Outdoor Thermal Comfort in the Hot Arid Climate

The effect of socio-economic background and cultural differences

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ABSTRACT: Climate-sensitive open spaces within cities may benefit the three dimensions of sustainability, affecting economical, social and environmental factors. Aiming to improve microclimatic conditions in urban spaces can enable people to spend more time outdoors, with the potential to influence the social cohesion of a space and increase economic activity. The wider aim of this research is to develop better understanding of the complex relation between microclimate and human behaviour in open public spaces in hot arid climates. Case studies were carefully selected in two different parts of the world (Marrakech in North Africa and Phoenix-Arizona in North America) to represent a variety of users in similar climatic context. This enabled us to study the effect of the socio-economic and cultural diversity on thermal comfort, behaviour and use of space. Field surveys included structured interviews with a standard questionnaire and observations of the human activities, along with microclimatic monitoring, carried out during winter and summer 2008 and 2009. The analysis consists of the microclimatic influence on the thermal sensation, preference and people attendance; the effect of psychological adaptation on subjective thermal evaluation of outdoor spaces; and finally, investigation of socio-economic and socio-cultural impact on behaviour of people in outdoor space.
Keywords: Thermal comfort, public spaces, hot arid climate, psychological adaptation, social differences, culture.

INTRODUCTION

Recently, there has been an increased interest in research focusing on thermal comfort in outdoor settings. Most of the work has been carried out in developed counties, where the majority of people spend most their time indoors [1]. Research in this area has been focusing on aspects such as the relations between thermal comfort, microclimate, behaviour and use of place and spatial variation [1, 2, 3, 4]. The psychological variables related to the thermal comfort of users in outdoor places have been the focus of a number of studies [2, 5, 6, 7]. Recently, more research has been dealing with the association between culture and climatic characteristics that influence the use of outdoor spaces [4, 8, 9], but all conducted in temperate or cold climates.

This paper presents the initial results of a study conducted in outdoor spaces in the hot arid climate. The wider aim of this research is to develop better understanding of the complex relation between microclimate and human behaviour in open public spaces in hot arid climates, taking into account socio-economic background and cultural differences. Case studies were carefully selected in two different parts of the world (Marrakech in N. Africa 31°62'N 8°03'W and Phoenix-Arizona in N. America 33°26'N 112°1'W) to represent different cultural backgrounds in a similar climatic context. This enabled us to study the effect of the socio-economic and cultural diversity on thermal comfort, behaviour and use of space. The field surveys were carried out during summer and winter 2008-2009.

METHODOLOGY

Filed surveys were employed, where people could be studied in their "real world settings" in order to include the full complexity of conditions that subjects experience in each case study area. Data collection included environmental and human monitoring.

Environmental Monitoring The environmental monitoring focused on measuring the microclimatic parameters as air temperature, wind speed, solar radiation and relative humidity and their variation, which directly affect human comfort and behaviour in the study areas. A portable set of instruments was used, to enable monitoring of the conditions different subjects were exposed to. The sensors, selected to conform to ISO 7726 [10], were fixed on the top of an adapted case, while the data logger and power supply were located inside it.

Human Monitoring Two approaches were used for the human monitoring. First, the researcher observed people and activities in the case study areas. For that, an observation sheet was prepared for each case study area and filled in every 20 min. Secondly, people participated in the study directly, responding to questionnaires through structured-interviews.

The questionnaire included four parts. The first part investigates the evaluation of different climatic parameters, thermal sensation and preference of subjects. The second part investigates various aspects of physical and psychological adaptation as well as evaluation and use of the space. It also included wider aspects, such as the effect of the climatic context in childhood, recent thermal history, etc. The third part of the questionnaire was designed to evaluate the subject's socio-economic conditions. Three questions about educational level, job type, and financial abilities [11] were used to rank subjects according to their socio-economic background. Observation data such as age, gender, clothing etc. were included in the last part of the questionnaire.

Study areas Five case study sites were carefully selected in two different parts of the world (Marrakech in North Africa and Phoenix-Arizona in North America) to represent the difference in cultural backgrounds in a similar climatic context (Fig. 1).

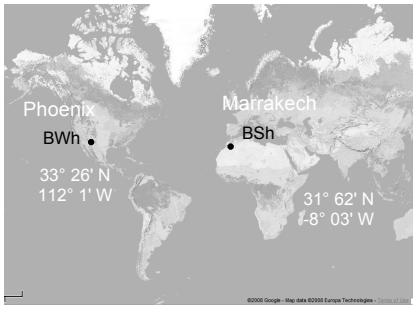
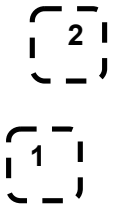


Figure 1: Adapted map showing the location of Marrakech and Phoenix (http://maps.google.com accessed in Jan. 2008).

The two sites in Marrakech, park and plaza (Fig.2a), are located close to the historical Mosque of Al Koutoubia near the centre of the old city of Marrakech. Site (1) Al Koutoubia Garden offers more shaded benches (Fig. 2a), whereas site (2) Al Koutoubia Plaza has very few number most of which are not shaded. People meeting and talking are the most frequent activities for site (1), where in site (2) people gather predominantly to watch other people and chatting. Three sites were selected in Phoenix, site (3) Chaparral Park in Scottsdale (Fig. 2-b), site (4) Tempe Beach Park (Fig. 2-c) and Tempe Marketplace in Tempe (Fig. 2-d). Sites (3) and (4) are parks, suitable for sports and physical exercises as well as recreational activities (e.g. cycling, jogging, skating, picnics, etc). Site (3) offers ample shaded areas and site (4) water-related activities (e.g. fishing, water slides, canoeing, etc.). Site (5), Tempe Marketplace, is a modern outdoor shopping mall, opened in 2007. It was designed to provide visitors with improved microclimatic conditions in the very hot summer. In addition to the compact blocks and narrow paths and spaces (Fig. 2-e), various techniques such as providing extensive shading devices and water sprinklers were used.



a-Site 1 Al Koutoubia Garden, Site 2 Al Koutoubia Plaza

b-Site 3 Chaparral Park

c-Site 4 Tempe Beach Park

d-Site 5 Tempe Marketplace

Figure 2: Case study areas (sites 1, 2, 3 and 4 views were taken from http://maps.google.com accessed in January 2008.

RESULTS

The analysis presented here includes the data collected during summer from both cities, as well as the winter surveys from Marrakech. The analysis for the winter data from Phoenix is not included as the author had just returned from Phoenix, when this paper was written. 429 interviews were carried out, 247 and 182 in winter and summer, respectively. In Marrakech, there were 186 interviews in winter and 117 in the summer, while in Phoenix 65 in the summer and 61 in winter. The reason why the number of interviews is small in Phoenix is due to the small number of people found outdoors.

Microclimatic impact on human behaviour The average microclimatic variables in the surveys are presented in Table 1. It is apparent that air temperature is very high in both cities throughout the year, with a mean summer air temperature of 36-37 ºC in Marrakech and 41 ºC in Phoenix. This is very high and would exclude any outdoor activities in a northern or even temperate climate. The winter mean air temperature is at a more comfortable 17-18 ºC in Phoenix and 23-27 ºC in Marrakech. Relative humidity is low throughout the year for both cities. Solar

radiation is also quite low as the majority of the surveys were in shaded places. Non-parametric test Spearman's rho was used for the correlation analysis.

Solar radiation appears to have the greatest negative influence on both attendance and activities in summer time. The relationship between number of people in the place and solar radiation (S) was found to be negatively and strongly related in site (5), Tempe Marketplace ($r= -0.922$, $p<0.001$). Thus, as the intensity of solar radiation increases the number of people in the place decreases. Negative but medium correlations were found between number of people in the place and solar radiation (S) in sites (1, 2, and 3) Al Koutoubia Garden, Al Koutoubia Plaza and Chaparral Park (-0.685, $p<0.001$; -0.605, $p< 0.001$ and -0.488, $p< 0.001$ respectively).

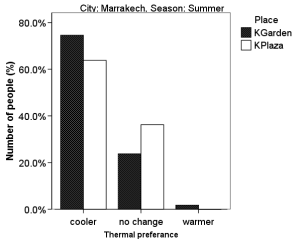
Spaces in these sites are relatively open compared to site (5) Tempe Marketplace. Shaded areas are confined under trees and few sunshades. In addition, these sites (1, 2, and 3), unlike site (5) are not provided with air-conditioned premises such as nearby shops and cafés. Therefore, under these conditions, people may be tolerating the solar radiation more than in site (5), where air-conditioning is an easy option. Site (4) has similar conditions to sites (1, 2, and 3). However, water activities in site (4) attract people throughout the day. This is probably the reason why there is no significant correlation between the number of people and solar radiation in this space.

Similarly, the number of activities in the place was found to be negatively and strongly correlated with solar radiation (S) in site (5), Tempe Marketplace ($r= -0.867$, $p<0.001$). Therefore, as the intensity of solar radiation increases the number of activities decreases. Negative and medium correlations were found between number of people in the place and solar radiation (S) in sites (1, 2, 3, and 4) Al Koutoubia Garden, Al Koutoubia Plaza, Chaparral Park and, Tempe Beach Park (-0.462, $p<0.001$; -0.509, $p< 0.01$; -0.696, $p< 0.001$ and -0.638, $p< 0.005$ respectively).

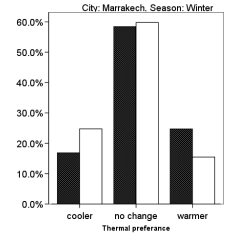
These differences are probably due to the different aspects of design of these places, as well as the types of activity. For example, in site (5) Tempe Marketplace people prefer to sit inside the nearby air-conditioned cafes and restaurants, rather than sitting on the seats provided in the outdoor space during midday and afternoon. People start moving out, using the outdoor public seats in the late afternoon and evening time when the space is almost fully shaded. On the other hand, in site (4) Tempe Beach Park, people tend to stay outdoors, particularly around the water splash area. Although water activities in this site are mainly for children, parents and carers are involved in other activities such as eating and drinking, reading, etc.

Thermal preference of people differs between sites and seasons. In summer, more than 60% of users preferred to be cooler in both cities (Fig. 3a and Fig. 3c). Although the mean air temperature was slightly higher in Phoenix (39-41) ºC compared to Marrakech (36-37) ºC, 15-35% of the people in Phoenix preferred being warmer. In Marrakech, however, less than 3% preferred being warmer in summer. This is explained in the following section.

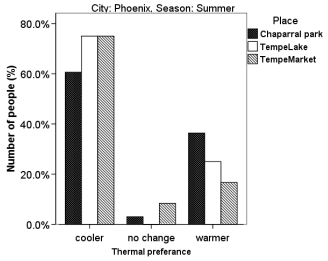
Those who preferred being cooler in Marrakech are mostly in the garden rather than the plaza (Fig. 3a). This might be due to the time of day in which the interviews occurred. That is, people can be found in the garden throughout the day, while people usually come to the plaza in the late afternoon and evenings.



a: Thermal preferences in Marrakech (winter)



b: Thermal preferences in Marrakech (summer)



c: Thermal preferences in Phoenix (summer)

Figure 3: Thermal preferences in the different cities

Impact of psychological adaptation on thermal sensation and behaviour The thermal sensation has been looked at in two different ways, subjective and objective. People were asked to evaluate their thermal sensation at the time of the interview on a five-point scale, varying from hot to cold (Actual Sensation Vote, ASV). This was then compared to the theoretical Predicted Mean Vote (PMV), as defined by ISO 7730 [12], based on the heat balance model and calculated for the conditions recorded during the interview. PMV has been used frequently to underline the effect of adaptation in outdoor settings. However, it is important to highlight that the PMV model was intended for indoor, fully conditioned buildings. Therefore, it is not an appropriate model to be used outdoors. The Percentage frequency distribution for PMV and ASV for Marrakech in winter and summer is shown in Fig. 4, while Fig. 5 is for Phoenix in the summer.

It is clear that there is a great inconsistency between the ASV and PMV curves. Around 55% of the PMV curve in Fig. 5 falls outside the theoretical comfort conditions (-1 to +1), around 35% feel hot and 20% feel cold. However, the ASV curve shows that only 20% fall outside the actual comfort conditions mainly in the hot region (+2). The graph also illustrates that the majority of those that have voted within the actual comfort conditions (-1 to +1), have voted for neutrality or the warm part of the scale (0 and +1). Conversely, the theoretical curve shows that the majority of votes within the predicted comfort conditions (-1 to +1), falls within the cool (-1) part of the scale 25% and neutrality (0) with 15%.

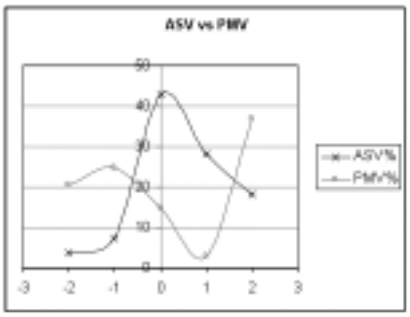


Figure 4: Percentage frequency distribution for Predicted Mean Vote and Actual Sensation Vote for Marrakech in winter and summer 2008

This may suggest that people in Marrakech tolerate hot conditions and vote it as warm (Fig.4). This may be due to their long experience and familiarity with warm and hot conditions. The fact that many interviewees complained about the poor thermal conditions of their house, being vey hot, especially near evening time, suggests that they use the open space as an escape in which they can find cooler conditions.

Table 1: Average microclimatic variables for Marrakech (sites 1, 2) and for Phoenix (sites 3, 4, 5).

			Tg (°C)	Tair (°C)	RH %	Ws m/s	S w/m²
Marrakech	site 1	winter	22	23	32	0.7	258
		summer	36	37	24	1.0	307
	site 2	winter	23	24	26	0.9	263
		summer	35	36	26	1.2	309
Phoenix	site 3	winter	18	18	34	0.6	262
		summer	39	39	24	1.2	381
	site 4	winter	18	17	39	0.7	245
		summer	41	41	23	1.3	229
	site 5	winter	18	18	34	0.6	262
		summer	41	41	27	0.9	536

The PMV curve in Fig. 5 fully falls outside the theoretical comfort conditions (-1 to +1), predicting +2 fr 100% of the people interviewed. However, the ASV curve shows that around 50% fall within the actual comfort conditions, most of them voting for the warm part of the scale (+1), with only just over 10% voting neutral (0). This also suggests that people in Phoenix tolerate what would be extremely hot conditions and vote it as warm, particularly when comparing it with the mean daily temperature of around 40ºC (Table 1). Once again, this is due to their experience and familiarity with hot conditions. Given that air-conditioned interiors are widely spread in Phoenix, and people spend long time in artificially cooled spaces, seeking environmental stimulation [6] could also explain why people in Phoenix may tolerate hot temperatures.

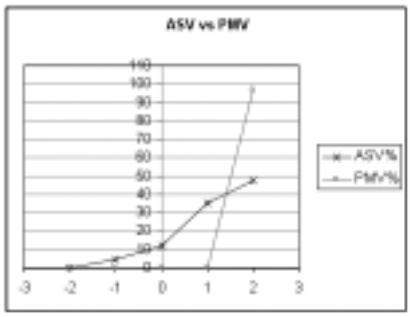


Figure 5: Percentage frequency distribution for Predicted Mean Vote and Actual Sensation Vote, Phoenix summer 2008.

Another interesting comparison is looking at the time people spent in the different areas. It seems that the interviewees who considered the conditions typical for the season tended to spend more time in the space. Those who did not consider the conditions as typical nor had any idea about the climatic conditions of the area, spent less time in it (Fig. 6). This is probably due to the unpleasant thermal conditions which they were not used to.

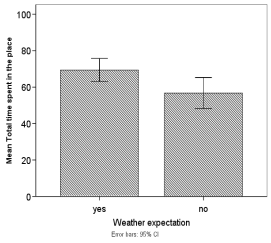


Figure 6: Mean time spent in place as function of weather expectation.

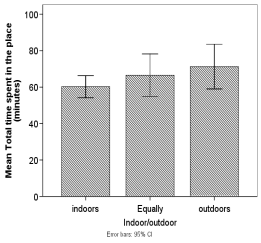


Figure 7: Mean time spent in place as function of the time usually spent indoors or outdoors.

Furthermore, those who usually spend their daytime during weekdays outdoors tend to spend more time in the case study sites compared with those who stay longer indoors (Fig. 7). Again, this is probably attributed to the familiarity of people with the outdoor conditions. Regarding thermal preference, very few interviewees preferred being warmer in Marrakech in

the summer (Fig. 8). On the other hand, around 30% of those interviewed in Phoenix preferred to be warmer (Fig. 8), despite the average air temperature being higher than in Marrakech (Table 1). This interesting aspect could be explained, when considering that people in Phoenix spend significantly more time in air-conditioned spaces (home, work, cars). As people tend to prefer a variable rather than static environment, it could be that seeking warmth in the outdoor spaces is a way of avoiding the fixed constant internal conditions, for change and environmental stimulation.

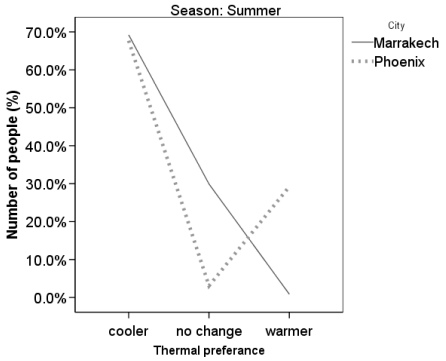


Figure 8: Thermal preference in Phoenix and Marrakech, in the Summer

Socio-economic background and socio-cultural impact on behaviour Three factors were chosen to classify subjects into three groups based on their socio-economic background: low, intermediate and high rank. These factors are education, job, and self-evaluation of the economic state of the interviewee [11]. For each city, the mean number of people from each social group is compared to the mean total time spent in the place. Time spent in the different spaces can be regarded as one indicator of satisfaction with the conditions of a place [13].

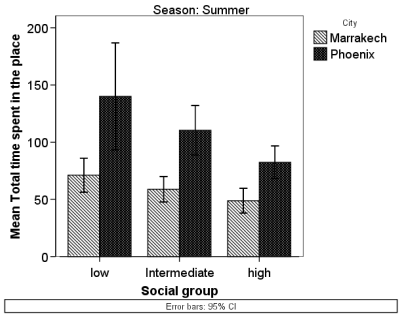


Figure 9: Mean time spent in the place as function of social groups.

It appears that people from lower rank spend more time in the outdoor spaces, compared with those who ranked higher in education, job and financial situation. For example, the mean time spent in Phoenix by people from the low rank group was around 140 min., while the mean time spent in the same sites by people from the high rank group was around 80 min. (Fig. 9).

It is unlikely that these socio-economic groups differ in the time they spent outdoors due to a difference in their perceptions of the place. All the three groups have similar perception in terms of interesting or boring (Fig. 10). It might be argued that thermal conditions, particularly solar radiation in this case, influences the time spent by each of these socio-economic related groups in the place (Fig. 11). When the intensity of solar radiation decreases time spent in the space increases (Fig. 11). This might be due to the fact that people with better financial condition have the option to move indoors to an air-conditioned space, unlike those who cannot easily afford such 'luxuries'.

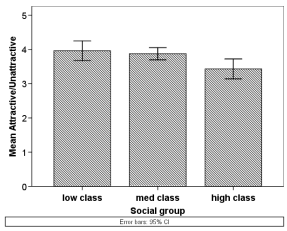


Figure 10: Place perception (Boring/Interesting) as function of social groups.

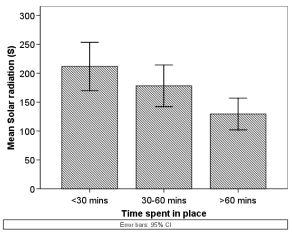


Figure 11: Solar radiation (S) as function of time spent in place.

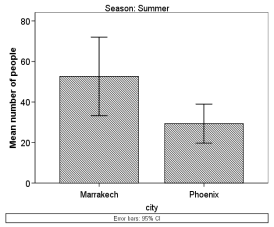


Figure 12: Mean number of people in both cities.

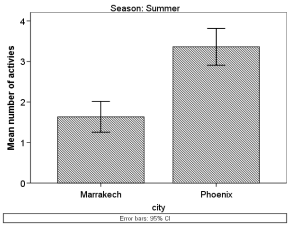


Figure 13: Mean number of activities in the spaces in both cities.

The impact of cultural differences appears in the patterns of use, activities, and ways of adaptation. The number of people who visited the sites in Marrakech was higher than the number of people found in Phoenix (Fig. 8). People in Marrakech tend to visit the sites in large groups and families. They sit in groups and chat or watch others. In Phoenix, people tend to visit the sites in smaller groups or individually. However the range of activities carried out is wider (Fig. 13). The variety and number of activities may explain why people spent more time in the sites in Phoenix compared to Marrakech (Fig. 14). Also, people in Phoenix wear lighter clothes in summer, e.g. T-shirts, shorts, short skirts, etc., while in Marrakech; People tend to wear clothes that cover most of their body for both genders, according to cultural rules in Marrakech (Fig. 15). Another difference that was noticed between the two cultures is in the type of activities. More than

80% of the people in Marrakech were sitting, with less than 10% standing in the area and very few walking or running. In Phoenix, on the other hand, around 44% of the people were sitting, around 35% walking, around 20% standing and some jogging (Fig. 16).

Finally, as mentioned earlier, people in Phoenix spend more time in air-conditioned spaces. Around 75% of those interviewed in Phoenix in the summer were in an air conditioned space less than an hour before the interview, compared to 10 % in Marrakech (Fig. 17). This may explain why fewer people tend to be found in outdoor spaces, in Phoenix in the summer, as most people stay inside the various air-conditioned spaces.

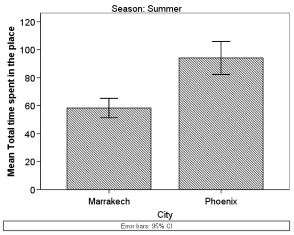


Figure 14: Mean time spent in the space in both cities.

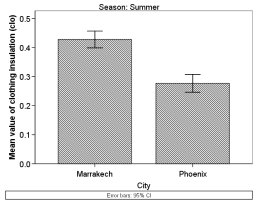


Figure 15: Mean clothing insulation values for people in both cities.

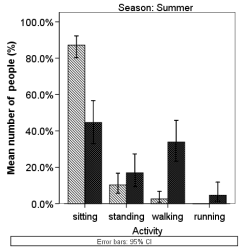


Figure 16: Activities by the interviewees for the last 10 minutes before the interview.

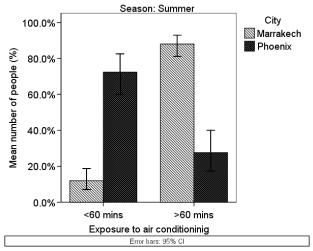


Figure 17: Exposure to air-conditioning before the interview in both cities.

CONCLUSION

This paper presented some of the initial findings of a study on thermal comfort in hot arid climate, towards understanding the relation between place microclimate and human behaviour. It has been found that solar radiation influences the number of people and activities outdoors particularly in the summer. In line with different climatic contexts, the findings support that a purely physiological approach is not enough to describe human thermal comfort in outdoor spaces. People from different social backgrounds in hot arid climates have different approaches to the use of outdoor space. It seems that those who have better education, job and financial circumstances, are more sensitive to environmental conditions. In this climatic context, people from different cultures have differences in the way they use outdoor spaces, particularly, the type and number of activities, which eventually influence the time spent outdoors. Finally, the design is an important parameter that can significantly improve microclimatic conditions, critical in the specific climatic context.

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