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Neuroarchitecture Approach to Female Perception of Safety in Public Space

Nesreen Aiad, Khalid S. Al-Hagala, Hassan Abdel Salam

(Eng. Nesreen Aiad, University of Alexandria, Faculty of Engineering, Alexandria, Egypt, nesreenaiad@gmail.com)
(Prof. Dr. Khaled Al-Hagla, University of Alexandria, Faculty of Engineering, Alexandria, Egypt, khagla@alexu.edu.eg)
(Prof. Dr. Hassan Abdel Salam, University of Alexandria, Faculty of Engineering, Alexandria, Egypt, hasalam@alex.edu.eg)

1 ABSTRACT

In the creation of public spaces, there is a lack of articulation of specific desired emotion to be elicited or avoided, over and beyond just utilitarian functions. Moreover, there is a lack of metrics to measure such emotions stimulated by certain design features. The neuro-architecture approach - defined as the measure of potential feelings triggered by a designed environment in an organism tested by brain response - was adopted in this study. The feeling of safety is listed as a key element of the design of public space. Women have different experiences when it comes to public space, including their perceptions of safety. Perceptions of a lack of safety in public spaces can make women less likely to occupy these spaces and miss out on the positive effects of public space on their health and wellbeing.

This paper aims to identify the design indicators that address issues of women's fears when walking on foot. In order to validate such indicators, a mixed method approach was used; including mobile electroencephalography (EEG) to understand the impact of street design on women's brain activity, interviews and a questionnaire survey, to provide context for the neuroimaging data. Syria street - an urban mixed-use street - in the city of Alexandria in Egypt was chosen for the study, where a group of women users walk along and rate indicators of safety on a Likert scale. The questionnaire included 7 indicators of safety emergent from the literature: active frontages, lighting, visibility, perimeter protection, informal control, mix of people, locomotive pathways. Results yielded significant correlations between each of the indicators investigated and perceived safety. Moreover, it established the ability of neuroarchitecture, as a tool, to develop designs that elicit specific desired emotion in users of public space.

Keywords: EEG, Perception, Feminist, Neuroarchitecture, safety

2 INTRODUCTION

"The real importance of architecture is its ability to move people's hearts deeply" – Tadao Ando (2016)

The design of public space is perceived as physical entity –a structure or a built form only. However, these are not the only factors involved. The designed environment also has effects on humans at the cognitive and the emotional level (JL Higuera-Trujillo 2021). It is possible to predict this influence in the early stages of design and before the structure is built. An emerging discipline, one that bridges neuroscience and architecture, is beginning to provide more rigorous methodologies and a growing number of research reports that explores the interaction between brain, body, and the environment (EA Edelstein 2012). The discipline derived is termed "neuroarchitecture" which may be used to articulate a testable idea about how a specific feature of design may influence psychological or physiological processes that may in turn be associated with measurable changes that reveal the impact of the designed settings on human health. The modern possibility of recording the neural activity of subjects during exposure to environmental situations, using neuroscientific techniques, provides a promising framework for future design and studies of the built environment (JL Higuera-Trujillo 2021).

Safety as an emotion, overshadows the other basic human needs (such as 'love and belonging', 'self esteem', and 'self actualization') as argued by Maslow (1943) in his seminal paper, 'A Theory of Human Motivation'. Moreover, in the design of public spaces, safety is listed as a key element of sustainable communities and an important contributor to people's wellbeing (Allik & Kearns, 2017).

Women's experience of public space is shaped by their identity which includes their vulnerabilities, specifically to different forms of discrimination and violence and harassment. Addressing these factors is about establishing adequate measures to improve the safety of women (Bhattacharya, 2016). A fundamental step in this process is to identify the factors that affect the 'feeling of safety'(Blumenthal, 2014). Moreover, measuring this 'feeling of safety' to make public spaces inclusive and safe for women is key to the issue.

Recent global prevalence figures indicate that about 35% women worldwide have experienced violence in their lifetime (WHO, 2016). According to a poll conducted by the Thomson Reuters Foundation, Egypt was the third most dangerous country for women in terms of violence. Moreover, the country topped the list of places that are dangerous for women to visit in a trip by Skyscanner survey released in August 2017. In large part this is due to the verbal and physical harassment that women routinely face there. According to a survey released in 2013 by UN-Women, 99.3% of Egyptian women reported being physically harassed in the street. Finally, a study launched in 2011, "Study on Ways and Methods to Eliminate Sexual Harassment in Egypt," was sponsored by UN Women in partnership with National Planning Institute and Demographics Centre in Cairo. The study showed that 86.5 percent of women in Egypt don't feel safe in public transportation and that it ranks high on the list of unsafe spaces, and is the second-highest place where sexual harassment takes place, with public streets being the highest.

Accordingly, the aim of this study is to identify the design indicators that address issues of women's fears when walking on foot in the Egyptian context. This is accredited by an empirical study for a mixed-use street in Alexandria city to validate the female indicators of safety deducted in the theoretical part. In order to validate such indicators, a mixed method approach was used, including a site analysis as a prelimenary stage were the female indicators of safety have been sited on maps of the street; mobile electroencephalography (EEG) to understand the impact of street design on women's brain activity; and questionnaire and self-reported measures to underpin interpretations of the EEG data.

3 LITERATURE REVIEW

"Every significant experience of architecture is multi-sensory; qualities of matter, space and scale are measured equally by the eye, ear, nose, skin, tongue skeleton and muscle." – Juhani Pallasma (1994).

Rapoport (1977) highlighted that perception is the key process to connect people within the surrounding environment (Emel Birer, Pınar Çalışır Adem, 2022). Actual safety is highly important, but it is the perceived safety that impact people's lives (Van der Giessen et al. 2017). Perception of safety (POS) is a concept that refers to an emotion generated by the perception of the potential risks to safety (Ruiter R, Abraham C, Kok G, 2001). As related to the perception of individuals, perceived safety is not directly related to objective measures of crime or of threats to safety (Bedimo-Rung AL, 2005). Low perceived safety is a negative emotional state of anxiety that is often considered as a larger problem than crime itself.

POS is considered as a multifaceted concept; thus, different measures to study the phenomenon may tap various aspects of it (Abbott et al., 2020). Jackson (2005) describes POS as a group of related concepts reflecting emotion, perceived risk, and vulnerability. The British Crime Survey (BCS) resorts to three indicators in the evaluation of POS as a construct, namely: no worry of victimization, perceived order and organization, and perceived risk or personal safety, which focus on both cognitive and emotional dimensions.

Low perceived safety has been shown to affect women's decisions and behaviours, leading to the avoidance of certain places (Miethe T., 1995). A growing research literature has investigated the factors that can affect perceived safety in open space (Maruthaveeran S, van den bosch CC, 2014) (Jansson M, Fors H, Lindgren T, Wiström B., 2013). The international research literature emphasises three groups of factors associated with perceived safety in open space: (1) personal attributes, (2) physical attributes (3) and, social attributes.

A theoretical review has been done in order to identify the factors that affect the 'feeling of safety' that are key elements to make public spaces inclusive and safe for marginalised groups. Since safety is critical to the wellbeing of all citizens, regardless of gender, the position was taken that despite group difference there are some universal principles underlying evaluation which most people share. In order to identify these principles, a literature review was conducted to identify the most effective approaches of several cities around the globe to urban safety. Approaches offers practical tools for how to begin building a safer, more inclusive city and address the causes of different forms of violence and physical harassment.

Each approach suggested various aspects that affected the feeling of safety in public spaces. These aspects were skimmed through and sorted to attain a coherent set of indicators that can be defined as general indicators of safety in public space. Each indicator was mentioned by several theories, using various terms that reflect the same value. Figure1 shows the different approaches to safety and the pinciples of each approach that has been consolidated into nine general indicators of safety.

In order to identify indicators of safety that specifically relate to female subjectivity, further review has been conducted. The literature review explored a number of reports, articles and empirical studies about street design and women's safety perception. Moreover a number of women's safety audits, conducted in different countries, was reviewed to extract strategies and policies which aim to reduce violence against women. Principles of such literature have been matched wth general indicators of safety to be short listed to six indicators of safety related specifically to women as seen in Figure 2.

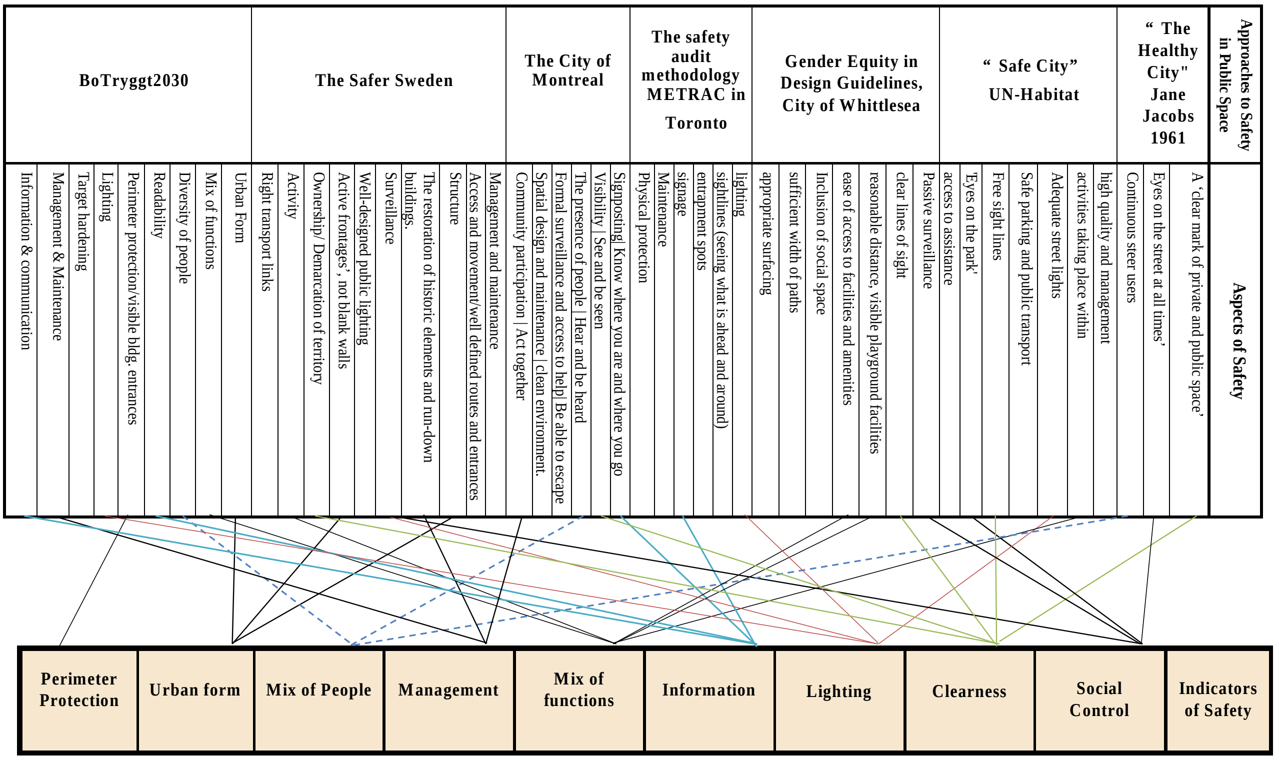


Fig. 1: General Indicators of Safety

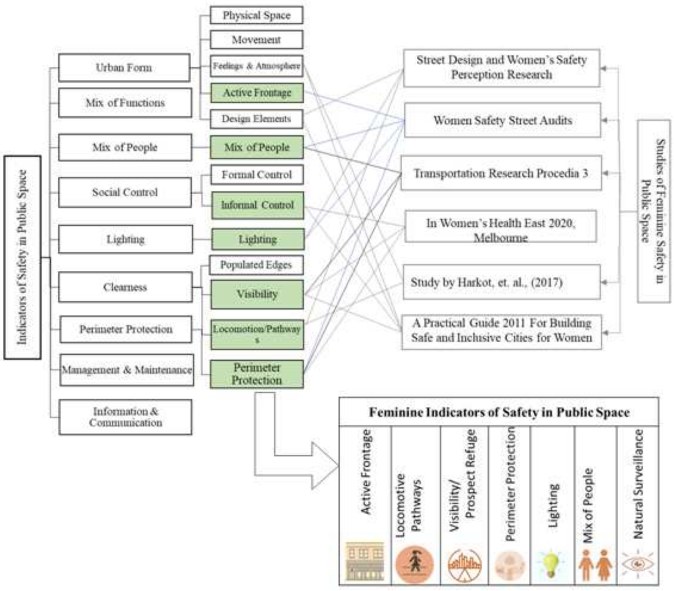


Fig. 2 : Indicators of Safety That Specifically Relate To Female Subjectivity. Source: Researchers, 2023.

4 THE RESEARCH FRAMEWORK AND CONCEPTUAL MODEL

The research perspective on physical and social indicators was predicated upon a combination of the environmental/physical POS theories (i.e., Broken Windows Theory, CPTED, and Defensible Space), which underpin the theoretical knowledge of the study and combination of principles of the most effective approaches of several cities around the globe to urban safety (i.e. The Healthy City-Jane Jacobs, “Safe City” UN-Habitat, Gender Equity in Design Guidelines-City of Whittlesea, The safety audit methodology-METRAC, The City of Montreal for safe cities, The Safer Sweden, BoTryggt2030). In the mentioned literature, some indicators for each factor are emphasised; however, the simultaneity of their effects has not

ISBN 978-3-9504945-2-5. Editors: M. SCHRENK, V. V: POPOVICH, P. ZEILE, P. ELISEI, C.BEYER, J. RYSER, H. R. KAUFMANN – Ljubljana, Slovenia

been investigated yet. The current study hence aimed to bridge the gap by modelling the possible relationships between these factors and their indicators. The research approach to women's POS was not based on unequal gender structure assumptions. However, in order to concentrate on women's POS, the search was for the indicators which affect POS among women with different individual characteristics in public spaces by reviewing a number of reports, articles, women safety audits and empirical studies about street design and women's safety perception (Study by Harkot, et. Al., 2017), Transportation Research Procedia 3 (2018), Women's Health East, Melbourne study (2020), Building safe and inclusive cities for women-2011 (a practical guide), Street Design and Women's Safety Perception Research (Rashid, Suhaila & Wahab, Mohammad Hussaini & Wan Mohd Rani, Wan., 2017) and a number of safety audits (Towards a Gender Inclusive City-Delhi, ActionAid International, 2013; UNHABITAT et al., 2010; Jagori, 2007, 2010; SAKHI, 2011; Women in Cities International, 2010a, 2010b) conducted in both the developed and the developing world. Figure 3 illustrates the conceptual model, including the primary factors of safety and their indicators, and in order to test this model, some demographic characteristics are taken into account.

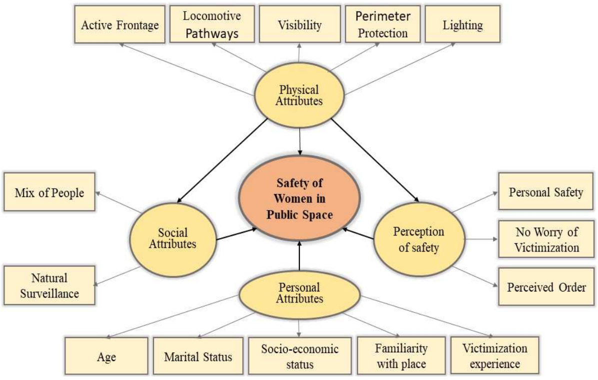


Fig 3: Conceptual Model of Feminist Safety Perception in Public Space (The Researcher, 2023)

5 METHODOLOGY

The aim of this study is to identify the most important indicators of public space that evoke appropriate emotional response (feeling safe) contributing to engagement of women in public space. This will be achieved by adopting a neuroarchitecture approach to validate how the identified indicators affect the neurophysiological correlates of emotion in women.

In order to achieve such aim, this paper uses a mixed method approach for the study, conducted in three phases: The preliminary phase (Site Analysis) where activities were mapped along the entire 630 m stretch on both sides of the street between the months of April–May (2023). Through this mapping all zones of the street, were identified for detailed study. Thereafter, the indicators affecting the perception of safety, as identified in the literature review, were listed and mapped along with the activity mapping in the different zones of the street. This was followed by an in-depth study of the gendered usage of space day and night. The outcome of the site analysis was the availability of most indicators of safety along the street except for a deserted area near the end of it.

Second phase was a questionnaire based survey, where 104 female users were surveyed using a structured questionnaire where they rated the female indicators of safety extracted from literature on a Likert scale, as well as unstructured questionnaire wherein questions were asked about their social background, their experiences of harassment on the street, and there familarity with place.

Third phase was the EEG Measurments, where female participants were asked to wear the non invasive Emotiv mobile electroencephalography (EEG) to understand the impact of the street design on women's brain activity. During navigation experiment participants were asked to move from an origin to a destination, simulating naturally occurring condition in the street while the eeg device recorded their brainwaves.

6 CASE STUDY

6.1 Study Area and Sampling

The study is conducted in Syria street in Alexandria city of Egypt. The street is one of the most famous streets in the city and considered one of the best places to go out. It includes a wide variety of facilities such as banks, school, shops, and luxury apartments. Best street sights are a Jewelry trade building, Industrial School for Girls, shopping mall and an abandoned Palace. The street was selected as it represents some of the different kinds of urban mixed-use streets common in Alexandria city and include areas differing in visibility, vegetation density, extent of facilities and level of development.

The survey sample consisted of a number of 104 random female subjects who participated in the experiment with different demographic characteristics. An online advertisement was launched on social media apps seeking female volunteers. They were asked to walk through Syria street and observe the indicators of safety before rating them in the questionnaire form on the Likert scale.

The route was the same for all participants, it was selected to include all Syria street classified into two zones. Zone A,C (mixed use,busy commercial containing banks and a girls school, shops, residential buildings and many pedestrians); Zone B (residential use, path through 160 meter blank facade of a palace wall, residential villas, graffati and rubbish, poor lighting, few pedestrians). Photographs of the two zones are shown in Figure 4. The walk was conducted during day and night time to assess how lighting changes at different times of the day affected visibility.

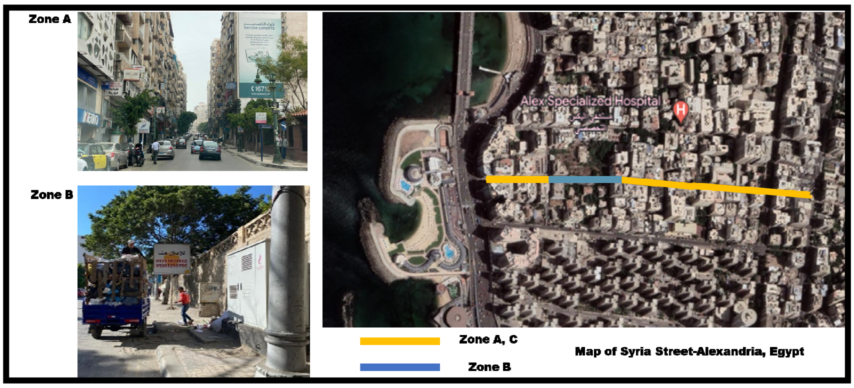


Fig.4 : Photos and Map of Syria street showing two different zones A,B,C

6.2 Questionnaire Survey Method

The questionnaire administrated to the sample of female participants was designed in two main sections. The first section included questions about the respondent's demographic characteristics including age, gender and occupation. In the second section, the respondents were asked to walk through the street and observe the naturally occuring enivironment to rate 28 indicator of safety investigated on a 5-point Likert scale. The street was selected upon the availability of safety indicators presenting sufficient variability in the physical and social attributes investigated. The research hypothesis to be tested is that the female safety perception has a positive relationship with the extracted safety indicators. The two versions of the questionnaire survey were pilot tested prior to data collection to insure clarity of the questions. This led to some improvements in the formatting of the questionnaire. The questionnaire form is illustrated in Table 1 with the coded street features to be rated.

Safety Factors	Code	Indicators	Architectural Features	
Physical attributes	PH1	Active Frontage	PH1.1- Density of buildings /no. of premises	
			PH1.2- Number of entrances	
			PH1.3- Number of windows	
			PH1.4- Transparency of facades	
			PH1.5- Variety of activities	
	PH2	Locomotive Pathways	PH2.1- Adequate width of pathways to walk freely without brushing	
			PH2.2- Good quality of the pavement	
			PH2.3- Absence of obstacles to locomotion	
	PH3	Visibility Prospect & Refuge	PH3.1- Absence of obstacles that block view	
			PH3.2- Density of trees	
			PH3.3- Clearings between trees	
			PH3.4- Form of tree not blocking visibility	
			PH3.5- Possibility of being seen and seeing around	
			PH3.6- Absence of places for offenders to hide	
	PH4	Perimeter Protection	PH4.1- Availability of possible escape routes	
			PH4.2- Visibility of entrances	
			PH4.3- Permeability of fencing system towards the street	
	PH5	lighting	PH5.1- Amount of lighting	
			PH5.2- No obstacles covering light posts	
			PH5.3- Amount of glare	
Social attributes	S1	Mix of people	S1.1- Presence of people on the street	
			S1.2- Absence of threatening people (homeless, drug takers….)	
			S1.3- day	Presence of women compared to men
			S1.4- night	
	S2	Natural Surveillance	S2.1- day	Degree of observation from inside buildings, (shops or restaurants with large windows, housing with balconies)
			S2.2- night	

Table 1: Coded Items To Be Rated In The Questionnaire Survey Form (The Researcher, 2023)

6.3 Neuroarchitecture Approach Method

Neuroarchitecture is the built environment designed with principles of neuroscience, which establishes spaces that enhances wellbeing, improve cognitive abilities, stimulate brain and eases nerves. Its goal is gaining a better understanding of the relationship between emotions and architectural design by observing people's responses and measuring the relevant regions of the brain. It provides an empirical basis for the design choices made by architects, rather than settling for purely theoretical debates in design.

Feminist Safety Perception	SP1	Personal safety	SP1.1- Feeling of safety while walking alone at night
			SP1.2- The level of presence in the street at night
			SP1.3- Lack of zones you avoid walking through
	SP2	No Worries of Victimization	SP2.1- Absence of sexual harassment (verbal, touching, chasing
			SP2.2- Absence of Violent Physical attack
			SP2.3- Absence of Robbery, murder, …
	SP3	Perceived order and organization	SP3.1- Absence of young hooligans
			SP3.2- Absence of ruined places
			SP3.3- Absence of rubbish or graffiti

Neuroarchtecture relies on philosophical constructs or analysis of behaviour patterns in order to relate human responses to design. Psychological studies using subjective methods, such as surveys or interviews, have also been used to test such relationships; however, these methods rely on the subject's understanding or ability to articulate why they respond to a design element in a particular way. In contrast, neuroscientific investigations offer a higher degree of objectivity, providing a number of additional tools that can measure both conscious and sub-conscious responses without the need to interrupt the subject. Nor do researchers interfere with the results themselves by asking subjects to think about how or why they respond as they do.

This paper builds on research using Emotiv mobile electroencephalography (EEG) to investigate particular indicators of safety extracted from literature, and explore it within the theoretical paradigm of neuroarchitecture to generate specific hypotheses for the design of public spaces that are safe for women.

To achieve such an objective, the literature review incorporated studies investigating design characteristics of the urban environment that included measuring objective neurophysiological response. The neuroimaging based studies have shown that different environments may be associated with distinctive patterns of brain activity (Chang, C.Y.; Hammitt, W.E.; Chen, P.; Machnik, L.; Su, W., 2008) (Ulrich, R.S., 1981). Further research has shown differences in neural activity derived and interpreted via Emotiv electroencephalography (EEG) proprietary software when walking in various urban environments, indicating changing neural activity in response to changing urban environments (Aspinall, P.; Mavros, P.; Coyne, R.; Roe, J., 2013).

Based on psychological and neuroscience research, it has been suggested that the responses along the dimensions of stress assosiated with feeling of fear and relaxation assosiated with feeling of safety are correlated with activity in particular regions of the brain.

6.3.1 The Expirement

For the naturalistic experiment, a pilot sample of female participants, who conducted the questionnaire survey, wearing EMOTIV EPOC headset were asked to walk along the same route in Syria street that took them through the busy commercial area into the deserted area. A custom-software platform to geoannotate emotional states from Emotiv's Affectiv suite was developed in the conduct of the outdoor studies.

6.3.2 EEG Data Acquisition

Brain electrical activity was recorded non-invasively from the scalp using the Emotiv EPOC+ EEG headset with 14 channels corresponding to the international 10–20 position system (AF3, AF4, F3, F4, F7, F8, FC5, FC6, T7, T8, P7, P8, O1, and O2). P3 and P4 acted as reference electrodes. Data was recorded using Emotiv Pro software. Where different recordings of each subject have been exported as CVS files to Emotiv cloud for analysing. The output from Emotive Performance Metrics is deduced emotional reactions from brain activity. The Performance Metrics creates a different profile for each subject then interprets the EEG activity from the available channels into six emotional parameters;"Engagement" En, "Excitement" Ex, "Focus "Fo, "Interest" In, "Relaxation" Re and "Stress" St (Emotiv, 2011).

Moreover, the Emotiv testbench provides Fast Fourier Transform (FFT) Method. This method employs mathematical means or tools to EEG data analysis and transforms a signal from the time domain into the frequency domain. Where the power of the different bands could be extracted in different lobes of the brain.

In this experiment the relaxation and stress parameters were selected for analysis. These parameters were normalised for each individual and scaled as values between 0 and 1, which allowed between subject comparisons, at each sampling point. Due to the intellectual property rights of Emotiv, it is unclear what particular EEG signature underlies each of the Performance Metrics outputs. Based on findings from previous research (Aspinall, P.; Mavros, P.; Coyne, R.; Roe, J, 2013). "Relaxation" is associated with a calm relaxed state and "Stress" has negative valence. The EEG data set was generated by creating three sequential means per walking segment at the individual level and then averaging these means across the whole cohort for each walking route. These means were generated using the time taken for a given participant to complete a particular section of the walk and then dividing this into three time locked sections. It is these means that are used for the analysis of the Performance Metrics data extracted from the Emotiv pro software.

The experiment also builds on the scientific fact that Alpha and Beta frequency power are linked to negative mood, stress and depression. whereby Alpha band has higher activation in the frontal lobe in non-stressful environments (active zones of the street) and Beta band higher activation in the stressful deserted area of the street. This is associated with an increase in the P7 and P8 electrodes which are closest to the amygdala in the brain, which is a fear-related area (Pizzo et al., 2019). Therefore, using the Emotive pro tesbench, the power of Alfa and Beta bands were extracted in the frontal lobe channels F3 and F4, and in the parietal lobe channels P7, P8. The research hypothesis that there will be an increase in Alfa power band in zone A, C and an increase in Beta band in zone B, is associated with the Performance Metrics results hypothesis that there will be an increase in stress along zone B and an increase in relaxation along zone A, C.

7 RESULTS

7.1 Questionnaire Survey Analysis

The analysis of the questionnaire survey method was done using the statistical package for social sciences (SPSS V. 28) for basic descriptive statistics, and (SmartPLS 3.2.9) for SEM-PLS modeling. The first section deals with demographic characteristics. The measurement model was evaluated for the reliability and validity of the instruments with several descriptive statistics and bivariate correlations in the second section. Finaly, the examining structural model for testing hypotheses underlying this paper includes path coefficients, collinearity diagnostics, coefficient of determination (R2), effect size (f^2), predictive relevance (Q2), and global goodness of fit criteria.

7.1.1 Measurement Model

Factor loadings, average variance extracted (AVE), composite reliability (CR), and discriminant validity were used to assess construct validity (Hair & Lukas, 2014). (Hair et al., 2017). The values of composite reliability should be greater than 0.6 and AVE above 0.4 (Fornell and Larcker, 1981). These indicate that the study satisfied these requirements for convergent validity and internal consistency of the scales. The values for Skewness between -2 to +2 and kurtosis between -7 and +7 are considered acceptable in order to prove normal distribution (Hair et al. 2014; Byrne 2016). The results of the normality test show that the values of Skewness and kurtosis for the constructs of the model were within the specified range.

Fig. 5: Visualization of the correlation matrix

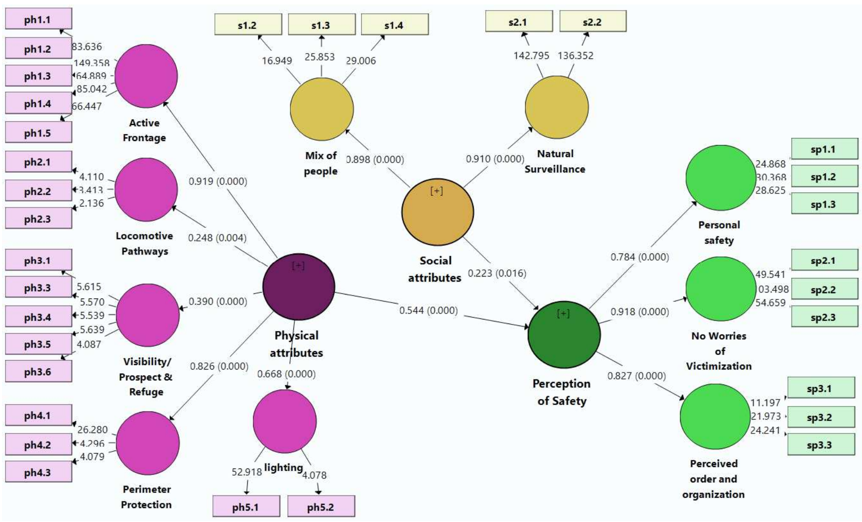
The Pearson product-moment correlation coefficient was calculated to determine the strength and the direction of the relationship between the selected constructs. Figure 5 shows the matrix of Pearson correlation coefficients between all constructs and the dimensions. It was indicated that there is a positive relationship between the independent variables (and its dimensions) with the dependent variable (and its dimensions). It is also observed that there is a significant positive relationship between Physical attributes and Perception of Safety since $(r(208) = .649, P < 0.001)$ and between Social attributes and Perception of Safety since $(r(208) = .651, P < 0.001)$.

7.1.2 Assessing the Structural Model

Examining the structural model includes path coefficients, collinearity diagnostics, coefficient of determination (R^3), effect size (f^2), predictive relevance (Q^2), and global goodness of fit criteria. Prior to analysing the structural model, the collinearity between constructs was examined (table 2) using variance inflation factors (VIF), and found that all values were less than the threshold of 5 (Hair et al., 2017).

Path	B	t-value	P-value	95% Bias-Corrected CI		Remark
				LB	UB	
H1: Physical attributes -> Perception of Safety	0.544	6.269	0	0.377	0.712	Supported
Active Frontage -> Perception of Safety	0.348	3.297	0.001	0.151	0.554	Supported
Locomotive Pathways -> Perception of Safety	0.028	0.539	0.59	-0.081	0.12	Not Supported
Perimeter Protection -> Perception of Safety	0.186	2.413	0.016	0.023	0.33	Supported
Visibility/Prospect & Refuge -> Perception of Safety	0.128	2.196	0.028	0.002	0.231	Supported
lighting -> Perception of Safety	0.033	0.473	0.636	-0.11	0.168	Not Supported
H2: Social attributes -> Perception of Safety	0.223	2.421	0.016	0.028	0.385	Supported
Mix of people -> Perception of Safety	0.122	2.03	0.043	-0.008	0.234	Supported
Natural Surveillance -> Perception of Safety	0.174	1.873	0.061	-0.016	0.349	Not Supported

Table 2: Results of Hypothesis Testing



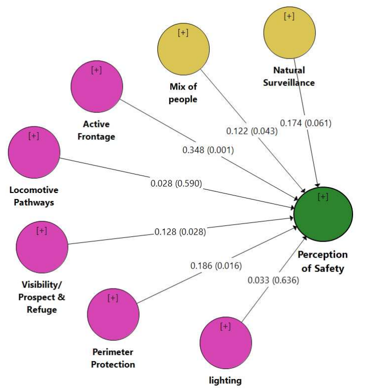
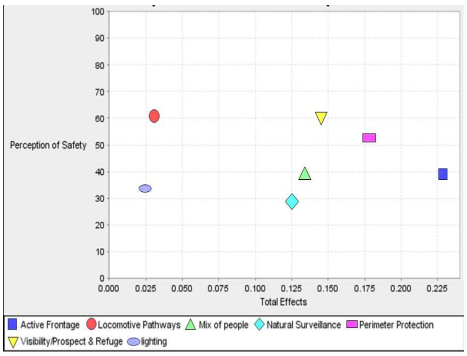


Fig. 6: Structural model assessment. Fig. 7: Sub-hypotheses testing

The results of hypothesis testing in Table 2 and Figure 6 showed that Physical attributes yielded a significant positive effect on Perception of Safety since $(\beta = 0.544, t = 6.269, P < 0.001, 95\%\ CI\ \text{for}\ \beta = [0.377, 0.712])$, consequently, the first hypothesis is confirmed. Moreover, Social attributes yielded a significant positive effect on POS since $(\beta = 0.223, t = 2.421, P < 0.001, 95\%\ CI\ \text{for}\ \beta = [0.028, 0.385])$, consequently, the second hypothesis is confirmed. The sub-hypotheses were also tested and given in Table 2 and Figure 7.



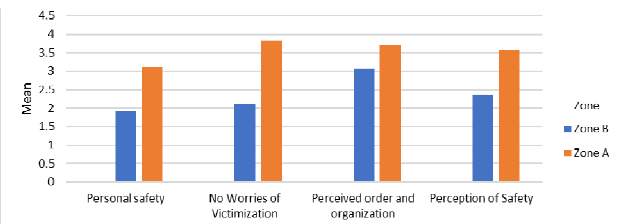


Fig. 8: Importance Performance Map. Source: Researcher, 2023. Fig. 9: Difference in perception of safety across zones.

7.1.3 Importance Performance Map Analysis

Importance performance map analysis (IPMA) was utilised to provide additional insights by combining the importance (I) and performance (P) dimensions analysis (Ringle & Sarstedt, 2016). IPMA enables the identification of places where action is necessary. Figure 8 depict the dimensions of the constructs that influence the dependent variable Perception of Safety. Figure 8 show that Active Frontage was the most important construct, followed by Perimeter Protection, Visibility, Mix of people, Natural Surveillance, Locomotive Pathways, and lighting. Moreover, Locomotive Pathways performed the best, followed by the Visibility, Perimeter Protection, Mix of people, Active Frontage, lighting, and Natural Surveillanc.

7.1.4 Personal Attributes Testing

In this section the analysis of the personal attributes will be investigated upon the respondent's satisfaction. The appropriate tests are the parametric tests, since the data were normally distributed (Table 3). The demographic variables are categorical variables with more than two independent categories, so the suitable parametric test is the analysis of variance (ANOVA) test. Concerning the age; the results show that there is a significant difference in Perception of Safety and its dimensions. Furthermore, the results for marital status show that there is a significant difference in only Perceived order and organization across the levels of marital status. Moreover, the results of Familiarity with Space show that there is a significant difference in only Personal safety.

Variable	Age		Marital Status		Familiarity with Space		Zone	
Test	F	*P-value*	F	*P-value*	F	*P-value*	t	*P-value*
Personal safety	4.438	0.013	0.378	0.686	3.506	0.032	9.968	<.001
No Worries of Victimization	1.092	0.337	0.361	0.697	0.870	0.421	12.378	<.001
Perceived order and organization	3.192	0.043	3.453	0.033	2.159	0.118	5.017	<.001
Perception of Safety	3.594	0.029	1.037	0.356	1.978	0.141	11.755	<.001

Table 3: Personal attributes results

7.1.5 Difference in Female Safety Perception Across the street zones

Since the zones of the streets are categorical variables with two independent categories, so the suitable parametric test is the independent-samples t-test. The results show that there is a significant difference in Perception of Safety and it's all dimensions between zone A and zone B since P-value is less than 0.05 as for Personal safety $(t = 9.968, P < 0.001)$, No Worries of Victimization $(t = 12.378, P < 0.001)$, Perceived order and organization $(t = 5.017, P < 0.001)$, and OS $(t = 11.755, P < 0.001)$. These differences were visually represented in Figure 9.

7.2 Neuroarchitechture Approach: Results

Although based on a small sample, the results of this pilot study was in line with the paper’s hypothesis that the extracted female indicators of safety trigger a positive emotion in subjects concerning their safety perception. The results also demonstrated the potential of mobile EEG to tap into the emotional and cognitive states of women who are engaged in naturalistic tasks, like walking in urban environments. The analysis of the extracted EEG data are analysed using two methods elaborated in the following sections.

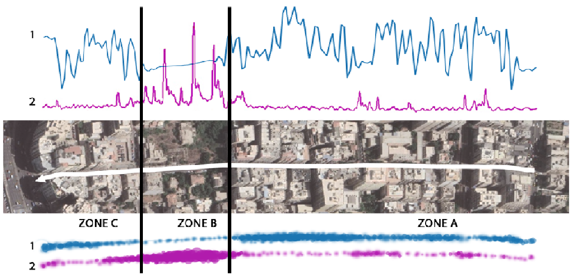
7.2.1 Performance Metrics Analysis

This anylsis is to test the first hypothesis of the neuroarchitecture approach method. At a descriptive level, a map of the route and a typical EEG record from one participant are shown in Figure 10 . The chart at the top shows the emotional levels from relaxation (1) and stress (2) that have been smoothed by Emotiv’s software.

A record of the fluctuations in relaxation and stress is plotted as a map according to their geographical location in figure 11 below. For example, this participant remains relaxed through zones A and C, which are full of active frontages, whereas relaxation falls in zone B which is a deserted blank frontage. Conversely, stress seems to be lowest at the start of the walk and highest towards the end.

An aggregate visualisation of the relaxation levels of three participants (peaks are in red, yellow and blue, respectively) Figure 11, reveals shared patterns of emotional activity, even though the experiment was performed on different days.

ISBN 978-3-9504945-2-5. Editors: M. SCHRENK, V. V: POPOVICH, P. ZEILE, P. ELISEI, C.BEYER, J. RYSER, H. R. KAUFMANN – Ljubljana, Slovenia



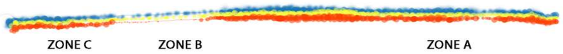
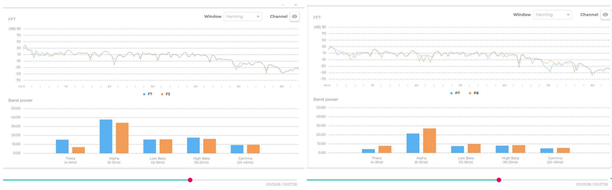


Fig. 10: Map of the route in Syria street. Emotional activity of one participant during the route, in charts (top of the map) and plot in space (bottom of map). Cyan shows relaxation; Magenta shows stress. Source: Researcher, 2023. Fig. 11: Shows aggregate of relaxaion levels from the three participants. Peaks are in red, yellow and blue, respectively, for each participant. Source: Researcher, 2023.

7.2.2 Fast Fourier Transform (FFT) Method

Testing the second hypothesis of the neuroarchitecture approach method, the outcomes were in line with the FFT extracted results. As seen in Figure 12, the readings of one participant shows an increase in Alpha bands associated with relaxation in Zone A,C of the street in the F3 and F4, P6, P7 channels after 5 minutes walk and conversely an increase in the power of Beta band associated with stress in the F3 and F4, P6, P7 channels when the participant walked through zone B after 7 minutes walk shown in Figure 13.



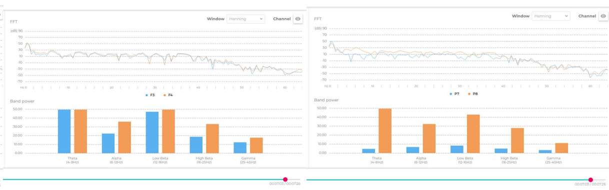


Fig. 12: Increase in Alfa band in F7, F3, P7, P8 in Zones A & C (FFT of Emotiv Pro Software). Fig. 13 : Increase in Beta band in F3, F4, P7, P8 in Zone B (FFT of Emotiv Pro Software)

8 DISCUSSION AND CONCLUSION

This paper piloted and presented a novel mixed methods study focusing on the changing mood of female subjects while walking in an active mixed-use urban street with one deserted area, using interpretations of EEG along with subjective scales. This approach allows for a deeper understanding of mood variation amongst women by identifying the indicators of safety of the physical and social environment, which influences how they feel during a walk in the street at day and night time. A Female Safety Conceptual Model was conducted to identify the different attributes that affect the safety of women in public space, which was a base for validating the indicators of safety through the questionnaire survey method. The analysis of the indicators of safety using the questionnaire survey method was done using the statistical package for social sciences (SPSS V. 28) for basic descriptive statistics, and (SmartPLS 3.2.9) for SEM-PLS modeling. The results showed that physical and social attributes yielded a significant positive effect on women‘s perception of safety in public space. Consequently the first hypothesis of the paper is confirmed. Only three of the indicators were found to have no effect on perception of safety which are locomotive pathways, lighting, and natural surveillance which contradicted with literature and previous studies.

Importance performance map analysis (IPMA) was used to identify the most important indicator for the perception of safety. Active Frontage was the most important indicator, while lighting was the least important. Moreover, Locomotive Pathways performed the best and Natural Surveillance performed the least. Concerning the personal attributes and the perception of safety, the paper used the analysis of variance (ANOVA) test. The results showed that there is a significant difference in Perception of Safety across the levels of age, marital status and familiarity with space. The levels of POS tend to increase with age, which is contradicting with the reviewed literature. The familiarity with space was found to help increase the POS while the divorced category was found to be the highest in their POS.

The independent-samples t-test was conducted to show that there is a significant difference in Perception of Safety between zone A (active) and zone B (deserted) of the street. Where, the perception of safety was high in the presence of such indicators in the active area of the street and the POS dropped down in the deserted area of the street, which was the base to examine the validation of such hypothesis in the context of neuroarchitecture.

The EEG recordings extracted from the Emotiv pro software has been analysed using two methods; the Performance Metrics Analysis and the FFT analysis method. The Performance Metrics Analysis presented the findings from the female participants that started their walk in the active Zone A of the street and then walked into the the deserted zone B. This pilot found evidence of high relaxation when walking through zone A, and higher stress when moving into zone B—and higher relaxation when moving out of it. The FFT analysis found an increase in the power of the Alpha band associated with relaxation while walking along the street and conversely an increase in the power of Beta band associated with stress in the deserted fearful area of the street. Consequently the second and third hypothesis of the paper are confirmed.

Results of the Neuroarchitecture approach method were found to be consistent with the results of the qustionnaire survey method. Analysis of the Performance metrics and FFT data appeared to show interpretable differences between walking through the two zones of the street, further supported by the questionnaire survey analysis, which suggested that participants experienced a beneficial effect all over Syria street except for the deserted area towards the end of it. Such evidence shows that the availability of the proposed safety indicators along the street has a main role to play in contributing to women's safety perception through mediating the stress induced by the fearful zone of the street.

This paper seeks for improvement of women engagement in public space. It is a search for the scientific evidence which could support the design. The innovative part is that instead of asking subjects about their feelings towards different design features, their brains were "asked" directly by observing which brainwave patterns were active while moving along different areas of a street setting. This new approach highlighted the most important features of public space contributing to safety perception.

This study is one of the first to use a mobile EEG system outdoors and EEG-based emotion recognition software to record emotional changes as female subjects walk through an urban environment, supported by a questionnaire survey method that provided insight into interpretations of the Emotiv testbench. However, there is still difficulty in establishing reliable interpretations of the Affectiv terms for use in this context, suggesting that further research is required using a larger sample.

Nonetheless, the paper findings are consistent with the theories and principles of perception of safety in public space and encourage the use of the technology to extend current research by developing novel and objective cortical correlates of emotion. This would be particularly beneficial in exploring the health improving potential of environments while women are on the move.

9 REFERENCES

ABBOTT, J., McGrath, S. A., & May, D. C. (2020). The efects of police efort on victims' fear of crime. American Journal of Criminal Justice, 45(5), 880–898. https://doi.org/10.1007/s12103-020-09523-7

ALLIK, Mirjam & Kearns, Ade. "There goes the fear": feelings of safety at home and in the neighborhood: The role of personal, social, and service factors: Feeling Safe at Home and in the Neighbourhood. Journal of Community Psychology., 2016 45. 10.1002/jcop.21875.

ASPINALL, P.; Mavros, P.; Coyne, R.; Roe, J. The urban brain: Analysing outdoor physical activity with mobile EEG. Br. J. Sports Med. 2013, 49, 272–276.

BEDIMO-Rung AL, Mowen AJ, Cohen DA. The significance of parks to physical activity and public health: a conceptual model. Am J Prev Med 2005;28:159–68.

BLUMENTHAL, Terry D. The more-or-less interrupting effects of the startle response, 2014, Vol 52.

BRÅ. The Swedish Crime Survey 2014: concerning exposure to crime, insecurity and confidence. Stockholm: The Swedish National Council for Crime Prevention; 2014.

BRUNTON-Smith, I., & Sturgis, P., 2011. Do neighborhoods generate fear of crime? An empirical test using the British Crime Survey. Criminol, 49(2), 331–369.

BURGESS J. Focusing on fear 1996: the use of focus groups in a project for the Community Forest Unit, Countryside Commission. Area;28:130–6.

BYRNE, B. (2016). Structural equation modeling with AMOS. New York, NY: Routledge.

CHUN-Yen Chang, William E. Hammitt, Ping-Kun Chen, Lisa Machnik, Wei-Chia Su, Psychophysiological responses and restorative values of natural environments in Taiwan, Landscape and Urban Planning, Volume 85, Issue 2, 2008, Pages 79-84,

DELONE, G. J., 2008. Public housing and the fear of crime. Journal of Criminal Justice, 36(2), 115–125.

EDELSTEIN, E.A., Macagno, E. Form Follows Function: Bridging Neuroscience and Architecture. In: Rassia., S.T., Pardalos, P.M. (eds) Sustainable Environmental Design in Architecture. Springer Optimization and Its Applications, 2012, Vol 56. Springer, New York, NY.

EMEL Birer, Pınar Çalışır Adem, 2022. Role of public space design on the perception of historical environment: A pilot study in Amasya, Frontiers of Architectural Research, Volume 11, Issue 1,

EMOTIV, 2011. Emotiv software development kit user manual for release 1.0.0.3. Hong Kong: Emotiv Ltd.

FATTAH, E. A., & Sacco, V. F. (1989). Crime and victimization of the elderly. Springer. https://doi.org/10. 1007/978-1-4613-8888

FORNELL, C., & Larcker, D. F. Evaluating structural equation models with unobservable variables and measurement error. Journal of Marketing Research, 1981, 18(1), 39–50.
GLASER M. Security v. park and recreation service delivery: reduced effectiveness of public investment. J Urban Affairs 1994;16(4):359–69.
HAIR, J. F., & Lukas, B. Marketing research, 2014 (vol. 2). McGraw-Hill Education
HAIR, J. F., Hult, G. T., Ringle, C. M., & Sarstedt, M. A Primer on Partial Least Squares Structural Equation Modeling (PLS-SEM) (2nd Ed.). Los Angeles, CA: SAGE, 2017.
HARKOT, M.K., Andrade, M.H., Giannotti, M., Santoro, P. Gender and walking: does the quality of built environment equally promote walking for women and men? In Cidades de Pedestres: a Caminhabilidade no Brasil e no mundo (C. C. Linke, V. Andrade, eds.). Babilonia Cultura Editorial. Rio de Janeiro, Brazil, 2017
HATTACHARYYA, Rituparna. Street Violence against Women in India: Mapping Prevention Strategies. Asian Social Work and Policy Review, 2016. 10. 10.1111/aswp.12099.
JACOBS J. The Death and Life of Great American Cities. New York, NY: Random House; 1961.
JAGORI. Understanding Women's Safety: Toward a Gender Inclusive City; Research Findings, Delhi,2009-10. Delhi, 2010. http://jagori.org/wp-content/uploads/2010/11/gic-delhi-report.pdf
JAGORI. Safe Cities Free of Violence Against Women and Girls Initiative: Report of the Baseline Survey, Delhi, 2011.
JANSSON M, Fors H, Lindgren T, Wiström B. Perceived personal safety in relation to urban woodland vegetation: a review. Urban Urban Greening 2013 ;12:127–33.
JUAN Luis Higuera-Trujillo, Carmen Llinares. The Cognitive-Emotional Design and Study of Architectural Space: A Scoping Review of Neuroarchitecture and Its Precursor Approaches, 2021, Vol 21, Issue 6
KRENICHYN K. Women and physical activity in an urban park: enrichment and support through an ethic of care. J Environ Psychol 2004; 24:117–30
LYNCH, K. The Image of the City. Cambridge, MIT Press, 1960.
MADGE C. Public parks and the geography of fear. Tijdschrift voor Economische en Sociale Geografie; 1997, 88(3):237–50.
MARUTHAVEERAN S, van den bosch CC. A socio-ecological exploration of fear of crime in urban green spaces: a systematic review. Urban Forestry Urban Greening 2014; 13:1–18.
MASLOW A. H. A Theory of Human Motivation, 1943.
MESCH GS. Perceptions of risk, lifestyle activities, and fear of crime. Deviant Behav 2000; 21:47–62
MIETHE T. Fear and withdrawal from urban life. Ann Am Acad Political Soc Sci 1995;539(1):14–27.
OLDER People's Experiences of Mobility and Mood in an Urban Environment: A Mixed Methods Approach Using Electroencephalography (EEG) and Interviews. Int. J. Environ. Res. Public Health 2017, 14(2), 151
PALLASMAA, Juhani.& Mallgrave Harry. and Arbib, Michael. Architecture and Neuroscience. Finland: Tapio Wirkkala-Rut Bryk Foundation, 2015.
PIZZO, F., Roehri, N., Medina Villalon, S., Trébuchon, A., Chen, S., Lagarde, S., Carron, R., Gavaret, M., Giusiano, B., McGonigal, A., Bartolomei, F., Badier, J. M., & Bénar, C. G. 2019. Deep brain activities can be detected with magnetoencephalography. Nature Communications, 10(1).
RANGAJEEWA Ratnayake. Sense of safety in public spaces: university student safety experiences in an Australian regional city, Rural Society, 2017, 26:1, 69-84.
RASHID, Suhaila & Wahab, Mohammad Hussaini & Wan Mohd Rani, Wan. Street design and women's safety perception. Journal of the Malaysian Institute of Planners. 15. 10.21837/pmjournal, 2017, v15.i4.313.
RINGLE, C. M., & Sarstedt, M. Gain more insight from your PLS-SEM results: The importance-performance map analysis. Industrial management & data systems, 2016.
RUITER R, Abraham C, Kok G. Scary warnings and rational precautions: a review of the psychology of fear appeals. Psychol Health 2001;16:613–30.
SEOUL Foundation of Women and Family, Seoul Metropolitan Government. Women-Friendly Seoul Project Facilities Guidelines I. Seoul, 2009.
ULRICH, R.S. Natural Versus Urban Scenes: Some Psychophysiological Effects. Environ. Behav. 1981, 13, 523–556.
UN-HABITAT. Gender Equality for Smarter Cities: Challenges and Progress, 2009. http://www.unhabitat.org/pmss/listItemDetails.aspx?publicationID=2887
UN-HABITAT. Women's Safety Audits: What Works and Where? 2009 . http://www.unhabitat.org/pmss/listItemDetails.aspx?publicationID=2847
VAN DER GIESSEN, M., Brein, E. and Jacobs, G. Community policing: The relevance of social contexts. Community Policing-A European Perspective: Strategies, Best Practices and Guidelines, 2017, pp.35-50.
WOMEN'S Initiatives for Safer Environments. Women's Community Safety Audit Guide. Ottawa, 2005. http://www.femmesetvilles.org/pdf-general/WISE_new%20safety%20 audit%20guide.pdf
WOOLLEY H, Amin N. Pakistani teenagers' use of public open space in Sheffield. Managing Leisure 1999; 4:156–67.