination" in the design. Contrary to this, the ambivalence of non-architects in the design may be reflected in their drawings. In addition, the "delay" in the time to start the design, (shown in Figure 5) may also be an indication of this ambivalence.

The study also overlaps with Schön's [55] approach, which suggests as "thinking in action" within the education of design. Designers have stated that they are more successful than other professions in problem solving in situations that are uncertain, fuzzy, contradictory, and only specific to a situation. In their study of the relations between design process and representations in terms of creativity, Suwa et al. [29] discuses mental syntheses, mental image adaptations and the functioning of memory.

By comparing the cognitive processes of experts and non-experts, they emphasize the importance of short-term memory in developing creative representations.

The early design phase is important in the design system. This phase is a process of information gathering, analysis, synthesis and evaluation phases and an example of a smaller scale of the overall design process [12]. Participants who successfully completed this phase and continued to the design process were also successful in developing a thinking system based on a holistic design approach. The 50 architects who completed the early design phase successfully in the study had a higher score on the overall design than the other participants. This can be defined as the process by which 'pre-existing information' and 'new information on the design problem at hand' are assembled together to form the first design decision in the early design phase.

Design thinking as a significant process in early design stage, is a unique process that relates to the generation of ideas and design solutions; so it is an issue that should be addressed [56]. In the early design phase, the conventional environment is used for the synthesis phase, while the digital environment is used for evaluation and drawing purposes. This position is important in terms of the continuous development of hand-eye coordination. In addition, the architectural product finds existence by expressing the designer's way of thinking. Approaches on how to set up a planning system of design are taught through the education of architecture. It is determined that the frontal lobe of the brain is active in the recordings of the brain imaging of those who have successfully completed the architectural education. This lobe in the frontal part of the brain is related to reasoning, synthesis, motor skills, and high-level cognitive ability. This field receives information from the various lobes of the brain and utilizes this information to complement the movements of the body. Therefore, it is thought that the information coming from the architects during the design phase is processed more intensively in the frontal lobe. And as such, it was an expected finding that architects in the group would be able to do the ‘synthesis’.

The design and development utilized the British Design Council [57] which addresses four key iterative cycles in the design process: “Discover, Define, Develop and Deliver”. It’s called double diamond design process. The “discovery” and “define” phases of design thinking provided a critical foundation for the design process and also it can be thought that the early design phase is related to the “discover” and “define” definitions.

Zull [58] explains that the back of the brain controls the "past" and the front of the brain the "future" when looking at the physical structure of the cortex, which is the center of thought of the human brain. The finding that the frontal lobe activity is active in the design of a new object/product is particularly important for future design education in architecture. . In other words, extensive expertise in design and attention may contribute to the activation of the right frontal lobe for the integration of knowledge and empowerment of positive emotions, thus disabling negative emotions against a faulty design. However, the "extensive daily aesthetic experience" that architects must deal with for their profession brings more brain activation into aesthetic judgments and brings the aesthetic feelings along with more activity.

In addition, our results indicate that both conditions affected the EEGs; for example, during visual stimulation with the design for the non-architect participants, an increased high alpha-wave and high beta-wave activity were observed, which means an improved relaxation and attention. In addition, when the non-architect subjects started to design a procedure, their relative fast alpha power spectrum increased indicating improved relaxation and creativity compared with what was observed for the control. In contrast, our results show an increase in the beta waves indicate that the architect participants were more attentive thus lower values indicated a lack of concentration. In general, an increase in beta wave activity occurs during an emergent situation, and lower beta waves occur during a state of drowsiness [40]. The (EEG) Neuro-Sky Mind Wave Sense meter meditation results show that the architect subjects' meditation mean scores were higher when starting to design, which means that the subjects were calmer than those in the control group. In contrast, a lower meditation score indicates anxiety, stress or perhaps lack of interest. This finding supported one study that indicated that the presence of design affects meditation and attention, which are useful for boosting an individual's work performance.

In recent neuro-cognitive studies [59;60] have revealed that there are some nervous sub-bases of aesthetic sensibilities and aesthetic decisions. Accordingly, aesthetic judgments can be considered to interact during the product design. Therefore, it also supports the findings of Yeh et al., (2017) that in architecture education, the aesthetic judgments are important to be taught in the early design phase.

Beside, as shown in Figure 6 and Figure 7, the frontal lobe of the brains of the group of architects was found to work much more during the design. This lobe, located at the front of the brain, is associated with reasoning, motor skills, high-level cognitive abilities, and spoken language. The motor cortex lies at the posterior part of the frontal lobe. This area of the brain receives information from various lobes of the brain and utilizes this information to perform body movements. The excessive activity of the frontal lobe here is believed to be particularly relevant to reasoning and cognitive activities. Based on this, the extent of cognitive effect and frontal lobe activity associated with the early design phase can be seen clearly. This highlights the need to place emphasis on the early design phase in design education. This education should encourage the correct transfer of knowledge and the renewal of design methodologies used in the early design phase.

7 Conclusion

In this study, participants were examined to determine how they transferred the knowledge they possessed to make the first decisions in the early design phase. The purpose of this deliberation was to draw conclusions to support design teaching methods and explain the structure of the design activity, especially during the early design stage and to consider its effects on the whole design process.

The early design phase is important in the thought system design. It is a process in which the steps of information gathering, analysis, synthesis and evaluation occur. In this study, participants (architects and non-architects) who successfully completed this phase and continued the design process were also successful in developing a design thinking system based on a holistic design approach.

Although design components do not change today, the process itself has become a design product. Many data-intensive designs have expanded over the boundaries of design and architecture. In the conventional design process, developing and progressing phases are different from each other, and nowadays they interact with each other. The design process develops as a continuous cycle and it brings along the increase in information resources, the acceleration of information access, and the globalization of the design process. Nowadays, the design process can be stopped without interruption at any moment, as time is infinite within the production process. Design knowledge includes the production of knowledge at the same time.

The data obtained on the formation of productivity and on human nature in the design process allowed designers to handle their own processes more consciously, manage them more effectively and make them more efficient. In this context, studies on design cognition are of importance for both the development of more productive education models, and the development of knowledge-based systems and computational design tools. Moreover, the sketch environment, which supports the visual reasoning of the designer to allow a basis for creativity and productivity, enables designers to establish relationships between their mental images and the physical images they create as a means of thinking in the early phases of architectural design. The designer questions and transforms these relationships throughout the design process creating new images and design ideas. In this context, this study emphasizes the importance of the early stages of architectural design and paves the way for further research of its impact on design productivity.

In the early design phase, one of the most creative mental processes emerges within the design process. In this phase, which involves the generation of many alternatives, knowledge and the formation of new design ideas, many numerous actions are carried out simultaneously and in association with each other [61]. The creativity factor comes to the fore during the simultaneous construction of design relationships, having complex and numerous variables in the mind, and affects the development of the early design phase as well as the overall design process.

Conclusions drawn from this research provide important results on the relationship between a professional designer and non-professionals and also provide valuable information about the differences in brainwave activity that occur in various environments.

Acknowledgments. I thank all the subjects who helped us by voluntarily participating my study. I would like to thank the reviewers for their thoughtful comments and efforts towards improving our manuscript.

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