The impact of cultural and climatic background on thermal sensation votes

INJI KENAWY[1], HISHAM ELKADI[2]

[12]School of Architecture and Built Environment, Deakin University, Geelong, Australia

ABSTRACT:

The increasing number of migration and the creation of multicultural cities have generated a new challenge for urban designers. The design of shared, welcoming and well utilised urban open places is important in order to promote inclusion, interaction, belonging, and diversity within cities. Thermal comfort is directly related to the users' attitude and behaviour in outdoor places. Fulfilling the comfort needs for users having a variety of cultural and climatic backgrounds needs therefore to be taken into consideration. Microclimatic parameters strongly affect thermal sensation, however, physical, physiological and psychological adaptation have also proven to have significant influence. The satisfaction with the thermal environment does not only depend on the place, but also on personal variables people bring to that place with them. The paper investigates the role of the culture and climatic background of users' in the complex relationships between microclimate, thermal adaptation factors and human behaviour in open public places. The paper aims to understand the influence of users' cultural and climatic background variations on their thermal needs and usage of the outdoor places. Climatic measurements, surveys and observations were carried out in Federation square in Melbourne along the year to examine thermal comfort and patterns of behaviours of users having different cultural origins. Quantitative analysis is used to examine the influence of culture and climatic background of the users' on thermal sensations and adaptation factors. The findings contribute to guiding the design of outdoor public places in multicultural cities.
Keywords: outdoor thermal comfort, cultural diversity, thermal adaptation

INTRODUCTION

Creating comfort within public places has a direct influence to their users' attendance and behaviour. In multicultural societies, the diversity of users visiting public places is a visible indicator of their sustainability (Janssens et al. 2010). Accordingly ensuring thermal comfort in such places can contribute to their usability and accordingly improve the liveability of multicultural cities' inhabitants.

There have been several attempts to understand the different factors influencing outdoor thermal comfort. Nikolopoulou and Steemers (2003) argued that although microclimatic parameters strongly influence thermal sensation, they cannot fully account for the wide variation between objective and subjective comfort evaluation, whereas, physical, physiological and psychological adaptation seems to becoming increasingly important. This means that the satisfaction with the thermal environment of the space does not only depend on the space, but also on personal variables people bring to the area with them. Ahmed-Ouameur and Potvin (2007) added that pedestrian's thermal comfort is a variable which depends on the urban morphology, microclimate attributes, and the adaptive opportunity in urban space. Different authors have examined the importance of including the culture influence on thermal comfort (Aljawabra & Nikolopoulou 2010; Knez & Thorsson 2006). An awareness of these issues would be valuable to architects, planners and urban designers, not by the way of limiting possible solutions, rather by enriching the design possibilities.

The main aim of the research is to improve the quality of urban public places by examining the relationship between the cultural and climatic background of multicultural cities' inhabitant and the microclimatic perception. To achieve this aim, objective measurements and subjective analyses were used to assess thermal comfort for the different users. The objective approach included simultaneous physical measurements of the microclimatic parameters. The subjective approach involved collecting personal information about subjects included in the thermal comfort study using questionnaires and unobtrusive observations. The outdoor thermal sensations of individuals (human subjective assessment) are assumed to vary from the outcome of calculated thermal comfort values based on the climatic parameters (Makaremi et al. 2012). The results of the microclimatic measurements and findings from human responses are compared in order to understand the thermal comfort conditions of outdoor spaces based on human responses and thermal environments.

CASE STUDY DESCRIPTION

The study examines thermal comfort perceptions in multicultural cities, with focus on urban public places. The City of Melbourne, Australia has been chosen as the convenient context for the investigations. Melbourne comprises an estimated resident population of 100611 in 2011 where 47.5% are born overseas (City of Melbourne 2012).

Melbourne is located at 37º49’ south latitude and 144º58’ east and is considered among the temperate climatic group according to the Köppen climate classification. The major statistics recorded from 1855 and 2012 show that the mean minimum and maximum temperature varies between 13.2 - 25.9ºC and 6 - 15ºC in summer and winter respectively (BOM, 2012).

Federation square in Melbourne, a well-recognised public place in the city centre, covers an area of 3.2 hectares. Since its opening in 2002, it has hosted over 50 million visitors. To assess the pattern of usage of the place in relation to thermal comfort, field surveys took places during summer and winter in the place.

Figure 1: Federation Square in Melbourne.

OBJECTIVE MEASUREMENTS

Data collection included measurements of the different climatic parameters including air temperature (Ta in ºC), globe temperature (Tg in ºC), air velocity (v in m/s), relative humidity (RH in %) and solar radiation (R in w/s^2). The measurements took place along the summer and winter using two mobile laboratory comfort carts placed in the sun and shade (Fig. 2).

Figure 2: The mobile laboratory comfort carts used in measurement.

The temperatures (Ta and Tg) were recorded by three linear thermistor of a 0.1ºC accuracy. Integrated humidity sensor of 2% accuracy was used to measure the relative humidity. The air velocity and radiations were measured using an omni-directional anemometer and a standard pyranometer respectively. The mean radiant temperature was calculated from the conversion of globe temperature data measured with a globe thermometer having a 38 mm diameters black tennis table ball covering a thermocouple wire. The data logger on both comfort carts were programmed to automatically record measurements at 1 minutes and 15 minutes intervals at three different heights to correspond to the different activities of users (0.1 m, 0.6 m and 1.1m respectively).

The Physiological equivalent temperature (PET) index was used to assess thermal comfort as recommended by various institutions and researchers (VDI-3787, 1998; Ng and Cheng, 2011; Matzarakis, 2010). The Rayman software, version 1,2 was used to compute the PET (Matzarakis, Rutz & Mayer 2007).

The mean of the air temperature (Ta) values was 23.6°C with a standard deviation of 2.1 during summer, and 13.6°C with a standard deviation of 1.5 during winter. The measured air velocity (v) values were having a mean of 0.4 and 0.9 m/s during summer and winter respectively. The mean values of the relative humidity (RH) in summer (55.4%) and winter (55.3%) were having almost similar values. However, in summer relative humidity maximum values increased to reach the value of 82.9% and decreased to the minimum of 31.6%. The summary of the descriptive statistics of the measured thermal variables are shown in Table (1).

Table 1: Descriptive statistics of the measured thermal variables.

	Summer			Winter		
	Ta (°C)	v (m/s)	RH (%)	Ta (°C)	v (m/s)	RH (%)
Mean	23.6	0.44	55.4	13.6	0.9	55.3
Std.D	2.1	0.15	10.2	1.5	0.3	6.4
Min.	19.3	0.15	31.6	9.9	0.4	41.4
Max.	28.8	0.77	82.9	17.1	1.5	66.2

SUBJECTIVE ASSESSMENT

In addition to the objective measurement, subjective assessment took place in order to understand the human thermal perception, behaviour and background. Accordingly, questionnaires and observations were gathered in parallel to the climatic measurements. The questionnaire was divided into three parts. The first part aimed to gather personal and demographic information of the respondents such as the age, gender, origin and duration of living in Australia. Participants with less than 3 years residency in Australia were excluded. The second part investigated the respondents' subjective responses in relation to the different climatic parameters as well as their overall comfort using the seven points ASHRAE scale (Table 2). The last part included physical and psychological considerations such as the duration and reason of visiting the place. Other relevant information were added through the observations including the respondents clothing and metabolic rates (ASHRAE 2004). The pattern of usage and number of attendance of users were also monitored through observations.

Table 2: ASHRAE seven points scale.

Cold	Cool	Slightly cool	Neutral	Slightly warm	Warm	Hot
-3	-2	-1	0	+1	+2	+3

GATHERED SAMPLE

Totals of 523 and 498 valid questionnaires were gathered during summer and winter respectively. A percentage of 42% of the respondents are native Australians distributed along the different states (Fig. 3). The rest of the sample having other cultural origins was classified into nine different groups adopted from the distribution and categorisation of immigrants according to the Australian bureau of statistics (Fig. 4). The nine groups are North West Europe, Southern & Eastern Europe, North Africa & Middle East, South East Asia, North East Asia, Southern and Central Asia, Americas, Sub Saharan Africa, and Oceania & Antarctica.

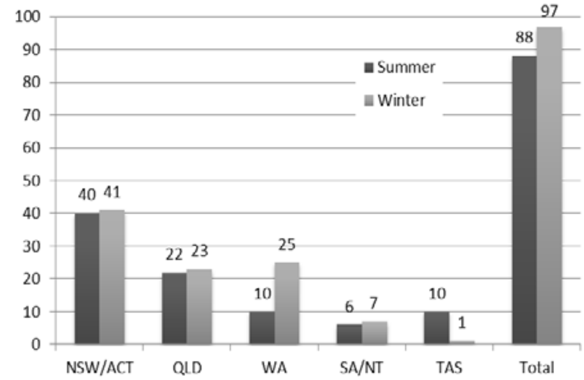

Figure 3: Geographic distribution of Australian respondents.

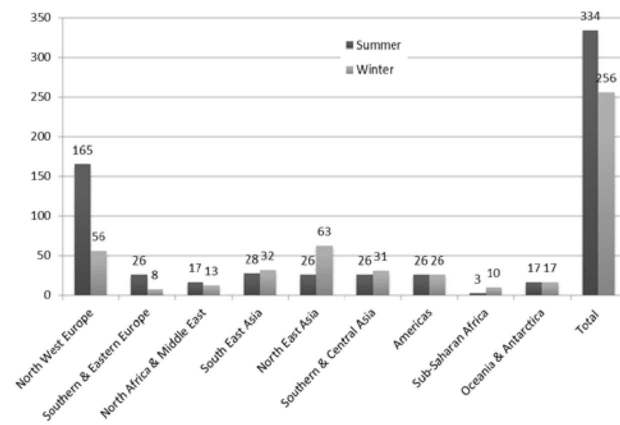

Figure 4: distribution of respondents according to their culture origins.

OVERALL THERMAL SENSATION VOTES

The thermal sensation votes for the overall respondents indicated that 51.7% and 31.6% have voted towards the cold (TSV < 0) and the warm (TSV > 0) direction of the ASHRAE scale respectively. A remaining percentage of 16.7% voted for neutral thermal feeling.

The thermal sensation votes distribution, during summer and winter, shows that winter season responses are more skewed with a value of 0.670 with a mean of -1.62 (cool). On the other side, the skewness of summer season is - 0.475, and the mean is 0.56 (neutral). This shows that the overall responses for users are less tolerant to winter than summer. As the mean temperature during summer and winter was calculated to be 23.6 and 13.6 respectively, the overall thermal sensation responses are coherent with the PET comfort classification for temperate regions sorted by Matzarakis et al. (1999) (Table 3).

Table 3: thermal perception classification for temperate region.

Thermal perception	thermal perception classification for temperate region
Cold	4 - 8
Cool	8 - 13
Slightly cool	13 - 18
Neutral	18 - 23
Slightly warm	23 - 29
Warm	29 - 35
Hot	35 - 41

CULTURAL BACKGROUND INFLUENCE

To examine the cultural influence on thermal sensation, the votes of each cultural category were separately examined. Most of the votes towards the cold direction are found to be from the users from Sub-Saharan Africa, NE Asia, SC Asia, and N Africa and ME. In contrast, the users from SE Europe and NW Europe voted towards the hot direction of the ASHRAE scale.

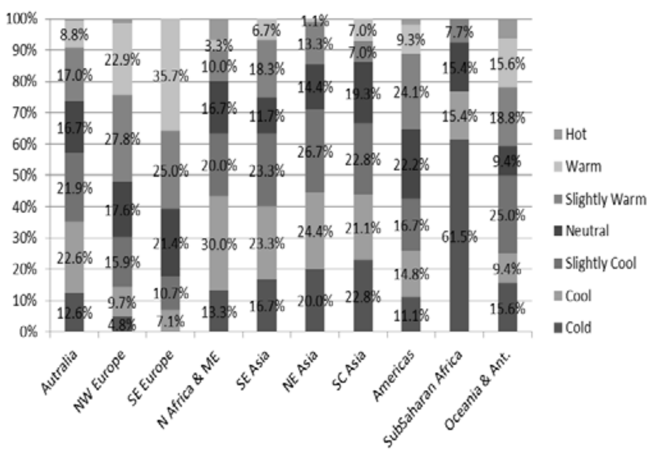

Figure 5: Distribution of thermal sensation votes according to culture origins.

To examine the the variation in the mean of thermal sensation votes (MTSV) in relation to the culture origins, a Kruskal-Wallis test were employed. This test was employed due to the non-parametric nature of the data. The test indicated a statistically significant Chi square of X^2 (9, N= 1021) = 182.038, $p < 0.01$. Accordingly, the culture origins variations are significantly affecting the variation of their thermal votes. The calculated effect size indicates that 17.8% of the variability in MTSV can be explained by the users' cultural origins. The same significance was found when the test was repeated for different seasons separately. A Chi square of value of X^2 (9, N= 523) = 84.036, $p < 0.01$ and X^2 (9, N= 498) = 88.479, $p < 0.01$ and calculated effect size of 16.1% and 17.8% were found for summer and winter respectively.

The MTSV for different cultures (Table 4) show that during summer the users originally from Oceania and Ant., America, NW Europe and Australia are the least tolerant to the heat stress with an MTSV of .8576, 0.6520, 0.6463, and 0.5370 respectively. The results of the Sub-Saharan group are not taken into account due to the very small number of participants. On the other side the users originally from Southern & Central Asia, NE Asia are the most tolerant to the heat stress. During winter the users from SC Asia, SE Asia, NW Europe and Australia were the most tolerant to cold conditions with a very close means values. The users originally from Sub Saharan Africa, NE Asia, and SE Europe were in contrast the least tolerant to cold conditions.

Table 4: MTSV of users having different culture backgrounds during summer and winter.

	Summer			Winter		
Culture	Mean	N	Std.D.	Mean	N	Std.D.
Australia	.53	189	.64	-1.5	241	.42
NW Europe	.64	165	.64	-1.5	62	.35
SE Europe	.45	26	.42	-1.7	2	.09
N Africa & ME	.47	17	1.11	-1.6	13	.21
SE Asia	.51	28	.75	-1.5	32	.45
NE Asia	.42	26	.71	-1.7	64	.23
SC Asia	.31	26	.84	-1.5	31	.37
Americas	.65	26	.57	-1.6	28	.26
Sub S. Africa	.70	3	.64	-1.8	10	.47
Oceania	.85	17	.62	-1.6	15	.23

CLIMATE BACKGROUND INFLUENCE

The climatic background is also investigated through grouping the users according to their climatic background using the main five Köppen climate classifications. Another Kruskal-Wallis test were employed to understand the relation between the climatic background and thermal sensation votes. The test has indicated a statistically significant Chi square of X^2 (3, N= 1020) =18.422, $p < 0.01$. The effect size in this case is calculated to be 1.8% that is quiet a small effect. The effect size for the climatic background is then smaller than the cultural origins effect, which can again be explained by the fact that the culture includes climatic background among other different factors affecting thermal comfort.

The mean thermal sensation votes for users having the different climatic background indicate that during summer the users from the dry regions are the most tolerant to the heat stress followed by the tropical, cold and temperate regions. During winter, the users from dry are the least tolerant to cold conditions, followed by the temperate, cold and tropical regions.

Table 4: MTSV of users having different climatic backgrounds during summer and winter.

	Summer			Winter		
Climate	Mean	N	Std.D.	Mean	N	Std.D.
Tropical	-.09	55	1.25	-1.4	69	1.42
Dry	.11	34	1.32	-1.9	42	.92
Temperate	.68	38 6	1.17	-1.6	331	1.09
Cold	.64	48	1.22	-1.5	55	1.06

In order to understand the relationship between the culture and climatic origin, a cross tab was employed (Table 5). It is observed from the table that the TSV of the users from Australia, NW Europe, and Oceania can be related to their climatic background as being mainly from temperate climatic regions explain their weak tolerance to the heat stress. On the other side the users from SC Asia are mostly from tropical and dry background which explains their high tolerance to the heat stress. The results of the users from SE Europe and NE Asia cannot be explained in relation to their climatic background.

Table 5: Cross tab between different culture and climatic groups.

	Köppen climate classifications			
Culture	Tropical	Dry	Temperate	Cold
Australia	0.0%	11.2%	88.8%	0.0%
NW Europe	0.0%	0.0%	94.3%	5.7%
SE Europe	0.0%	0.0%	82.1%	17.9%
N Africa & ME	0.0%	40.0%	60.0%	0.0%
SE Asia	100.0%	0.0%	0.0%	0.0%
NE Asia	0.0%	0.0%	34.8%	65.2%
SC Asia	61.4%	14.0%	24.6%	0.0%
Americas	38.9%	11.1%	0.0%	50.0%
Sub S. Africa	30.8%	15.4%	53.8%	0.0%
Oceania	12.5%	0.0%	87.5%	0.0%

CONCLUSION

The paper investigated the influence of the cultural and climatic backgrounds of users on their thermal sensation votes. Federation Square in Melbourne is used as a case study for its variety of users with different cultural and climatic backgrounds. Climatic measurements were used to evaluate the thermal condition in the place through the calculation of the PET as the thermal comfort index. On the other side, subjective assessments were examined through questionnaires and observations. The collected data were analysed using the SPSS statistical software. The test employed indicated significant results for thermal sensations votes' variations in relation to the variability of both of cultural and climatic backgrounds. However, cultural influence was found to have more effect size than the climatic background, which was explained by the fact that the culture includes climatic background among other different factors affecting thermal comfort.

The findings confirm the limitation of the physiological approach in assessing thermal comfort, and the importance of considering the thermal adaptation factors. The results are in accordance with the previous studies showing the linkage between thermal assessment and psychological and cultural process rather (Aljawabra & Nikolopoulou 2010; Knez & Thorsson 2006). In multicultural societies, urban designers need to consider these facts to support the design of comfortable, shared and welcoming public places to all users. There is a need, for example, to cater for varieties of temporary shade devices as well as permanent canopies, semi closed as well as open enclaves.

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