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Adaptive Human Mechanisms of Outdoor Thermal Comfort in Cold Stress

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Abstract
In small cites improving the quality of living environment in outdoor spaces is based on improving the outdoor thermal environment. Guelma is an example of such a city, where the quality of the living environment could be assessed from several views, this study aims to highlight adaptive human mechanisms in outdoor spaces during cold stress, the Garden "Bou El Mokh brothers" was selected to conduct the investigation. Three microclimatic parameters were measured in January 29th , 2019 Temperature, Relative humidity, and Wind Velocity, simultaneously a series of interviews was administrated in the garden carrying out of anthropogenic factors and users behaviors. The scientific methodology of this study consists on coupling measured parameters to interviews to identify the direct impact of microclimatic parameters that cause discomfort (sensation), and to identify how user respond (adaptive mechanisms). The findings of our study were discussed in a way to distinguish the human adaptation in the selected garden between physical and psychological adaptive mechanisms.

Keywords: Adaptive human mechanisms; Thermal Comfort; Cold stress; Outdoor spaces; Guelma.

Highlights:

- Study conducted in a garden located in Guelma city, Algeria during cold stress (January 29th , 2019).
- Three microclimatic parameters were measured, Air temperature, Relative humidity and wind velocity.
- A series of interviews were administrated simultaneously with microclimatic measurements.
- Data processing was carried out by SPSS (Statistical Package for the Social Sciences).
- Thermal sensation was obtained using the five scale (very cold, cold, cool, neutral, and warm).
- Adaptive human mechanisms are almost physical and physiological.

1. Introduction

Outdoor spaces are of prime interest, in term of providing the populations wellbeing. Squares and gardens play an important role to improve citizen's health in both winter and summer (1). Many researchers have addresses studies on the use of outdoor spaces and its impacts on human health in summertime, recently a technical report discussing the heat wave and human health, have been published by United States Agency for International Development (2). Some studies have shed light on the relationship between the thermal environment in outdoor spaces and the human health.For example a study conducted in Germany (3), found that death rates increase with increasing cold stress, thus staying in cold is not just a discomfortable situation, but it is a threat for human health and human life. The use of outdoor spaces is significantly affected by thermal comfort (4). Previous studies have showed that outdoor thermal environment is defined by microclimatic parameters such as air temperature, relative humidity, wind velocity and other parameters (5-7), also it was demonstrated that thermal conditions affect people's use of outdoor spaces (8). Nowadays the study of anthropogenic factors has become the keystone to assess thermal outdoor comfort in urban areas and to consider adaptation in discomfort situations (9,10). The ultimate goal of this study is to draw up a state about adaptive mechanisms in outdoor spaces in cold season, so it examines the relationships between microclimatic parameters and physical activities performed in a garden in the city of Guelma, Algeria.

2. Study site

Our study was conducted in the city of Guelma (36° 27' 43 N ; 7° 25' 33 E ; 840 ft-Elevation) located in north-eastern of Algeria. (Figure. 2; a). The study area is a garden "Garden of the brothers Bou El Mokh" that has an area of 1900 m² surrounded by medium-density urban buildings. It's located in a crowded administrative area of Guelma city, it should be noted that this space is marked by a strong male presence. (Figure. 2; b).

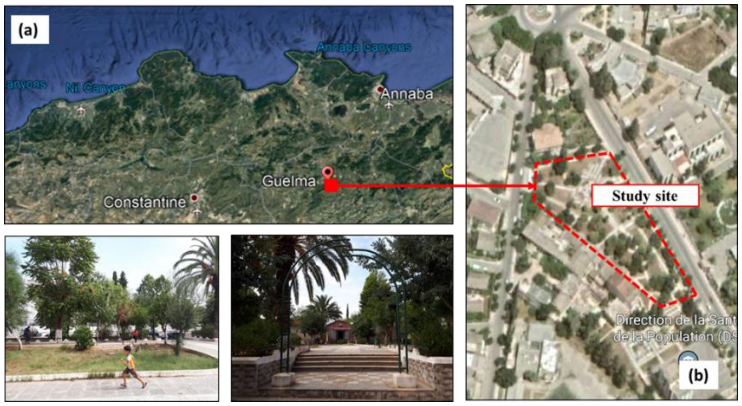


Figure 1. (a) The location of the city of Guelma, (b) study spaces: Google earth (https://www.google.com/earth/).

3. Methods

3.1. Methodology design

The scientific methodology of this study consists on coupling measured parameters to interviews to identify the direct impact of microclimatic parameters that cause discomfort (sensation), and to identify how user respond (adaptive mechanisms).

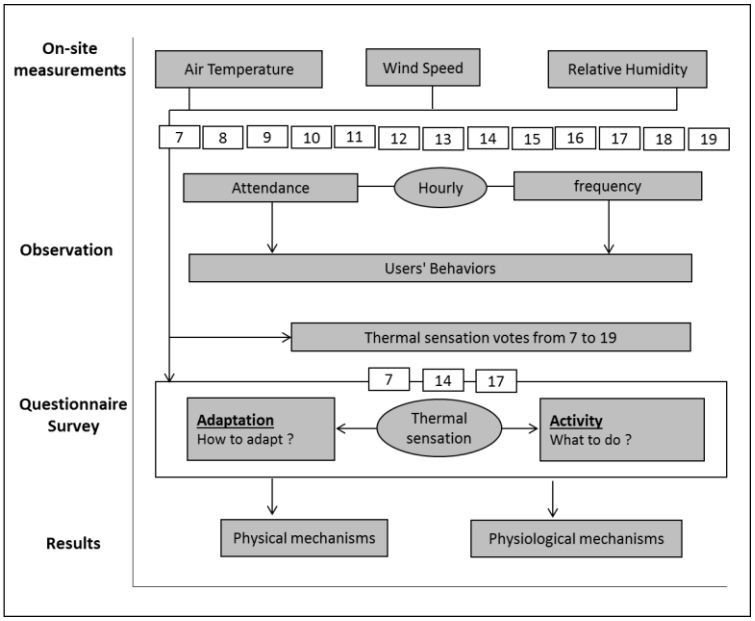


Figure 2. Methodology design.

3.2. On site measurements

The microclimatic measures were collected in the coldest period of the current year (2019), January 29th,2019 was the selected day to conduct the investigation., using a multifunction hand-held device **(Testo 480 – AG 501 1ST, 0563 4800)** we obtained hourly temperature, relative humidity, and wind velocity that have been mentioned in Table 1.

Figure 3. (a) The location of the city of Guelma, (b) Study space: Google earth (https://www.google.com/earth/).

3.3. Survey Questionnaire

A total number of 304 valid interviwes were conducted simultaneously with the on-site measurements during the coldest period of 2019. The questionnaire, firstly have questioned the interviewee profile using direct questions, then multiple choice questions were used to explore the outdoor spaces attendance, likert scale questions were used to evaluate the thermal sensation and the adaptive mechanisms, open-ended questions were used to offer a large feedback on outdoor thermal adaptation. The data was analysed using SPSS (Statistical Package for the Social Sciences).

4. Results and discussion

4.1. Summary of collected data.

Table 1. Summary of collected data, recorded measurements, interviews, and observation.

	Microclimatic parameters			Interviews				Observation
Period	T (C°)	H (%)	W.V (m/s)	**Groups**	Activities	Th.sensation	Adaptation	
07-08	8.1	52.1	1.4	26	Responds activities the moment of the interview: Sitting, standing, walking, running, exercising	Thermal sensation was assessed for the mentioned groups following the scale: very cold ,cold, cool, neutral, warm	The actions of users to improve their thermal sensation in the outdoor space (adaptive mechanisms)	The hourly frequency / the intensity of use each time period .
08-09	8.6	59.9	1.4	19				
09-10	9.1	58.4	1.3	23				
10-11	9.1	55.8	1.1	28				
11-12	10	56.2	1	34				
12-13	9.6	58.2	1.1	21				
13-14	12.1	62.3	0.8	22				
14-15	14.3	44.8	1.7	41				
15-16	13.3	42.6	2.8	39				
16-17	11	62.9	1.2	23				
17-18	10.9	58.9	0.3	13				
18-19	9.1	69	1.8	07				
19-20	10.5	72.5	2.6	07				

4.2. Thermal sensation votes

Users thermal sensation was obtained using the five scale (very cold, cold, cool, neutral, warm). The respondents were asked to express their sensation regarding the overall conditions of the microclimate in the selected garden. Results in **Figure.4** shows the hourly respondents' sensation.

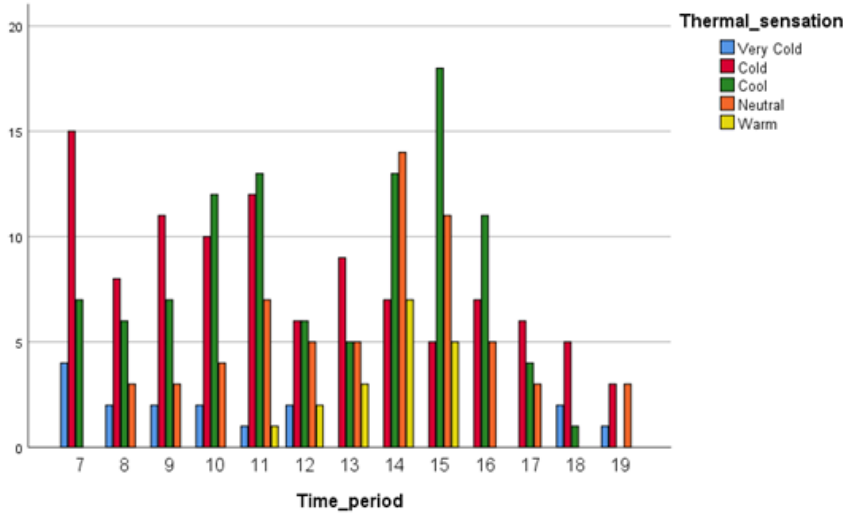


Figure 4. Hourly thermal sensation votes in the Garden for the period time (07-19).

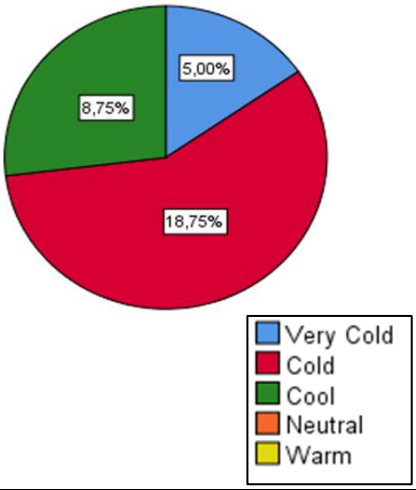
For the morning period (07-11Am) where temperature does not exceed 10°, the majority (41.5%) of votes goes to the cold sensation, according to the respondents the cause is cold winds. For the afternoon period (12-15Pm) where the average temperature was 12.5°, the majority of votes are spilt between the sensation cool (34.1%) and neutral (28.4%), which is justified by the high temperatures compared to the morning period; we note that users' attendance was maximum in this period. In the evening period (16-19 Pm), the cold sensation is predominant (50%). The decrease

of respondents' number in the evening hours leads us to make the relationship between the users' attendance and the hard microclimatic conditions.

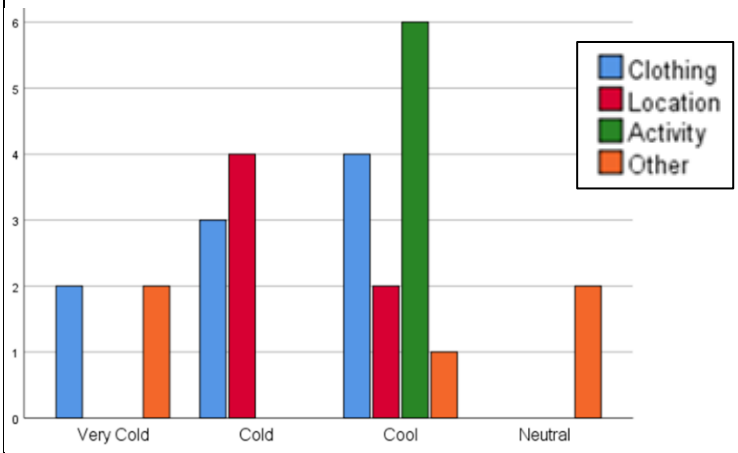
4.3. Adaptive human mechanisms

As the mine objective is to study the anthropogenic factors, a time of one hour was chosen from previous periods to make the correlation between the human sensation, the activity and the adaptation. Respondents were asked regarding their sensation and their activity and observed regarding their location.

Thermal sensation 07-08 Am



Thermal sensation /VS/ Adaptation



Thermal sensation /VS/ Activity

Figure.5 shows the results for the period time 07-08Am, where temperature 8.1°, humidity 52.1%, and wind velocity 1.4m/s.

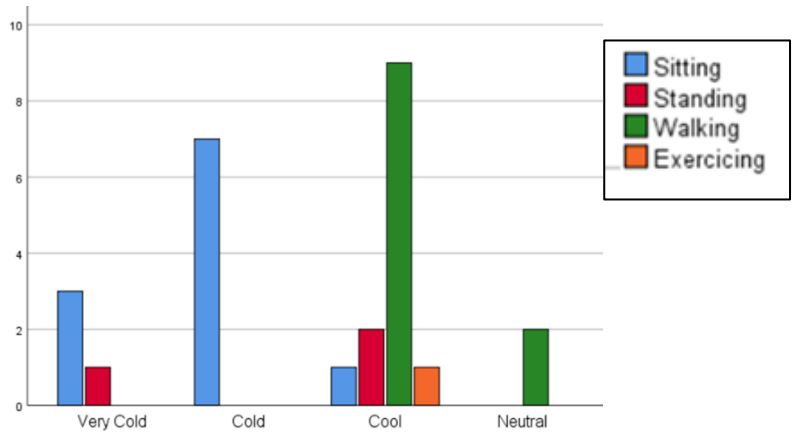


Figure 5. The correlation Thermal sensation/vs/Adaptation and the correlation Thermal sensation/vs/Activity in the garden for the period time (07-08 AM).

-Persons in activity –walk (69.2%) feel cool compared to those sitting (7.7%) and feel cold, persons exposed to sun feel cool (15,4%) in different activities sitting and standing.

-Persons feeling cold in rest or sitting believe that activity and clothing are two factors that can improve the outdoor thermal sensation.

-Most of users think that they can manage discomfort situations regarding to the importance of the garden.

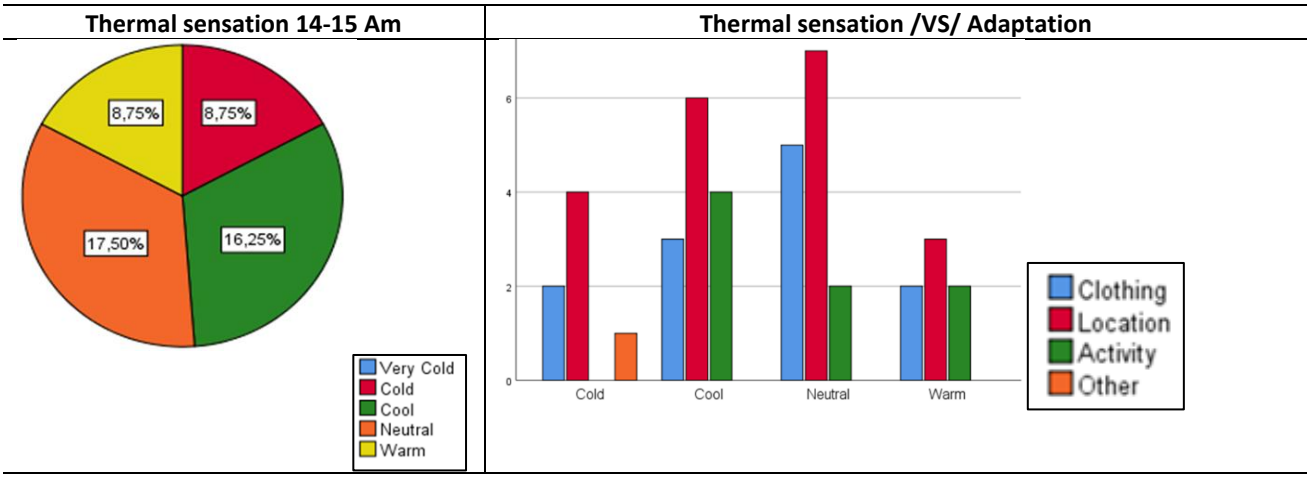


Figure.6 shows the results for the time period 14-15Pm, where temperature 14.3°, humidity 44.8 %, and wind velocity 1.7 m/s.

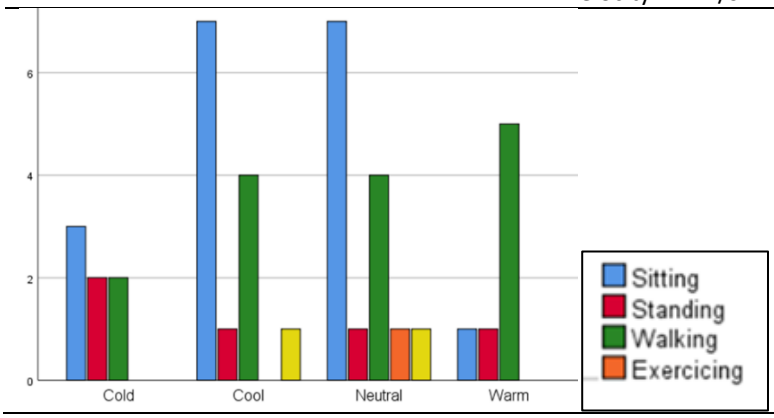


Figure 6. The correlation Thermal sensation/vs/Adaptation and the correlation Thermal sensation/vs/Activity in the garden for the period time (14-15 AM).

-Persons feeling cold with different activities, sitting (42.9%), standing (28.6%) and walking (28.9 %) showed their annoyance about winds, they believe too that they can feel more suitable by changing their location.
-Persons felling cool (46.2%) and neutral (50%) think that their posture and their location behind buildings, under trees and sitting in groups contributes to their comfortable sensation.
-According to users the activity walking (28.6%) and the clothing (28.6%) helped them to feel warm in such period.

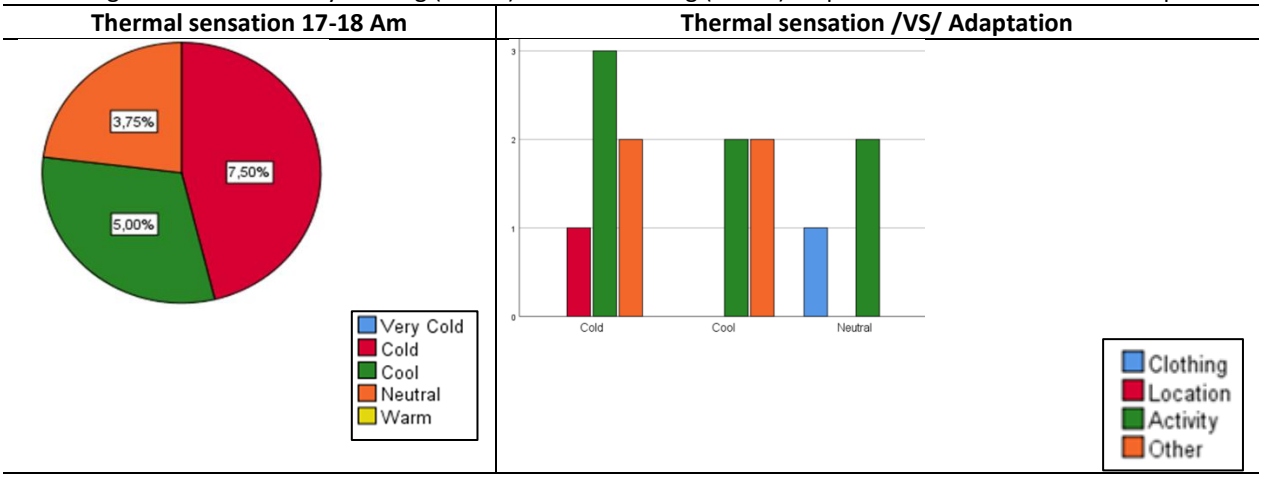


Figure.7 shows the results for the time period 17-18Pm, where temperature 10.9°, humidity 58.9 %, and wind velocity 0.3 m/s.

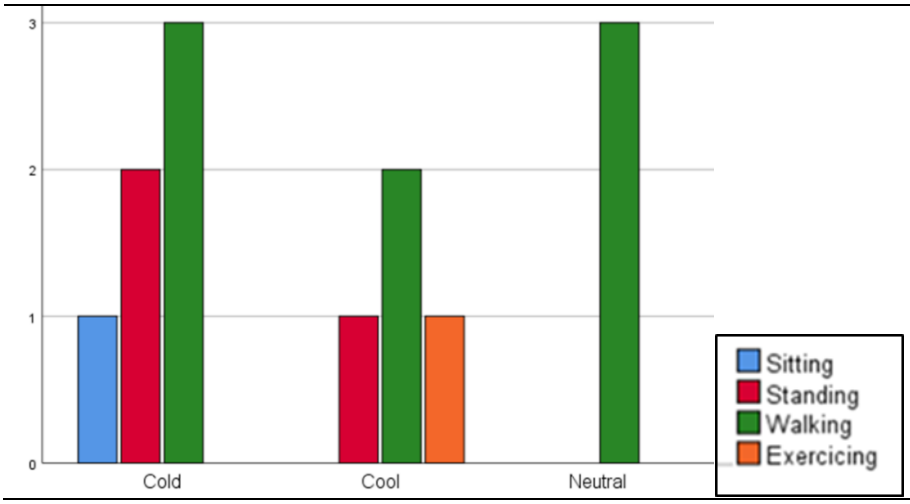


Figure 7. The correlation Thermal sensation/vs/Adaptation and the correlation Thermal sensation/vs/Activity in the garden for the period time (17-18 AM).

-Persons feeling cold with activity standing (33.3%) and walking (50%) said that microclimatic conditions become harder in the evening and go home is the solution to fight cold.

-Persons felling cool (50%) and neutral (66.7%) believe that activity is the significant way to adapt to low temperature.

-Most of respondents (50%) think that eating or drinking something helps to feel good in discomfort situations.

-Persons in activity walking, running, or exercising feel more comfortable than those in rest or setting on bench, also sun exposure and wind protection are important factors that improves thermal sensation.

5. Conclusions

This paper investigated the human adaptation of outdoor thermal comfort, the study of the anthropogenic factors allowed us to draw up a state about how users responds in discomfort situations in the "Garden of the brothers Bou El Mokh". In outdoors spaces, people cannot change their thermal environment, so they ought to adjust their behaviour, according to users behavioural adjustments can be personal, like clothing, eating, drinking, posture, activity and stay in groups …. Etc. it can be environmental by changing its location, move from shady to sunny areas, to protect by staying under a tree or behind a building.Taking into account previous studies we can classify the mentioned adaptive mechanisms into:

- Physical adaptation: all changes made by a user, in order to adjust itself to the outdoor thermal environment, Clothing, Activity, Eat and drink, Location.
- Psychological adaptation: all about how people perceive their thermal environment, how much the outdoor space is interesting for them, staying in groups is one of the common answer to fight cold stress.

In our study the "Garden of the brothers Bou El Mokh" represents a crossroads for high school students and those of the middle school, their answer to the question why do not take another path to get to school, showed the importance of the garden to this category of users.

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