Neural Correlates of Mobile EEG and the Built Environment

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Abstract

Enhancing urban trails design quality can encourage people to use them. This study compared two urban trails with different functions in Tehran. Trying to discover that while walking on the urban trails which parts of the path has the most effects on the cognitive functions of users. The aim is to enhance the urban trails quality by understanding human's reaction. We use electroencephalography device as a cognitive science tool. Results illustrate that first three minutes of strolling has the most cognitive effects on users. We suggest improving the space quality of urban trails after the first minutes of entrancing.

Keywords: urban trails; EEG; park; commercial walkway

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https://doi.org/10.21834/aje-bs.v2i4.199

1.0 Introduction

These days new developments lead cities to have more walkways and walking strategies (Azmi & Karim, 2012). Urban trails are the walkways in the cities that build for encouraging people to stroll in them and they would have a direct relation to users. Studies demonstrated that walking and cycling in urban trails can have positive effects on user's mental and physical well-being (Shamsuddin, Hassan, & Bilyamin, 2012). Other studies showed that having urban trails near residential neighbourhoods can encourage children to play in them (Aziz & Said, 2012).

Recent studies showed that design quality have some influences on people's desire to use the place (Mohamed & Othman, 2012). Architects and urban designers try to design in a way that encourage people to be in a place and enjoy the ambience. Urban trails are necessary for citizen's health and activity, and they should have human oriented design (Shamsuddin et al., 2012). As urban trails have a direct relation to users and influence their health, enhancing their design quality can encourage people to use them more and be healthy (Marans, 2012).

Urban walkways are designed in the way that people can stroll in them for a while, and most of them have some starting and ending points. Walking ways usually have long distance and because of that people would get bored while strolling. Hence, their design should be in an exciting and motivating way (Ujang, 2010). Usually for creating long walkways designers try to create noticeable signs in different places to catch people's attention.

Recently, new fields like neuroscience and cognitive science propose new ways to study people's reaction toward environment (Vartanian et al., 2013). By having these new technologies architectural studies can develop.

The aim of the current study is to enhance the urban trails quality by using cognitive tools and understanding human's reaction. This research tries to find out that while walking on the urban trails which part of the path has the most effects on the cognitive functions of users. We design a study to compare two different urban trails such as; recreational (park) and commercial (bazaar) walkways according to calmness and excitement feelings. We test the feeling by using research tools in neuroscience.

2.0 Literature Review

2.1 Cognitive science and design

New technologies and developments in cognitive science lead architects and urban designers to use them in their researches. Historically, architectural research relied on philosophical constructs or analysis of behaviour patterns to relate human responses to design (Pardalos, 2012, p. 28). Two major research methodologies and one design process have been developed for environmental behaviour studies mainly to relate to architecture and other design professions and processes. Those are user needs programming studies, post-occupancy evaluation (POE) studies, and evidence-based design (Eberhard, 2009, p. 171).

Environment-Behaviour studies—user needs studies and POEs—can help us understand what kind of the relationship might be between designed environments and behavioral outcomes. They will never be able to tell us, from a physiological and neuroscience point of view, “why” these relationships occur. It requires that neuroscience knowledge to be applied (Eberhard, 2009, p. 177). Neuroscientific data have an important role to play in bridging the conceptual gap between architecture and psychology by explaining some of the underlying mechanisms. The mechanisms that explain how systematic variations in architectural features lead to behavioral outcomes (Vartanian et al., 2013).

Tools in neuroscience such as; Electroencephalography (EEG), Functional magnetic resonance imaging (fMRI), Eye tracking, etc. can be used in architecture and environmental researches. Many studies were performed by these devices. For example, studying systematic variation in contour impacts aesthetic judgments and approach-avoidance decisions by using a functional magnetic resonance imaging (fMRI) (Vartanian et al., 2013). Their results show that participants were more likely to judge spaces as beautiful if they were curvilinear than rectilinear. Also, there are vast number of studies related to colors according to neuroscience and physiological data (Jalil, Yunus, & Said, 2012).

2.2 Electroencephalography (EEG)

EEG is a device in the neuroscience field that has usage in both clinical and research areas (Buzsaki, 2009). EEG device records the electrical activity along the scalp. EEG possesses many advantages over other brain monitoring tools, like its lower costs and few side effects for the patient (Niedermeyer & da Silva, 2005, p. 17). EEG signals divided into bands by frequencies. Four basebands are Alpha, Beta, Delta, and Theta.

Alpha is the frequency range from 7 to 13 Hz it is usually seen in the posterior regions of the head on both sides (Sadock, 2000, p. 159). Alpha is most often associated with quiet, passive, resting, but wakeful states (Zillmer, Spiers, & Culbertson, 2008, p. 41).

Beta is a low-amplitude, fast-activity wave with a frequency of more than 13Hz. Beta is usually seen in frontal lobe and is often divided into high beta (24–30 Hz), typically related to a narrow focus, over arousal, and anxiety; mid-beta (18–24 Hz), often linked to being active, alert, excited, or focused; and low beta (13–18 Hz), which has been connected with relaxed, external attention (Zillmer et al., 2008, p. 41).

Delta is the frequency range up to 3.5 Hz. It is considered normally in adults in deep sleep. Also, Theta is the frequency between 4 Hz to 7 Hz; sometimes Theta can be seen in the frontal lobe in healthy adults (Sadock, 2000, p. 159).

Many studies worked on EEG in relation to the environment. One study focused on the impact of fluorescent light on neurophysiological, and subjective indices of wellbeing and stress(R Küller & Wetterberg, 1993). Other studies show that we can use mobile EEG such as; Emotiv device in architecture and urban design for studying real environment, also this study shows some evidences to use EEG in acoustic researches(Roe, Aspinall, Mavros, & Coyne, 2013). Furthermore, another study worked on EEG signals for evaluating the arousal and performance toward the interior color (Rikard Küller, Mikellides, & Janssens, 2009).

3.0 Methodology

3.1 Study Design

This study tries to clarify the effects of urban trails on cognitive functions of users while strolling. We compared two different urban trails with recreational (Park-e-Shahr) and commercial function (Sepah-Salar) in Tehran (Fig.1).

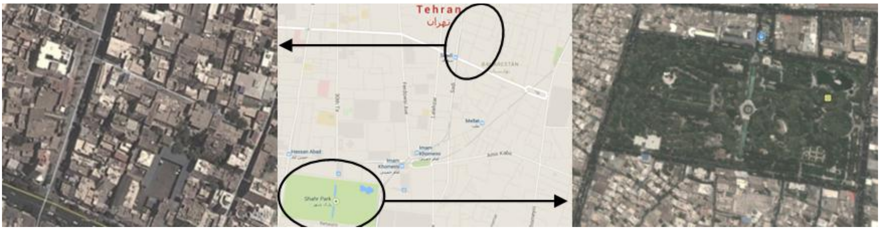

Figure 1: Locations of two urban trails in Tehran, Iran. (Park-E-Shahr and Sepah-Salar)
(Source: https://www.google.com/maps)

SWOT chart was used to analyse these two walkways. SWOT (strength, weakness, opportunity, threat) analyses involve brainstorming and recording a place's strengths and weaknesses, the opportunities that could be exploited and the likely threats(Carmona, 2010, p. 304).

Two walkways that had the same design quality were chosen. Both of them had North-South orientation with 10 m width and 250-300 m length. 20 healthy subjects (9 men and 11 women) participated in this study and their average age was29 years old (20 to 35). It was a convenience sampling, and they were volunteers from university students with different academic majors. Participants shouldn't be addicted to a cigarette, alcohol and, etc. Also, they shouldn't have any mental disease like; depression, stress and, etc. Moreover, they shouldn't use any drugs related to mental health. We asked participants about their level of health for choosing them for the test.

Participants were strolling the ways for about 10 minutes while the EEG EMOTIV device was recording their brain functions. EEG signals were recorded by the Emotiv EPOC device with 14 channels. Emotiv is a mobile EEG device. In this study, EEG signals were recorded by a laptop.

3.2 Data processing

Frequency changes of each part of the brain have different meaning in EEG analysis (Zillmer et al., 2008, p. 40). Researches in neuroscience field show that relaxing is related to 7-13Hz (Alpha) changes of occipital part of the head and excitement is related to 18-24 Hz (Mid-Beta) changes of the frontal part of the head (Zillmer et al., 2008, p. 41). Therefore, in this study, we calculated frequency changes for relaxing and exciting in those two parts of the head.

EEG signals were recorded by Emotiv EPOC device according to 10-20 standards with 14 channels with references to both mastoids. Its channels include AF3, AF4, F3, F4, F7, F8, FC5, FC6, T7, T8, P7, P8, O1 and O2. In this paper, we analyzed AF3, AF4, O1 and O2 channels. Also, Frequency sampling was 128 Hz. Fig. 3 shows the channel locations of electrodes for occipital and frontal lobe.

EEG signals were analysed by EEGLAB and MATLAB software. Paired samples t-test was done for signifying the data ($p<0.05$). EEG frequency bands were extracted, and High-pass filtering EEG at 0.1 Hz was done. Also, Direct Current (DC offset) was removed from the EEG signals. Time were devided into three equal parts and examined each period according to calmness and excitement changes.

4.0 Results and Discussions

Six different dimensions for urban design were defined by Carmona, such as; morphological, perceptual, social, visual, functional and temporal dimensions(Carmona, 2010). In this study, we focus on the visual dimension and compare these two urban trails in this field with SWOT chart. For visual dimension, we worked on townscape aesthetic, serial visions, height-to-width ratio, rhythm, and harmony.

Table 1. shows the SWOT analyses comparision result according to the visual dimension. It shows that both walkways have the same level of strengths and weaknesses in the visual dimension. Interviews after the test showed that the experiment locations were not regular and usual places for the participants. Therefore, it can cause the participants to pay more attention to the environment.

Table 2. shows Alpha changes in park and bazaar (commercial trail) for each period. The Paired samples t-test has significant meaning in the first period ($p=0.04$). The level of Alpha band in the park for the first period is higher than Beta.

Table 1: SWOT analysis according to visual dimensions for park and commercial trails

	Urban Design Dimensions (Visual Dimension)	
	Park	**Commercial**
Strength	Trees make soft landscape Having statue and landscape facilities Trees have fabulous harmony	Shop's facade make the townscape active Having statue and landscape facilities
Weakness	Monotone serial visions Monotone Height-to-width ratio Not suitable pedestrian materials	Monotone serial visions Monotone Height-to-width ratio Weaknesses in townscape aesthetics by paying no attention to rhythm, color, harmony, etc. Façade's old materials
Opportunity	Natural aesthetic potential of old trees	Shops have high potential to rebuild the townscape
Threat	Few number of visitors	Lack of harmony in building new shops

(Source: authors)

Table 2: Paired Sample T-Test for Alpha band (7-13 Hz) in each period for the park and Bazaar- (*P<0.05)

Pair (3rd period) Alpha park3 – Alpha bazaar3	Pair (2nd period) Alpha park2 – Alpha bazaar2	Pair (1st period) Alpha park1 – Alpha bazaar1		
-.00138	-.00117	.00205	**Mean**	
.00434	.00368	.00320	**Std. Deviation**	
.00097	.00082	.00089	**Std. Error Mean**	
-.00341	-.00289	.00011	**Lower**	**95% Confidence Interval of the Difference**
.00064	.00055	.00399	**Upper**	
-1.424	-1.422	2.308	**t**	
19	19	12	**df**	
.171	.171	.040	***Sig. (2-tailed)**	

(Source: authors)

Table 3. shows the Mid-Beta changes in park and commercial trial for each period. It illustrates that first period has significant meaning (p=0.033). Second and third periods did not show significant result (ps>0.221).

Table 3: Paired Sample T-Test for Mid-Beta band (18-24 Hz) in each period for the park and Bazaar-(*P<0.05)

Pair (3rd period)	Pair (2nd period)	Pair (1st period)		
Beta park3 – Beta bazaar3	Beta park2 – Beta bazaar2	Beta park1 – Beta bazaar1		
-.00002	.00002	-.00005	Mean	
.00009	.00008	.00008	Std. Deviation	
.00002	.00001	.00002	Std. Error Mean	
-.00007	-.00001	-.00010	Lower	95% Confidence Interval of the Difference
.00002	.00006	-.00000	Upper	
-1.062	1.267	-2.386	t	
19	19	13	df	
.302	.221	.033	*Sig. (2-tailed)	

(Source: authors)

Moreover, Comparing the brain maps shows that Alpha activity of the occipital part in the park is higher than bazaar that illustrates relaxing feeling in the park. Also, Mid-Beta activity in the bazaar of the frontal lobe is greater than the park that shows more excitement.

It is deducible that the park makes us feel calm, and bazaar makes us feel the excitement. This study showed that these ambiences fade after some minutes. Results illustrated that first period (0-3 minutes) had the most cognitive and emotional effects on users in relation to space function. In addition, EEG results showed that the relaxing level was significantly higher in the first period in the park and decreased during the time. Also, EEG findings in the commercial walkway demonstrated that the excitement level was significantly greater in the first period and reduced by the time passing.

5.0 Conclusion

Current study tries to use new tools in neuroscience field to improve architecture and urban studies. We compare park and commercial walking pass by using Mobile EEG device. Results showed that the primary moments of strolling in the area had the most effects on people, and they felt the environment ambience. After walking for some minutes, the effects of the space faded. Hence, for catching the attention of people, we suggest putting some noticeable elements in this part of the way and improve the design.

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