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COGNITIVE MAP EFFECT ON EVALUATING OUTDOOR THERMAL COMFORT IN OPEN SPACES FOR HOT ARID CLIMATE

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Abstract- The investigation for human cognitive mapping and its implications regarding thermal comfort in hot and arid climates, emphasis is placed on outdoor conditions largely unexplored. Consequently, this study evaluates the role of cognitive mapping for open spaces in hot dry climate on thermal comfort. An analysis for selected case studies in the city of Baghdad were done using ArcGis pro map. A questionnaire was conducted encompassing key indicators related to the evaluation of human perception of outdoor thermal comfort, and analysis it with statistical software (SPSS). The results include frequencies, mean, minimum, maximum and linear regression for the main indicators of the research. The research found that the cognitive maps and spatial cues that include places, activities and urban land uses had a major effect on individual sensation of thermal comfort. Also, there was a relationship between cognitive maps and psychological adaptation for the open spaces' users. The research conducted that there is a necessity of adopting cognitive maps strategies for developing thermal comfort in urban open spaces.

Keywords: Cognitive Maps, Thermal Comfort, Psychological Adaptation, Spatial Cues.

1. INTRODUCTION

Public spaces are playing a crucial role in enhancing the quality of life and promoting the social, economic and environmental value of cities. Current scholarly investigations have been directed towards the evaluation of thermal comfort with a focus on its physical dimensions [1-3]. Many studies had related the thermal comfort to the physiological state of the body [4]. However, thermal comfort is not related with physical aspect (metrological factors) only, but individual clothing and the physical activities are also factors that affect human thermal comfort (physiological aspect) [5].

The acceptance or avoidance of urban places is affected by microclimate [6]. Had demonstrated that merely 50% of the assessment of thermal comfort is subject to the influence of microclimate parameters, underscoring the significant role of psychological adaptation in the assessment of thermal comfort. The psychological aspect serves as a subjective representation of thermal comfort that profoundly impacts individual thermal comfort experiences [7]. Individuals perceive themselves as comfortable despite reporting a sensation of warmth, as indicated by a thermal sensation rating of +3 on the ASHRAE scale [8]. Other had studied the psychological variables that influence human thermal comfort [9-12]. Numerous studies have investigated the relationship between the evaluation of thermal comfort and cultural as well as personal backgrounds [13], [14]. Other study had proved that psychological thermal comfort influenced by perception [12]. Perception entails a sequence of internal cognitive processes intertwined with transformations occurring in response to information pertaining to an event. This cognitive process is influenced by various factors including but not limited to experience, prejudice, decision-making, and choices [15]. These variables serve as stimuli guided by schemata. Schema refers to an internal information structure that receives specific information and compels it to generate or enhance additional information through the cognitive cycle. The existing information starts a schema [15]. The cognitive map is consisting of a set of schemata [12]. Cognitive map is a process consisted of a series of psychological transformations through which the individual acquires information about the locations and characteristics of phenomena in his daily spatial environment, stores it, retrieves it and decodes it [16, p. 7]. At this point, the cognitive map is then a relationship between the perception of place (spatial) and perception of environment (environmental) [17, p. 246].

The spatial behavior of an individual depends on the cognitive map of the spatial environment [18]. The individual response depends on the schemata more than the real situation [12]. Found that the individuals in outdoor spaces may neglect the thermal discomfort while walking [19]. In the extreme conditions, negative bias will occur in the thermal cognitive map, that lead to avoid the extreme environment even if the climatic conditions were got better [10]. Shows that there are several factors in the environment influence human behavior, these are formation, spatial, aesthetic and functional factors in outdoor spaces, but climatic factors had the most influence on individual behavior and attitude towards environment in hot and dry climates areas [19].

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2. THERMAL EXPERIENCE PERCEPTION

Psychological adaptation shows the deference between subjective and objective evaluation of thermal comfort [6], [9], [11]. Psychological adaptation consists of many factors, one of them is experience, which is not contributing in predicting of outdoor thermal comfort only, but it predicts the overall evaluation of environment. Long term and short-term experience are related with memory [14]. The modern cognitive psychology suggests when learning, remembering, thinking, imagining or concluding, a series of information processing occurs by stimulus (sight, hearing, smell, taste and touch) to the conscious experience of that stimulus. This series involves range of structures (the sensory system, the central nervous system and the brain). Experience shows a description of thermal perception at a specified moment and location, that is represent the present [20]. Long term memory represents the past which gives the understanding to the world, because it stores all the experiences and knowledge. [10] introduced an interpretation showing that the thermal perception for long time ranges through perception schema, where this schema is created by the repetition of the same stimuli for a long-time range, or a bias could be happened in this schema by a specific event, which leads to engrain this schema in the memory of individuals.

2.1. Perception, Evaluation and Preference

The objective methods described the outdoor thermal comfort were not sufficient, especially there is a difference between objective and subjective measurements in assessing outdoor thermal comfort. Assessment of outdoor thermal comfort through subjective means relay on 3 variables by which the individual describes his thermal comfort state [21]. This encompasses (perceptions) of outdoor thermal comfort, (evaluation) of outdoor thermal conditions, and individual (preferences) where individual had found the comfort state with. Factors influencing the perception of outdoor thermal comfort include physical factors like (air temperature, humidity, wind speed and radiant temperature), physiological factors like (age, gender and clothes) and psychological factors like the mood of the individual. The next step in assessing outdoor settings of thermal comfort is the evaluation, where individuals thermal comfort influenced by their feelings. The evaluation is affected by the previous thermal cultural and social experience [13]. Also, thermal comfort parameters exert a significant influence on the assessment of preference, which could be different among individuals and even among cultures [22].

2.2. Behavior and Psychological Adaptation

The psychological disposition toward outdoor thermal comfort among individuals is influenced by their thermal history and perceived thermal memory [23]. Had found many psychological factors affect evaluation of thermal comfort outdoors [6]. These factors are (naturalness, past experience, perceived control, time of exposure, environmental stimulation and expectation) as shown in Figure 1. These psychological factors influence the users of outdoor space to many of behavioral attitudes.

Like choosing a specific sort of food, dressing seasonal clothes, the selection of specific activities, to ensure the balance with the outer environment requirements. Human behavior influenced by adaptation [23]. Behavior can be examined visually, called open behavior, or visual examination is not applicable, as with attitudes, tendencies, and preferences. The key factor of such behavior is psychological adaptation, which is formulated by the repeated exposure to an environmental stimulus [6].

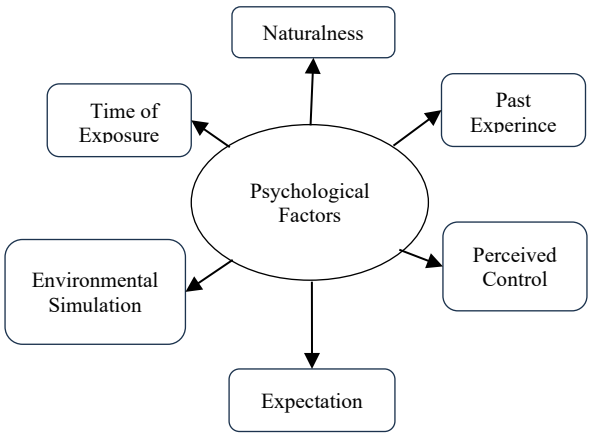

Figure 1. Psychological Factors Influencing assessment of outdoor thermal comfortClick or tap here to enter text.

2.3. Cognitive Map and Thermal Comfort

Cognitive map is a method used to collect information of perceived thermal comfort in outdoor space from individual. That used for linking perceived climatic elements and perceived spatial elements [12]. The cognition of the space (cognitive map) is important for decision making and behavior in the space, through the cognition of individual behavioral output, attitude, preference and evaluation of thermal environment. The cognitive map is the basic for implementing decision and implementing the strategy of spatial behavior, where cognitive map is a primary factor of adaptation in environmental factors [24].

Cognitive map is a primary method for the cognition of individual psychological evaluation of thermal comfort in the environment. Cognitive maps are associated with spatial cues and spatial perception. They represent a suitable method for developing a model that links spaces with Thermal surroundings and understanding influencing of outdoor settings on people's psychological thermal comfort within environmental conditions. This study had reached to a procedural definition of the concept of thermal cognitive maps, they are a set of psychological transformations through which an individual engages in the acquisition, encoding, storage, and retrieval of information about thermal comfort within the outdoor spatial environment. The individual represents this information into structures, relationships, and diagrams between spaces, reconstructing these spaces in the human mind.

3. RESEARCH METHODOLOGY

In this paper the relationship between cognitive maps and thermal comfort in open spaces had studied. The research conducted a questionnaire in two selected case studies in the city of Baghdad. The questionnaire was created based on ISO 10551 (2019E) and the theoretical study of the research. It consists of set of entries as follows: biographic questions, perceptual questions, evaluation questions and preferential questions. The first set is about personal data such as (age, gender, clothes, the time spent outside and the duration of experience). The second set is about the perception of spatial, thermal environment and thermal comfort. The third set is about the evaluation of the existence thermal conditions, and the last set is about the preference thermal and spatial conditions. Interviews were conducted with outdoor users to fill out the questionnaire because it couldn't be filled online, and instant answers are required.

In this context, this study has assessed outdoor thermal comfort through the behavior of the individuals and the perceived thermal comfort of the environment in outdoor places, then after the study has introduced a framework for assessing the behavior and psychological adaptation of outdoor thermal comfort Figure 2.

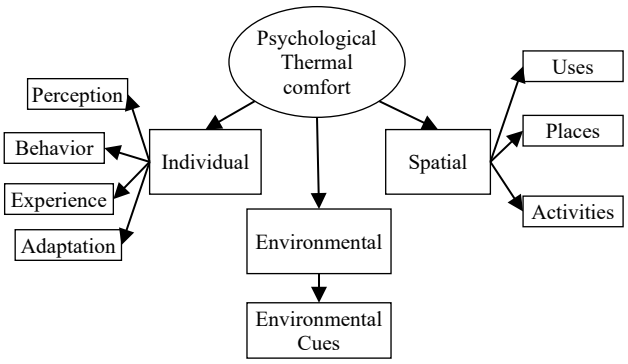

Figure 2. Conceptual Frame Work

This research had addressed the research problem: that how does cognitive map assessing comfort levels within the environment's thermal conditions at open spaces? And how do individuals perceive thermal comfort?

This relationship will be studied according to the main assumption that cognitive maps developed by individual of the open spaces, influence the outdoor thermal comfort.

3.1. Research Objectives

The central focus of this paper is to investigate the relationship between and environmental perception. The second objective is to examine how the spatial cues (places, activities, urban and uses) influence individual thermal perception, this study has hypothesized that thermal cognitive map influence thermal comfort outdoors. Therefor in accordance with the objectives outlined in this paper, a qualitative study required to assess outdoor thermal comfort based on individual opinions. This research will address the testing of the selected case study by adopting statistical method, to reveal the impact of thermal cognitive maps on thermal comfort of outdoor spaces Figure 3.

Tow case studies were selected according to the following factors:

I) Places of recreational

II) Public spaces with physical elements (squares, plazas, streets and parks).

III) Public spaces with a mental images' memory of the users, reflecting the moral value of the place.

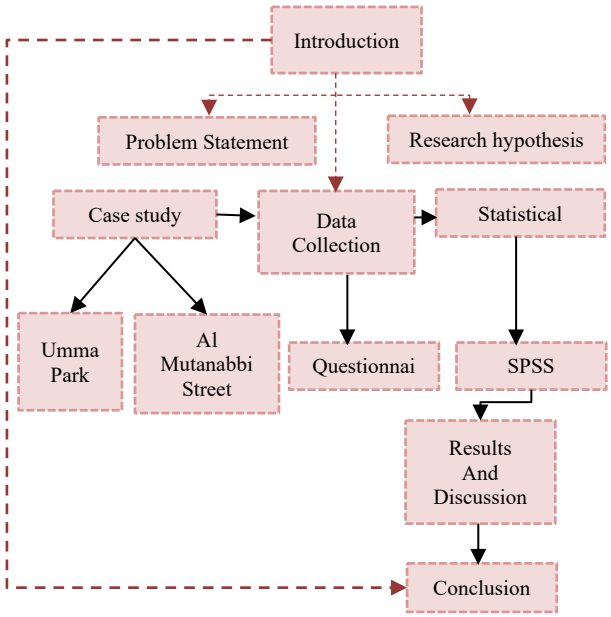

Figure 3. Methods and Research Design

3.2.1. Umma Park

Umma Park and Tahreer square are one of the main parks in the middle of Baghdad, the capital of Iraq. It is located in Bab Al-Sharqi in the Russafa district. It had a crucial role in some main revolutions in Baghdad. There are many of buildings and national symbols enclose the park, which are consisting of variety of uses, like educational, cultural, commercial and public buildings [25]. At some spots there are a residential activity at the top stories behind the main streets. A great statue is located on the left side of the park, called freedom statue, which is designed and constructed by Jawad Saleem. The main buildings are the school of Aqeeda and Dijlah, the building of Turkish restaurant and Marjan building at the left. On the south of the park many libraries like Al-Nahdha library are located. At the north, the national museum of modern art is located, and at the right is the location of Tayaran square. The park is enclosed by temporary slums markets making noise and visual pollution Figure 5.

3.2.2. Al Mutanabbi Street

It is one of the famous Baghdad streets and located in old Russafa district. It is facing to the Tigris River bank, at the south of the street, a statue of Al Mutanabbi who is a poet of Abbasid era, The Qushla building built by Ottomans era. At the right there is Al-Sarray market. And at the north, Al-Rasheed Street is located in Jadeed Ali Pasha neighborhood in the historic Russafa. It is erected

by the Abbasid, they called it darb Zkha, it was consisting of educational institutions and schools.

Its name was changing through eras, till it was named Al Mutanabbi street in 1932 in the period of King Faisal I in the honoring the poet Al Mutanabbi [26]. The street nowadays considers as the main cultural place in Baghdad because it has a variety of buildings and activities of cultural uses. The uses of enclosed buildings and spaces consisting of cultural, commercial, historical and public buildings. It has the oldest and largest market for selling books and it has many of traditional coffee shops. Recently, the street has been the most cultural and entertainment center in Baghdad. This is including many artistic, cultural and festival activities Figure 4.

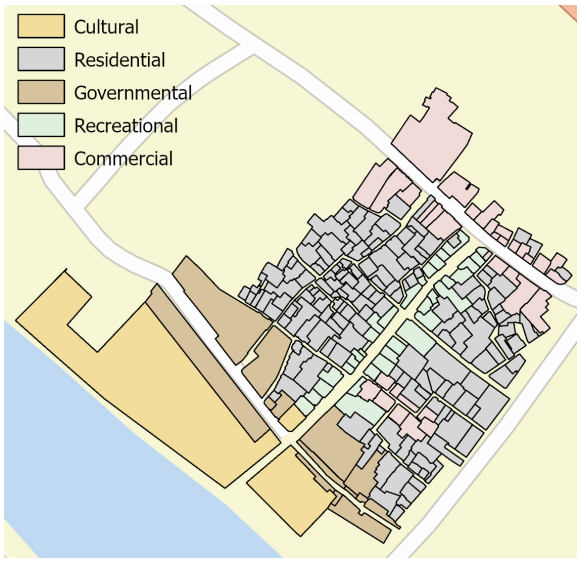

Figure 4. Case Study Selection Al Mutanabbi Street

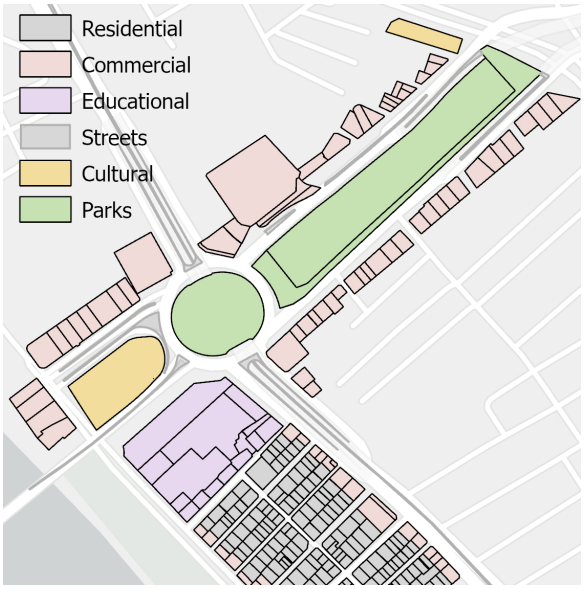

Figure 5. Case Study Selection Umma Park

3.3. Data Collection

The study applied the research approaches that require collecting data and analyzing it, in order to achieve the study aims Table 1. The study has applied the following steps:

i) Layout the study area maps, including buildings, spaces, uses, urban morphology and streets. It was done with ArcGis pro and Autocad software.

ii) Conducting interviews for the selected study cases.

iii) The questionnaire answers were entered and analyzed using statistical software (SPSS) for obtaining the results.

iv) Analyzing the questionnaire results to check the validity of the research assumption.

Table 1. Table of Variables

Dependent Variables	Sub Variables	Indicators	Source of Data
Psychological Thermal Perception	Individual	Thermal Evaluation	Questionnaire (Subjective)
	Behavior	Phycological Adaptation	
	Experience	Duration of Experience	
	Evaluation and Preference	Perception of Thermal Comfort and Thermal Preference	
Outcomes			
Thermal Cognitive Map			

4. RESULTS AND DISCUSSIONS

In the context of studying and assessing the variables outlined in Table 1, a questionnaire was administered in the study areas on 21st of September 2023 at 01:00 pm., for each of the selected places. The characteristics of the climate on this period seems to be hot and dry with 41° air temperature and 16% relative humidity at Umma Park, while 40° air temperature and 24% relative humidity in Al Mutanabbi street. 42 Individual had interviewed in total, 21 users were interviewed in Al Mutanabbi street, and 21 users were interviewed in Umma Park, the interviewee were asked in Arabic language. The findings from the interviews shed light on the complex interplay between environmental factors and human experiences of thermal comfort. Despite the similar climatic conditions, distinct comfort perceptions and behaviors were observed between the two study areas. These variations underscore the importance of considering contextual factors, such as surrounding activities and design features, in shaping individuals' comfort experiences.

4.1. Data Analysis

The study has used IBM SPSS 26 software for data analysis, by using descriptive statistics (including frequencies, mean, minimum, maximum and linear regression) and graphs statistics (including bar and histograms). The results of biographic questions can be summarized as illustrated in Tables 2, 6 and Figures 6, 7.

4.2. Perception of the Place and Perception of Thermal Sensation

The results show how the people perceive the spaces and activities and how do they behave, in Umma Park the largest number of individuals noticed to be moving more than be sitting and the most reasons for coming here is because of work. People are visiting the park in same periods of different time's classification. The most individuals are not agreed with the uses of the spaces enclosing the park, because of the slums markets causing noise and uncomfortable feelings, one another reason for

achieving this is because the location of the park whose access is intersecting with cars streets.

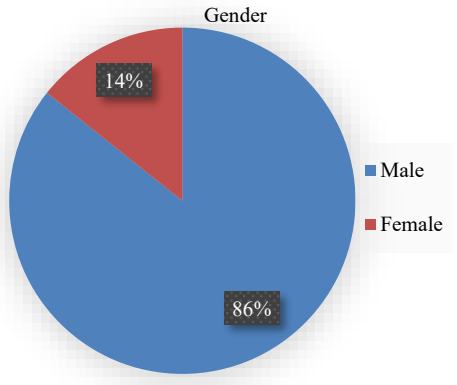

Figure 6. Gender answers of Umma Park

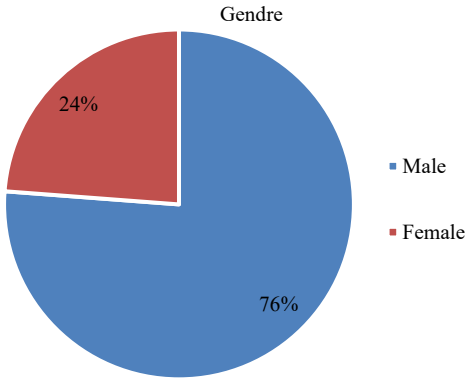

Figure 7. Gender answers of Al Mutanabbi street

Table 2. Summary of outdoor respondents of Umma Park

Number of samples		21
Gender	Male	18
	Female	3
Age	Mean	33
	Minimum	19
	Maximum	60
Experience of visiting the park	Every day	29%
	Every week	29%
	Every month	29%
	Every year	13%

The study used regression analysis and ANOVA for understanding the distribution of the uses of the spaces and activities enclosing the park and the instant feelings of thermal comfort. The study incorporated linear regression analysis in SPSS for finding out a statistical model that predicts variability in the dependent parameter (instant feeling of thermal comfort). In the output of the linear regression analysis, there are three important tables are produced; these are model summary, ANOVA and coefficient. The study explained each of the tables as below:

The model summary (Table 3) shows many elements, R-value represents there is a correlation between dependent and independent variables values, that is greater than 0.4 is taken for further analysis. In this case study, the value is 0.499. *R* square shows for what extent the independent variables influence the dependent variables. It is 0.24, that means 24% of the uses and activities of the park influence thermal comfort. The std. error of estimate (0.76) gives borders of this prediction.

Table 3. Model Summary of thermal comfort feelings

Model	*R*	*R* Square	Std. Error of the Estimate
1	0.499[a]	0.249	0.769
a. Predictors: (Constant), Do you think that the type of uses and functions of the buildings and squares in this place are appropriate for the location?			
b. Dependent Variable: How do you feel at this particular moment?			

ANOVA (Table 4) determines whether the model is significant enough to determine the outcomes. The elements of this table are sig which is the significance level that is chosen for the study. The values should be less than 0.05, in this case study the value is 0.021<0.05. The *F* ratio represents the improvement prediction. If the inaccuracy presented in the model is considered $F(1.19)=6.308$. A value greater than 1 represents efficient model.

Table 4. ANOVA of thermal comfort feelings

Model		Sum of Squares	*df*	*F*	*Sig.*
1	Regression	3.727	1	6.308	0.021[b]
	Residual	11.226	19		
	Total	14.952	20		
a. Dependent Variable: How do you feel at this particular moment?					
b. Predictors: (Constant), Do you think that the type of uses and functions of the buildings and squares in this place are appropriate for the location?					

Coefficient table is used to determine how each variable is contributing to the model. There is only one value is important in this table which is the sig. if *Sig.*<0.005 then, there is an impact of the variable on the outcome. *Sig*=0.021<0.05, that's mean the uses and activities of the enclosing buildings and spaces of the park are influencing the thermal comfort in the park with 1% increase of the satisfying of the uses and activities lead to increasing of thermal comfort of 0.265%.

Table 5. Coefficient of thermal comfort feelings

Model	*Sig.*	VIF
1	0.000	
	0.021	0.265
a. Dependent Variable: How do you feel at this particular moment?		

Figure 8 shows the relationship of independent variable (the uses and activities) and dependent variable (thermal comfort sensation) that reflect the most of the respondents that not satisfied with the uses and activities of the park are feeling uncomfortable. The descriptive results of thermal comfort sensation have been as follow, most of the responses felt under or at neutral level, 10 of them said that they feel neutral, 6 of them felt slightly thermally uncomfortable and 5 of them were thermally uncomfortable. It is unexpected that one of the respondents said to be slightly satisfied. At this point the results of thermal comfort sensation reflect that most of the respondents were on the neutral and uncomfortable side of the scale Figure 9.

In Al Mutanabbi street, most of the individuals were sitting of 76.19% percents. The most reason for coming

here is for working, walking respectively. The most of people are coming here every day. Most of individuals seem to be happy with the uses of the place.

As it plays a crucial role in attracting people at all times of the day because of the recreational activities and the moral value that is represented and because of the design of the street with appropriate H/W ratio which gives the feeling of enclosing.

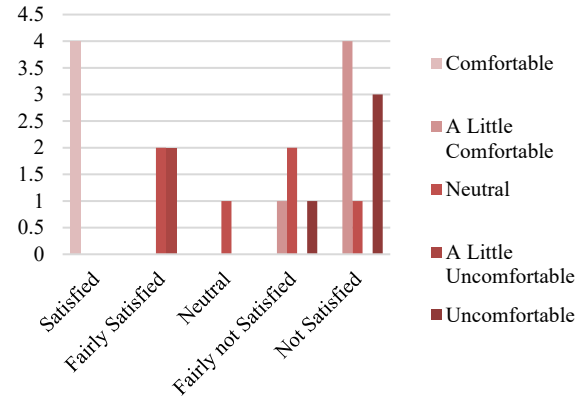

Figure 8. The relationship between thermal comfort sensation and uses and function in Umma Park

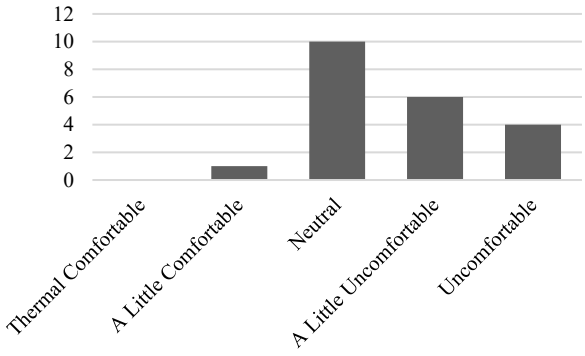

Figure 9. Thermal comfort sensation votes

Table 6. Summary of outdoor respondents of Mutanabbi street

Number of samples		21
Gender	Male	18
	Female	3
Age	Mean	33
	Minimum	19
	Maximum	60
Experience of visiting the park	Every day	29%
	Every week	29%
	Every month	29%
	Every year	13%

Model summary Table 7 shows, *R*-value is 0.559. *R* square is 0.312, that means 31% of the uses and activities of the park influence thermal comfort. The std. error of estimate (1.04) gives borders of this prediction. ANOVA Table 8 shows the sig value is 0.008<0.05. *f* ratio is *F*(1.19)=6.308. A value greater than 1 represents efficient model.

In coefficient Table 9, the *Sig*=0.008<0.05, that's mean the uses and activities of the enclosing buildings and spaces of the street are influencing the thermal comfort in the street with 1% increase of the satisfying of the uses and activities lead to increasing of thermal comfort of 0.493%.

Table 7. Model Summary of thermal comfort feelings

Model	*R*	*R* Square	Std. Error of the Estimate
0.559[a]	0.312	0.276	0.312
a. Predictors: (Constant), Do you think that the type of uses and functions of the buildings and squares in this place are appropriate for the location?			
b. Dependent Variable: How do you feel at this particular moment?			

Table 8. ANOVA of thermal comfort feelings

Model		Sum of Squares	*df*	Mean Square	*F*	*Sig.*
1	Regression	9.359	1	9.359	8.615	.008[b]
	Residual	20.641	19	1.086		
	Total	30.000	20			
a. Dependent Variable: How do you feel at this particular moment?						
b. Predictors: (Constant), Do you think that the type of uses and functions of the buildings and squares in this place are appropriate for the location?						

Table 9. Coefficient of thermal comfort feelings

Model	Sig.	VIF
1	0.000	
	0.008	0.493
a. Dependent Variable: How do you feel at this particular moment?		

The bar chart Figure 10 shows that most of the respondents are feeling satisfied with the uses and activities of the street are feeling thermally comfortable.

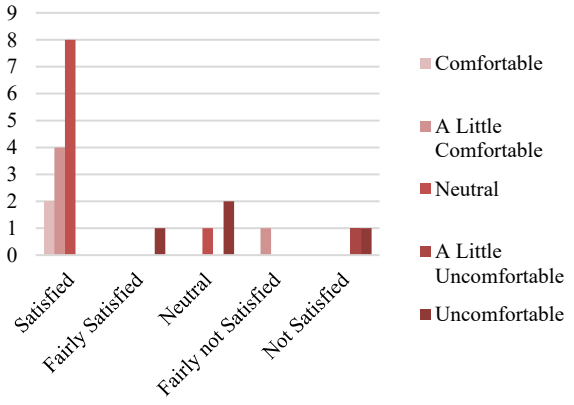

Figure 10. The relationship between thermal comfort sensation and uses and function in Al Mutanabbi street

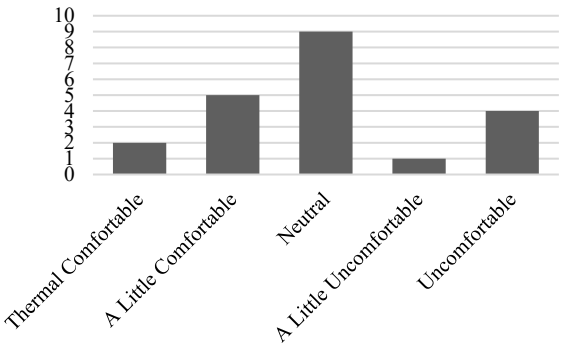

Figure 11. Thermal comfort sensation votes

Thermal comfort sensation chart Figure 11 shows that most of the respondents have felt neutral and above the neutral level towards the comfort zone, 9 of the respondents said they feel neutral, 5 of them said they are a little comfortable and 2 of them said they are thermally comfortable. On the other hand, only one said he has been a little uncomfortable and 4 of them said they are uncomfortable. In conclusion the most of the respondent find it is thermally comfortable in the street of Mutanabbi. At the same time, the users of Umma park said they have been feeling thermally uncomfortable.

4.3. Thermal Perception and Preferences

The descriptive results of thermal perception in Umma park were as follow, when the respondents were asked to answer five point-scale questions of their perception of multi climatic indicators, comprising the air temperature, the wind speed, the humidity and solar radiation. The analysis reveals most of the respondent fined it a little high air temperature. Most of the respondent found the humidity as neutral. The wind speed results perceived to be neutral to a little humid, and finally the most respondents voted to the solar radiation as sunny.

When most of the respondents voted negatively to the thermal perception questions, they were asked to answer to their preferences questions, and the results were as follow, most of the respondents preferred the air temperature to be neutral and a little cooler, and they preferred the humidity to be neutral, wind speed was on the fast scale side where most of the respondents preferred it to be a little fast to neutral. For the solar radiation, the users of the street responded for many scale selections. 7 of them voted to neutral situation, 5 of them preferred it to be slightly shaded, and 6 of them wanted it to be shaded, while 3 of them preferred to be slightly sunny.

The study found that most of the users of Umma park and Mutanabbi street suggested that increasing green and shaded areas respectively, that is mean the users of Mutanabbi street are tolerating the exposure of hot environment and asked to increase green and shaded areas. In contrast with the users of Umma park who had voted for thermally uncomfortable. The study found that most of the users of Umma park are wearing hats to cope with the hot environment as one of the physical and psychological adaptation methods, which reflects the uncomfortable thermal situation, in contrast with the respondent of Mutanabbi street who's the most of them were not wearing any accessories but many of them were wearing hats and sunglasses, respectively.

5. CONCLUSION

Thermal comfort is a complex and multidisciplinary issue, its evaluation according to physical parameters may not clear the whole picture; the psychological parameters had an effect on evaluating comfort levels. The investigation reveals that individuals may exhibit a willingness to tolerate discomfort in certain outdoor environments, suggesting the presence of motivational drivers beyond conventional comfort standards.

The analysis underscores the pivotal role of cognitive maps in shaping individual decisions and behaviors concerning thermal comfort. These mental representations intricately connect spatial cues with environmental stimuli, serving as the foundation for decision-making processes and behavioral responses. Spatial cues consist of many aspects that emerge as critical determinants influencing thermal comfort evaluations through the lens of cognitive mapping; these aspects are places, activities and urban land uses. The research found that people response to environmental physical stimulus should not relate directly to that stimulus, but depends on the mental information that people store in their memory.

Cognitive maps and spatial factors were the most indicators that effect individual thermal evaluation in outdoor places; psychological factors affect the thermal perception of the open space and the evaluation of thermal comfort. Moreover, the analysis of thermal perception and preferences sheds light on respondents' perceptions of multi-climatic indicators and their preferences for environmental conditions. While some respondents expressed discomfort with high air temperatures and solar radiation levels, others suggested preferences for cooler temperatures and shaded areas.

Interestingly, users of Umma Park and Al Mutanabbi street exhibited contrasting preferences, with the former expressing discomfort and the latter indicating a tolerance for hot environments while desiring more green and shaded areas. The research also showed that there is a relationship between cognitive maps and psychological adaptation through the apparent responses and reactions of the occupants of open urban space, where individuals employ various physical and psychological adaptation methods to cope with thermal discomfort, such as wearing hats and sunglasses. These behaviors reflect individuals' responses to uncomfortable thermal conditions and highlight the importance of considering both physical and psychological adaptation strategies in enhancing outdoor comfort.

In conclusion, the study contributes to understanding of thermal comfort dynamics in outdoor environments, emphasizing the significance of integrating psychological dimensions into comfort assessment frameworks. By acknowledging the complex interplay between physical and psychological factors, researchers and designers can develop more effective strategies for enhancing comfort and well-being in urban settings.

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