Architecture Energy and the Occupant's Perspective

PLEA 2009 Québec, Canada

UNIVERSITÉ LAVAL

Green Space Influence on Thermal Comfort

Contrasting Approaches in the Assessment of Conditions in Bragança (Portugal)

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GreenUrbe

Urban greening has been widely recognised as a key factor to mitigate the adverse effects of urbanisation in a sustainable manner [1]. Green spaces characteristics include trees, soft surfaces and wind shelters that can influence thermal sensations by inducing changes in such variables as solar radiation, temperatures of surrounding surfaces, air temperature, humidity and wind speed [2,3]. As part of the ongoing research entitled GreenUrbe (PPCDT/AMB/59174/2004), both users surveys and structured experiments are being developed, trying to establish relation between green spaces characteristics and thermal comfort. The city of Bragança is located in north-eastern Portugal. Local climate is characterised by a cold rainy winter and relatively short (June to September) hot and dry summer.

METHODS

Field surveys

- Carried out in four different green spaces, evaluating both thermal perceptions, by means of using questionnaires, and thermal conditions, by collecting data in a mobile meteorological station (Table 1)
- Field surveys were carried out in summer conditions (June, July and September 2007).
- 194 surveys were carried out, at approximately equal proportions between green spaces (Fig.1).

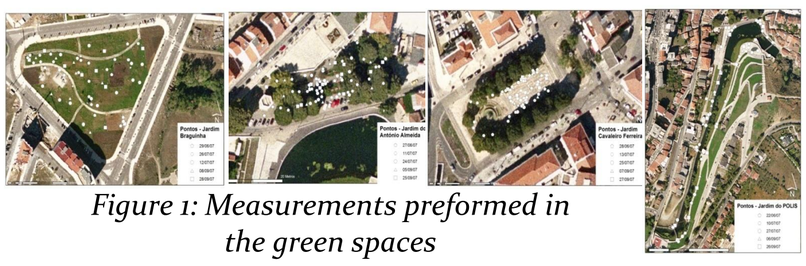

Figure 1: Measurements preformed in the green spaces

Table 1: Measured meteorological variables and instruments for both methods

Variable	Instrument
Air temperature, T_a	Campbell Sci., CS215
Globe temperature, T_g	Campbell Sci., 107 Thermistor
Relative humidity, RH	Campbell Sci., CS215
Wind speed, V	R.M. Young, 05103
Global solar radiation, S_t	Kipp & Zonen, CM6B

Structured experiments

- Study carried out in four different close locations (Fig. 2):

(A) Shadow under tree, over bare soil and near a water pound;
(B) Shadow under artificial cover and over grass;
(C) Sun exposure near wind shelter over grass;
(D) Sun exposure over pavement.

- 12 individuals participated in this study (six man and six women), grouped around four age groups (20-30; 31-40, 41-50 and over 50 years) and wearing jeans and a white t-shirt.
- Each participant filed in a questionnaire, assessing individual perceptions on thermal sensation, each time on a different location.
- Each group, with three participants, stayed seated in each location for 15 minutes (the last five filling in the questionnaire), moving to the next location after time had passed in a rotation scheme Fig. 3.
- This procedure was carried out three times during the same day, starting at 9 a.m. and finishing at 6 p.m., with a total of 144 questionnaires applied.

Figure 2 – Four situations used in structured experiments

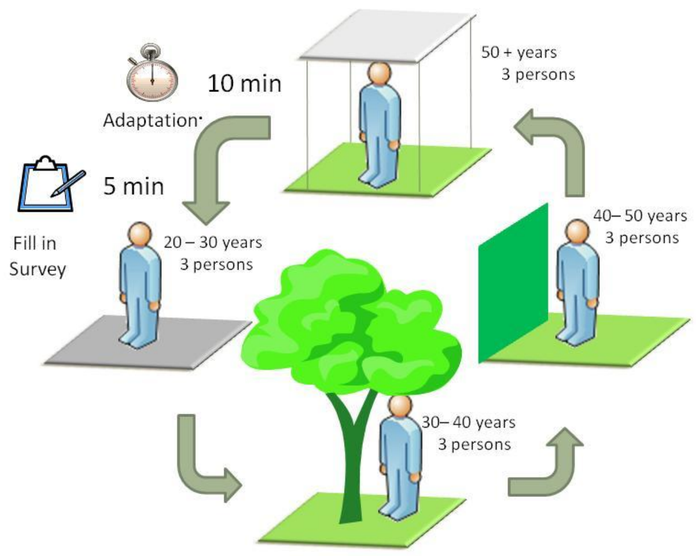

Figure 3 – Rotation scheme

RESULTS

Field surveys

- Results show a major tendency towards a comfort status (Table 3), despite the fact that surveys took place in conditions that could be generally described as ranging from cool to very hot days (just below 40ºC).
- May have influenced these results: the narrow amplitude of the scale; users' ability to choose when and where to stay in green spaces, looking for shadow elements in hot periods and sun exposure in more mild conditions and thus reducing the chances for extremelly uncomfortable situations.

Table 2: Average meteorological variables and PET for different Thermal Sensations

TS		Ta (ºC)	RH (%)	V (m/s)	St (Wm-2)	Tmrt (Cº)	PET
Cool	Mean	21,25	36,84	1,06	109,20	29,15	21,29
	Std. Error of Mean	0,75	2,96	0,15	35,66	3,32	1,38
	N	11	11	11	11	11	11
Neutral	Mean	23,42	36,30	1,08	296,98	39,74	27,38
	Std. Error of Mean	0,34	0,79	0,05	26,54	1,08	0,53
	N	132	132	132	132	132	132
Warm	Mean	25,41	31,60	1,16	362,65	44,08	30,76
	Std. Error of Mean	0,60	1,36	0,08	47,29	1,73	0,99
	N	42	42	42	42	42	42
Very Hot	Mean	24,45	29,87	1,08	479,54	48,96	32,47
	Std. Error of Mean	1,33	2,73	0,15	117,99	4,35	2,39
	N	9	9	9	9	9	9
Total	Mean	23,77	35,01	1,09	309,02	40,51	28,00
	Std. Error of Mean	0,28	0,66	0,04	21,93	0,90	0,47
	N	194	194	194	194	194	194

Structured experiments

- Results (Table 3) show: Small differences concerning Air temperature (T_a); higher RH is found in place A (near a water pound), as place D had the lowest values; wind shelter helped lowering wind speed (V) in location C; Thermal Sensation (Ts) values were considerably lower in shadow locations, with lower Mean Radiant Temperature (T_{mrt}).
- Differences were found between the four different locations concerning Ts, as participants felt predominant warm sensations under sun exposure, where Global solar radiation (S_t) was consistently higher, opposite to neutral to cool conditions found under shadow (Fig.4).
- Large Pearson correlation could be found between Ts and :

S_t (ρX,Y = 0,714) and **RH (ρX,Y = 0,593)** thus stating the strong relation with these variables.

- Using linear regression (stepwise):

TS=-0,642+0,005St-0,013RH

with a R2 value of 0,533.

Table 3: Average meteorological variables and PET for different locations

Location		Ta (ºC)	RH (%)	V (ms-1)	St (Wm-2)	Tmrt (ºC)	PET
Shadow Under Tree (A)	Mean	21,79	48,37	0,87	118,03	27,76	21,21
	Std. Error of Mean	0,36	2,75	0,03	5,41	0,32	0,30
Shadow Under Artificial Cover (B)	Mean	21,79	41,29	0,87	174,44	40,71	26,77
	Std. Error of Mean	0,36	2,46	0,03	6,66	1,14	0,70
Sun Near Wind Shelter (C)	Mean	21,94	36,11	0,68	488,62	46,81	30,92
	Std. Error of Mean	0,51	2,36	0,05	19,09	0,58	0,40
Sun Over Pavement (D)	Mean	21,94	42,10	0,87	488,62	46,80	29,82
	Std. Error of Mean	0,51	2,56	0,03	19,09	0,61	0,44
Total	Mean	21,87	41,97	0,83	317,43	40,52	27,18
	Std. Error of Mean	0,22	1,31	0,02	16,03	0,74	0,40

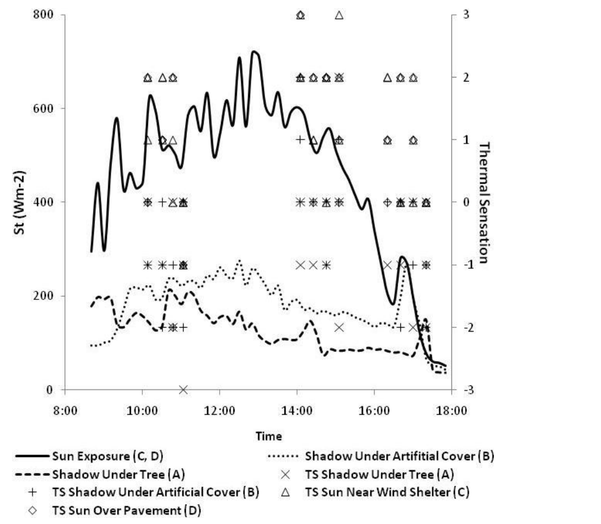

Figure 4: TS of subjects with measured solar radiation in different shadow conditions and in sun exposure

CONCLUSIONS

- Results so far suggest diverse elements inside Green spaces, may offer complementary conditions for thermal comfort.

Evaluating the two different approaches used:

- While field surveys offer a more natural approach, studying individual sensations in common behaviors, they may reflect choices that can restrain thermal sensations, especially concerning clothing, metabolism and time spent on different locations.
- Structured experiments offer a greater control over both personal (clothing, metabolism, age and gender ratio) and environmental conditions (testing contrasting conditions in equal proportions). However, it is difficult to engage as many users, narrowing the amount of users evaluated.
- Recognizing the added value of this kind of methodology, additional structured experiments will be conducted within the course of this project.

Centro de Investigação de Montanha CIMO

ACKNOWLEDGEMENTS. The authors thank the National Scientific Foundation of Portugal (FCT) for the financial support given to project GreenUrbe (PPCDT/AMB/59174/2004). Thanks must also go to the volunteer participants in this research.

REFERENCES

1. Bolund P. and Hunhammar S (1999). Ecosystem services in urban areas. *Ecological Economics*. 29: p. 293-301.
2. Oke, T.R., 1987: *Boundary layer climates*. Methuen & Co. Ltd., London.
3. Givoni B. M. N., Saaroni H., Pochter O., Yaacov N. F. Y. and Becker S. 2003. *Outdoor comfort research issues*. Energy and Buildings, 35: p.77-86.

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