AN ASSESSMENT OF THE OUTDOOR BIOCLIMATIC COMFORT IN LISBON

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Abstract

The relation between the climatic conditions and the perception of climatic comfort was analysed in an open urban area in Lisbon. This experiment consisted in simultaneous questionnaire surveys and meteorological measurements during two sunny days. The results showed that in outdoor conditions, thermal comfort can be maintained with temperatures well above standard values defined to indoor conditions. A spontaneous adaptation of clothing seems to exist when a threshold of 31ºC of Physiological Equivalent Temperature is surpassed. Perception of air temperature is difficult to separate from the perception of the global thermal environment and it is modified by others parameters, particularly wind. The perception of solar radiation is related with values of fluxes from different directions (incident on vertical and horizontal surfaces), weighted by the coefficients of incidence on the human body. Wind was the variable most intensely sensed, generally with a negative connotation. The perception of the wind depends largely on the extreme values and wind variability. Women showed a stronger negative reaction to high wind speed than men. The experiment proved that the methodology was suitable to achieve the objectives proposed and it may be applied in other areas and in other seasons.

Key words: climatic comfort, open urban area, perception

1. INTRODUCTION

Outdoor public spaces in urban areas contribute to the quality of life within cities, playing an important role on outdoor activities and social interactions of citizens (Nikolopoulou & Steemers, 2003; Thorsson et al., 2004).
Microclimatic conditions have great effect on the usage of open spaces, partly because they influence thermal and mechanical comfort (Givoni et al., 2003). However, the thermal and mechanical effects of the wind are difficult to disentangle; the combination of the thermal and mechanical aspects are included in the concept of climatic comfort.
Studies on outdoor comfort have focused mainly on thermal aspects with the use of models developed to standard indoor conditions (e.g. Svensson & Eliasson, 2002). Nevertheless, the steady-state conditions assumed in these models are not adequate to the study of the highly variable outdoor conditions (Parsons, 1993; Nikolopoulou and Steemers, 2003; Thorsson et al., 2004); the complexity of the outdoor environment requires the inclusion of subjective parameters in the analysis (Hoppe, 2002; Nikolopoulou & Steemers, 2003, Stathopoulos et al., 2004; Knes & Thorsson, 2006). Outdoor climatic comfort is influenced by air temperature (*Ta*), air humidity, wind speed (*v*) and radiation fluxes (mainly solar radiation - *K*) and by a set of personal parameters, such as physical activity, clothing level and age, and also by psychological factors, namely motivation and individual preferences (Nikolopoulou & Steemers, 2003; Stathopoulos et al., 2004; Knes & Thorsson, 2006). The understanding of the relation between environmental conditions, human characteristics and the usage of open urban spaces can provide the opportunity to improve open outdoor areas and contribute to the design of new and more attractive ones.
The purpose of this paper is to describe the experiment that is being carried out in Lisbon, concerning the perception of outdoor climatic comfort. This experiment is part of the research project *URBKLIM: Climate and urban sustainability. Perception of comfort and climatic risks* (POCI/GEO/61148/2004). The objectives of the experiment are: a) to assess the conditions of human comfort in different outdoor open spaces; b) to define thresholds of outdoor climatic comfort based on the atmospheric conditions, type of activity and individual characteristics; c) to analyse the relation between the perception of climatic comfort and the microclimatic conditions in different urban areas. The main aim in this early stage of the project was to define a framework methodology suitable for application in different geographical and meteorological contexts.

2. MATERIALS AND METHODS

The field data collection included questionnaire surveys, measurements of weather parameters and collection of photographs of the study area, during sessions from approximately noon till 5 pm. The field studies were conducted in springtime, on the 12th March and 23rd April 2006, both sunny and warm Sundays, with sky partially cloudy, temperatures above the monthly normal and variable wind speed, with maximum value of 6.8 m s^{-1}, and averages of 1.9 m s^{-1} on the 12th March and 2.6 m s^{-1} on the 23rd April 2006.

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2.1. Study area

For this first experiment, a riverside area in the southern part of Lisbon was selected (Fig. 1). It comprises a paved sidewalk and green areas, bordered by deciduous trees. There are benches facing south in both the green and paved areas. The area is used mainly as a sidewalk by the inhabitants of the city, especially on weekends.

2.2. Weather measurements

The weather parameters measured were Ta, RH, v, K and long wave radiation (L); measurements were made near the interviewees while the questionnaires were taking place. Values of *Ta*, *RH* and *v*, were recorded three times during each questionnaire. The measurements of the radiation fluxes were made every 15 minutes and mean radiant temperature (T_{mrt}) was calculated after the method of Jendritzky & Nübler (1981).

2.3. The questionnaire

The questionnaire was made to people passing by or sitting on the benches in the study area, selected randomly; only young and adult people engaged in a low or moderate physical activity were approached. The questionnaire was designed using concise and plain language in a short-answer format and it was divided in two parts: the first part comprises the individual characteristics of the interviewees and the other part covers their perception of comfort in relation to the meteorological parameters (Nikolopoulou & Steemers, 2003; Stathopoulos et al., 2004).
The questions in the first part included information about gender, age, and clothing. Activity developed, the exposure to the sun and the position of the individual, the birth place and residency, the professional activity, the reason and the time of permanency in the area and frequency of use. The questionnaire included also a list of selected diseases which may be related to atmospheric conditions, because climate affects directly or indirectly the human health and the individuals who have a specific health condition can be more vulnerable or sensitive to certain climatic conditions (Schlink et al., 2002).
To assess the level of clothing, a simple scale was created, through the definition of three types of clothing ensembles and other specific garments, based on the type of clothing people usually wear in this time of the year It was established a general relation between this scale and the values quantification of clothing, in Clo units, based on Parsons, 1993 (Table 1).

Table 1. Description of the types of clothing ensembles and other garments (extra-elements), and their values in Clo.

Clothing Ensembles		Clo	Extra-elements (a)	Clo	Extra-elements (r)	Clo
All include underwear, shoes w/ socks			Thick sweater	0.35	Boots	0.1
A	Trousers and 1 top layer	0.57	Long coat	0.7	Sleeveless vest	0.12
B	Trousers and 2 top layers	0.85	Thick coat	0.8	Skirt	0.2
C	Trousers and 3 or more top Layers	1.45	Cap	0.1	Short sleeves	0.15
			Scarf	0.08	Shorts	0.06

The second part of the questionnaire concerned the perception of the individual in relation to each meteorological parameter at the moment and to the overall perception of climatic conditions, in a 4-point nominal scale of comfort. It was also asked how the individuals would change the meteorological conditions to increase their comfort and which was the meteorological parameter they felt more unpleasant. The distinction between overall conditions and particular parameters was introduced, considering that, even when the overall environment is sensed as comfortable, it may still be improved by changing a specific meteorological parameter. These questions, although seemingly simple, involve complex problems: the importance of the psychological factors and, on the other hand, the fact that the climatic environment is perceived globally, because the human ability to separate the different thermal influences is limited.

2.4. Data analysis

The responses to the questionnaire were analysed assuming the possibility of a relation between three groups of parameters: the personal characteristics of the interviewees, the perception of comfort revealed by the interviewees and the atmospheric parameters, measured during the interview. The main focus is the relation between the measured atmospheric conditions and the level of comfort declared by the individuals.
The thermal influence, obtained from the combination of different atmospheric parameters, was analysed using the Physiological Equivalent Temperature (PET- Matzarakis et al., 1999), which is based on the model of the energy balance of the human body.

3. RESULTS AND DISCUSSION

3.1. Characteristics of the interviewees

In the two field surveys were obtained 91 interviews, corresponding to about 10% of the total of people that used the study area in both days, during the time the surveys were being performed. About 55% of the individuals were women. The age of the interviewees varied between 17 and 76 years old and the predominant age group was 25-34 years (37%), followed by the age groups 35-44 and 45-54. All the individuals were performing leisure activities in the area, specially walking, and 25% were seating on the benches. All the interviewees wore clothing included on ensembles A and B (table 1) with an average Clo value of 0.63.

3.2. Perception of the thermal conditions

The general thermal conditions were, in almost all the cases, considered comfortable, regardless of the broad range of *Ta* and PET values registered during field work. To interpret this result, it must be taken into consideration the motivation (all the individuals were in the area with the purpose of spending leisure time) and clothing, which can reveal an adaptation to the thermal conditions.
There was a clear differentiation in clothing periods with PET bellow and above 31ºC. Below this limit, 56% of the individuals wore clothing ensemble B and 44% wore ensemble A; the average Clo value was 0.67. Above 31ºC, people wearing clothing ensemble A correspond to 84% of the total and the average Clo value was 0.58. The differentiation between the Clo values in these two groups was tested with ANOVA and the result was statistically significant.
The individual parameters were also declared as pleasant in most cases (Fig. 2). However, some interviewees considered unpleasant some specific parameters, i.e., even if the interviewees feel globally comfortable, they can feel different levels of satisfaction depending on the meteorological parameters considered. The most interesting results report to Ta, v and K. With a Ta variation between 18ºC and 31ºC, 86% of the interviewees declared feeling pleasant; however, there was no significant statistical relation between the values of Ta measured and the level of satisfaction, which can be partly explained by the interference of other factors in the perception of Ta (e.g. wind) and the confusion between the perception of the overall comfort and of the Ta.
30% of the interviewees said that K was too strong and 12% said that K was the most unpleasant variable. There was no statistically significant relation between the values of K measured on the horizontal surface and the level of satisfaction declared. Considering that the human body has more vertical surfaces than horizontal ones, the radiation received by the human body (Kb) was calculated with the values of radiation coming from three directions: K↓ (received in the horizontal surface), KW and KS (coming from west and south, respectively, and falling upon the vertical surfaces) and weighted by the coefficients defined by Fanger (1972) for fluxes falling upon vertical and horizontal surfaces: respectively 0.06 and 0.22. Kb was, thus, calculated as: Kb =0.06 K↓ + 0.22 (KS + KW). The relation between Kb and the satisfaction with the solar radiation is statistically significant.
Wind results showed the strongest association with the responses obtained from the enquiries. 71% of the interviewees considered the v values as pleasant, while 27% of the individuals said the wind speed was excessive. It was possible to verify a relevant differentiation on v speed among the answers that classify wind as pleasant or excessive. This differentiation increases if we consider the maximum v of the three observations (vmax) instead of the average speed. Besides the speed, wind variability can also influence the level of comfort (thermal and mechanical). An empirical formula was obtained, combining the maximum speed and the variability of the wind, by adding the value of *v*max to the standard deviation of the three observations (s*v*): v_χ= *v*max + s*v*.
The differentiation of v_χ, for different levels of comfort is statistically significant. Gender is another factor that clearly affects the level of comfort sensed by the individuals in relation to wind. (fig. 3).The increase of v_χ values leads to a rapid decline of pleasant answers from women, while the percentage of men is only slightly reduced.

4. CONCLUSION

The methodology applied for this experiment proved to be appropriate. The results presented have shed some light on the relations existing between the factors that influence outdoor climatic comfort.
The individuals questioned in these specific environmental conditions may feel comfortable with temperature values much higher than the values accepted by the traditional models of thermal comfort. Besides, it was shown that there is a “spontaneous” adaptation of clothing to the thermal conditions; with PET values higher than 31ºC, the dominant clothing changes and the values of Clo are reduced. It was also acknowledged that Ta is difficult to perceive, because it is confounded with the perception of the global thermal environment and it is modified by the others parameters, particularly v. The K sensed by the interviewees is not significantly related to the K measured on the horizontal surface but to the values that take into account the coefficients of incidence on the human body according to the direction. Wind was the variable most intensely sensed by the interviewees and had, in general, a negative connotation. The relation between the individuals that stated the wind as “uncomfortable” (too windy) and the values of v was more significant with the extreme values and wind variability than with the average values. An empirical formula was obtained (v_χ), combining extreme values with variability and, when applied, it

showed a statistically significant relation with the perception by the interviewees. Women demonstrated a stronger negative reaction to high *vX* than men.

In summary, the results presented suggest that there is a relation between outdoor climatic comfort, the atmospheric parameters and the personal characteristics of the individuals. The level of influence of each variable depends on specific conditions that require a deeper analysis. The experiment described provides a framework for further investigation on this subject, considering the possibility to make adequate adjustments.

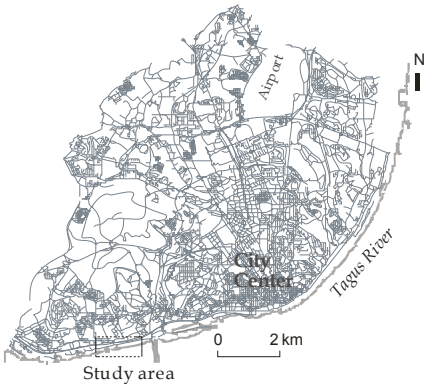

Fig. 1. Location of the study area in Lisbon

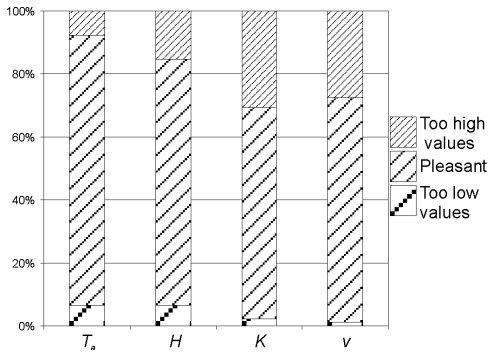

Fig. 2. Level of satisfaction declared by the interviewees in relation to specific meteorological parameters

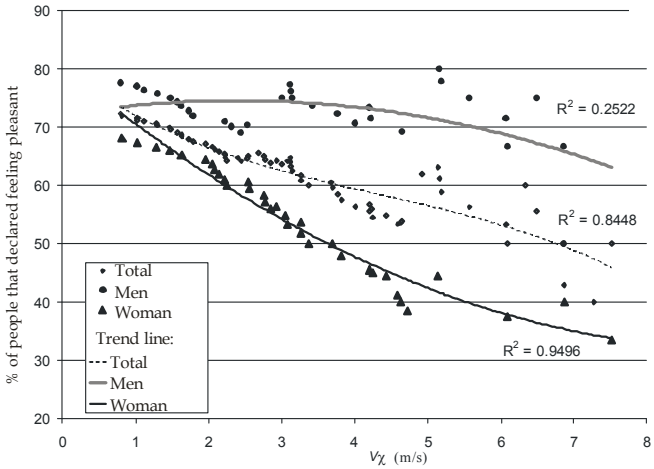

Fig. 3. Relation between gender and level of satisfaction with wind speed

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