Thermal Perception of Users of Different Age Groups in Urban Parks in Warm Weather Conditions

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ABSTRACT

Studies of thermal comfort in open spaces in various climatic and cultural contexts, seek to create design guidelines for attractive outdoor environments, which improve the quality of urban life. In general, these studies characterize microclimates and define the conditions for actual and/or calculated thermal comfort by predictive indexes in streets, squares and parks. In this context, this pilot study aimed to characterize the thermal perception of users and changes of the range of PET (Physiological Equivalent Temperature) for thermal neutrality according to the age of visitors to a park in the city of Bauru, State of Sao Paulo, Brazil. The study was conducted through microclimate monitoring and structured questionnaires to users in warm weather conditions. Results showed higher frequency of thermal sensation between comfortable and warm; a differential thermal preference according to the major microclimatic variations observed between morning and afternoon; little tolerance to the effect of direct solar radiation and minor differences of PET index between the age groups of children and teenagers and greater variations between these groups and adults/elderly.

INTRODUCTION

The open spaces have several ways of daily use in the city and, therefore, an important aesthetic and recreational function (Raja & Virk, 2001). Chen and Ng (2012) advocate that open spaces are key to more sustainable cities because they accommodate pedestrian traffic, the outdoor activities and contribute to the livability and urban vitality. Thus, they encourage more people to attend the open spaces in the cities benefitting their physical, environmental and socio economic dimensions.

The quest to create the most attractive open environments has contributed to the growth of research in open spaces, focused on different aspects, including thermal comfort. In this approach, the pioneering studies investigated the thermal environment, the human comfort parameters (Nikolopoulou, Baker & Steemers, 2001), the characteristics of space usage (Zacharias, Stathopoulos & Wu, 2001), the relationship between comfort psycological adaptation (Nikolopoulou & Steems, 2003), and thermal comfort and behavior patterns of users on streets, squares and parks (Thorsson, Lindqvist & Lindqvist, 2004).

These researches show the complexity of the evaluation of comfort in open spaces and proved that there is a close relationship between the thermal environment and the number and distribution of users, and also between the behavior of people in open spaces. These findings significantly influenced the development of research on the conditions for thermal comfort in open spaces in different climatic and cultural contexts (Katzschner, 2006; Thorsson, Honjo, Lindberg, Eliasson & Lim, 2007; Eliasson, Knez, Westerberg, Thorsson, Lindqvist & Lindqvist, 2004; Lin, 2009; Dacanal, Labaki & Silva, 2010; Labaki, Fontes, Bueno-Bartolomei & Dacanal, 2012 and Fontes, Nishimura, Sebastião & Faria, 2012; Lin, Lin & Hwang, 2013).

In general, these researches seek to analyze the thermal quality of open spaces, based on qualitative aspects (thermal perception of the users) and quantitatively with the use of different predictive indexes of comfort, such as the Physiological Equivalent Temperature - PET (Mayer & Höppe,1987; Höppe, 1999), to define the limits of thermal comfort. The aim is to create design subsidies that favor the creation of pleasant microclimates for human society and, consequently, contribute to the increment the daily use by the population.

So it is important that architects and landscapers use tools that have been developed from research in the area, with the goal of designing open spaces with adequate comfort conditions. Considering especially the effects of expanding cities adversely affect the microclimates of these spaces, because of the significant heat islands effects (Lin et al. 2013).

In this context, this research shows results of a pilot study investigating microclimates and thermal perceptions of users of a park located in Bauru, midsize city of São Paulo State, Brazil. However, the difference here presented, in relation to other similar studies, is to attempt to identify possible variations of PET for thermal neutrality according to the different age groups of visitors.

MATERIALS AND METHODS

Characterization of the study area

The study area is the Municipal Zoo of Bauru (Lat. 22 °18'54" S, Long. 49°03'39" W and average altitude of 530m), medium-sized city in the Midwest of São Paulo state, Brazil. According to Köppen climate classification, the local climate is Aw - tropical climate with summer marked by high temperatures and rainfalls and mild and dry winter. Figure 1 shows the thermal range of the city, from the analysis of historical data of air temperature over the period of ten years (2001-2010). The table also includes the minimum and maximum temperatures of two days of field survey in the months of October and November 2013.

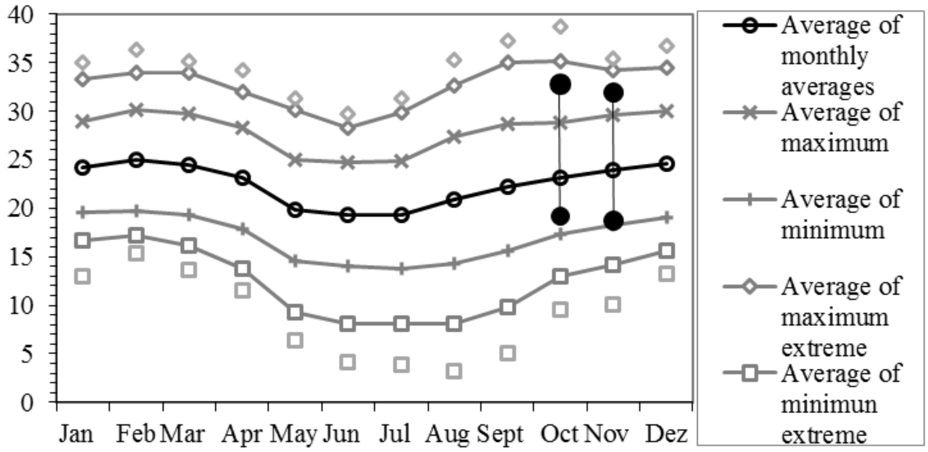

Figure 1 *Statistics of thermal data of Bauru (SP) over the period 2001-2010. Source: http://www.ipmet.unesp.br/*

The Zoo is an important recreational space for the city and region, comprising an area of 20 acres inserted into a region of cerrado vegetation of more than 200 acres (www.zoobauru.com.br). Its inner space consists of totally unshaded areas of direct solar incidence, areas partially shaded by vegetation and areas shaded by built covers, as can be seen in Figure 2 respectively.

To analyze the thermal perception of the users, one of the areas of longest permanence time within the park, "the Food Court" (Figure 3) was chosen. This place is quite shaded by vegetation and is used for relaxation and meals by users who have family picnics or to school tours. The permanence time at the site varies from a few minutes to two or three hours.

Figure 2 *Different areas of the Zoo: a) Area of felines (left) and circulation spaces, unshaded sites of direct solar incidence; b) Area of birds and local open spaces of permanence (center) partially shaded by adjacent vegetation; c) Area of primates, reptiles and penguins (right), areas shaded by built covers.*

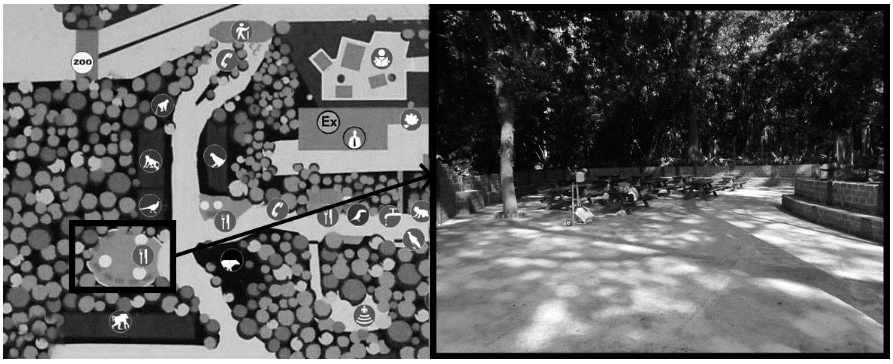

Figure 3 *Partial internal map of Bauru Zoo, especially the Food Court, site of the data collection. Adapted from www.zoobauru.com.br.*

Microclimate Monitoring

To monitor the microclimate in the food court, a mobile weather station was used with the following sensors: 1. Globe Temperature Sensor (Model 1: 0613 1712; manufacturer: Testo), built with official ping pong ball painted in gray-bourgeois (emissivity 0.9, solar reflectance 0.3); 2. Temperature and Humidity Data Logger (Model: Testo 175-H1); 3. Heated Sphere Omnidirectional Anemometer (Ø 3 mm, Model: 0635 1549; manufacturer: Testo); 4. Net radiometer (Kipp & Zonen manufacturer).

As this is a pilot study, with the aim to asess methodology for a larger project, the monitoring was carried out in just 2 days in warm weather conditions (October 26 and November 3, 2013), from 9 am until 4 pm, at intervals of 5 minutes. This Corresponds to 1 hour after the park opening team and one hour prior to its closing, During Which there is a greater number of people visiting the park.

Structured questionnaires

Structured questionnaires were applied to a sample of 115 users simultaneously to the monitoring of the microclimate. The questionnaire (Figure 4) addressed a question about the Actual Sensation Vote (ASV) on a 7-point scale, and questions about thermal preference, feeling about the wind and relative humidity. Personal data of each user were also collected: age, gender, weight, height, clothing, activity developed.

In the questionnaires, users were divided into 3 age groups: children (under 12 years), teenagers (13-20 years) and adults/elderly (over 21 years). In this division, children had some difficulty in understanding the questions and required further explanation of each question so that they could give a response that reflected their real thermal perception.

This study was unable to establish an optimal sampling in view of the lack of quantitative survey of visitors by park management. Moreover, the greater permanence space analyzed is used only by part of the users and not all park visitors. Thus, the option was to interview the maximum number of people available, coming to a final number of 115 respondents.

At the moment, what is your thermal sensation?

Very cold	Cold	Little cold	Neither cold nor warm	Little warm	Warm	Very warm

At the moment, what is your thermal preference?

Colder	Same temperature	Warmer

At the moment, what do you think about the wind?

Windless	Neither little wind nor windy	Windy

At the moment, what do you think about the humidity?

Dry	Neither dry nor wet	Wet

Do you feel comfortable?

Yes	No

Figure 4 *Part of the questionnaire applied.*

Thermal Comfort Index

In-loco surveys were used as input data of RayMan software (Matzarakis, Rutz & Mayer, 2007), to calculate the index PET (Physiological Equivalent Temperature), developed by Höppe (2002). This index is widely used in Brazilian studies (Dacanal et al., 2010; Fontes et al., 2012; Labaki et al., 2012, among others), due to the representativeness of their results, and also the ease of use by RayMan software.

For the insertion of data in the software, it was necessary to calculate the mean radiant temperature with Software Comfort 2:02 (Ruas, 2002) and also the body surface of each user, using the formula of Dubois (http://www.sbn.org. br/equacoes/eq6.htm) for the conversion of metabolic rate in W/m2 for W. Thus, the PET index was determined for each user and the following analyzes were performed: 1. Distribution of the thermal sensation frequency (ASV) and the thermal preference of users (for all users and by age group); 2. Frequency of users' thermal sensation in relation to ventilation and relative humidity; 3. Distribution of PET range for users in general and for different ages.

RESULTS AND DISCUSSION

During the fieldwork (October 26 and November 3, 2013), the data from the local weather station (IPMet) characterized the weather as hot and dry, with temperatures above the historical average for the months in question. In those days, the mornings were mild, with temperatures ranging from 23.8 ° C to 24.9 ° C at 9am in the early surveys, and reached 31.5 ° C at 4pm, end of microclimate monitoring. The relative humidity reached the highest value of 73.7% and the lowest 40% in the afternoon.

The data collected in the Food Court showed more pleasant microclimates observed in the IPMet, due to the fact that it is a place partially shaded by vegetation. The difference in air temperature in these two sites got an average of 1.4°C and reached the highest value of 2.8°C at 10:15am of the second day.

Regarding the relative humidity data the values mean monitored in zoo were until 8.7% higher than values observed in IPMet.

Figure 5 shows the behavior of the temperature and relative air humidity over the two days of measurement at fixed measuring point in the park. The air temperature ranged from 22.6 to 31.9°C and relative air humidity from 41.9 to 75.2%. The graphs show the high temperatures and low humidity in the afternoon. These data contributed decisively to thermal perceptions in this period compared to those observed during the mornings.

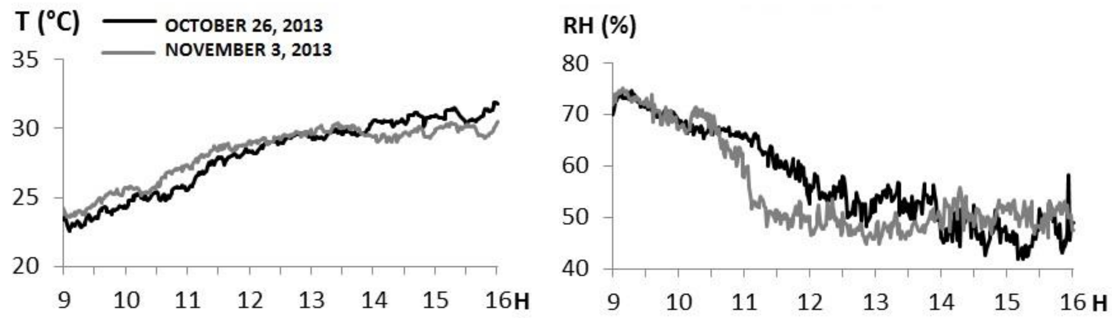

Figure 5 *Temperature and relative air humidity during the measurement days in Bauru.*

Regarding the questionnaires, the profile of the respondents had similar numbers between the genders, with 52% male and 48% female. As to age, 39% were children under 12 years, 18% of young people under 20 years and 43% of adults and elderly, with almost all wearing light clothing in view of the high temperatures of the period. 70% of the respondents were from cities in the region or further afield and only 30% were local residents.

Users proved tolerant to high temperatures, since 87% of respondents stated to be feeling comfortable (thermal satisfaction), although the thermal sensation was "little warm" or "warm." This difference between satisfaction and thermal sensation is due mainly to the influence of psychological aspects, since that was a moment of leisure in an environment surrounded by greenery. However, users have shown little tolerant to solar incidence, avoiding some of the circulation spaces with great exposure of direct sunlight. There was a tendency for users to take shelter in places shaded by vegetation, such as the Food Court, and also in areas with built roofing, instinctively seeking milder microclimates.

During the afternoon, with increasing temperature around 32°C, many users felt uncomfortable, and indicated thermal sensation of "warm". Figure 6a shows the frequency of the Actual Sensation Vote (ASV) for the period, where it is possible to observe a significant number of people in a comfortable situation, but a greater number of people feeling uncomfortable by the heat (+1, +2 and +3).

Regarding thermal preference (Fig.6b), users preferred cooler temperatures (52.2%); the same temperatures (33.9%) or warmer (13.9%). There were differences in thermal preference in relation to time of day. In the morning the users preferred the same temperature or warmer. During the afternoon, the user preference was for lower temperatures.

As for the relative air humidity, 53% of users were satisfied, 31% considered dry and 19% wet. The analysis of the periods (morning and afternoon) shows that the perception of "dry" weather was concentrated during the afternoon (42-50%) and "wet" in the morning (50-75%). However, on this variable, users were satisfied throughout the day.

In relation to the wind, 57% of users said they felt satisfied with the condition of the moment and 43% thought there was little wind. The air velocity measured was low and varied from 0.2 to 2.4 m/s. This aspect can be attributed to roughness of the vegetation. This behavior was also found in research in the woods of the city Campinas-SP, Brazil, developed by Dacanal et al. (2010). The responses on this variable showed to be very subjective. There is no clear relationship between air velocity and thermal perception of the user.

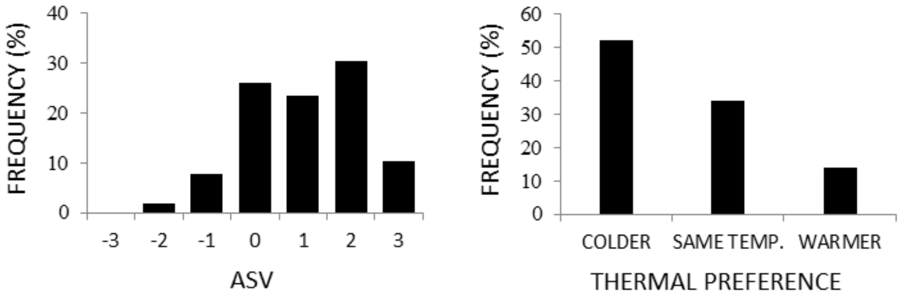

Figure 6 *Frequency of ASV and Frequency of Users' Thermal Preference, respectively. ASV.scale: -3 = very cold, -2 = cold, -1 = little cold, = 0 indifferent, 1 = little warm, 2 = warm, 3 = very warm.*

Figure 7 shows the ASV analyzed by age group (children, young people and adults/elderly). The total number of children interviewed was 45 and ASV this age group was distributed between "a little warm" (28.8%), "neither cold nor warm" (26.6%), "warm" (15.5%) 13.3% "very warm" and 2.2% "a little cold." Among young people (21 respondents), the highlight was the "hot" ASV (42.9%) and "neither hot nor cold" (33.3%). The "a little warm" scale appears with values of 14.3% and "a little cold" with 9.5%. Among adults/elderly (49 respondents), the most prominent feeling is "hot", with 38.8%, followed by "neither cold nor hot" and "a little warm", both with 22.4%. The remaining reached 4%.

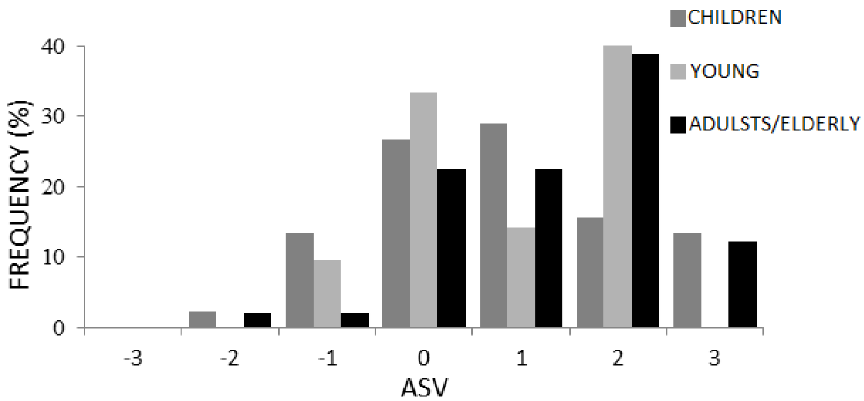

Figure 7 *Comparison of actual thermal sensation ASV between age groups.*

To define the range of comfort, the set of values of PET for each vote sensation was evaluated by means of statistical graphs Boxplot (Figure 8) which displays the PET data grouped according to the ASV, considering the total sample and the different range age (children, young people and adults/elderly). According to this graph, 50% of the central values for range of PET to the thermal neutrality were distributed between 23.5 to 29.1°C, with a median value of 25°C. This range shows values above the ones previously found by Fontes et. al (2012) for the city of Bauru (16-27 °C). However, the superposition with other intervals that indicate discomfort, either by heat or cold, makes it difficult to define precisely the limits of thermal comfort and thermal discomfort.

When analyzing the different age groups, the adults/elderly demonstrate greater tolerance to heat, with values of neutrality for PET between 25.1 to 30°C and a median value of 26.5°C. The values for the comfort range of other users are similar, i.e., they show values of PET from 23.2 to 26.5°C for children and from 22.1 to 26.7°C for young people and a median values of 24.3 and 24.1°C respectively.

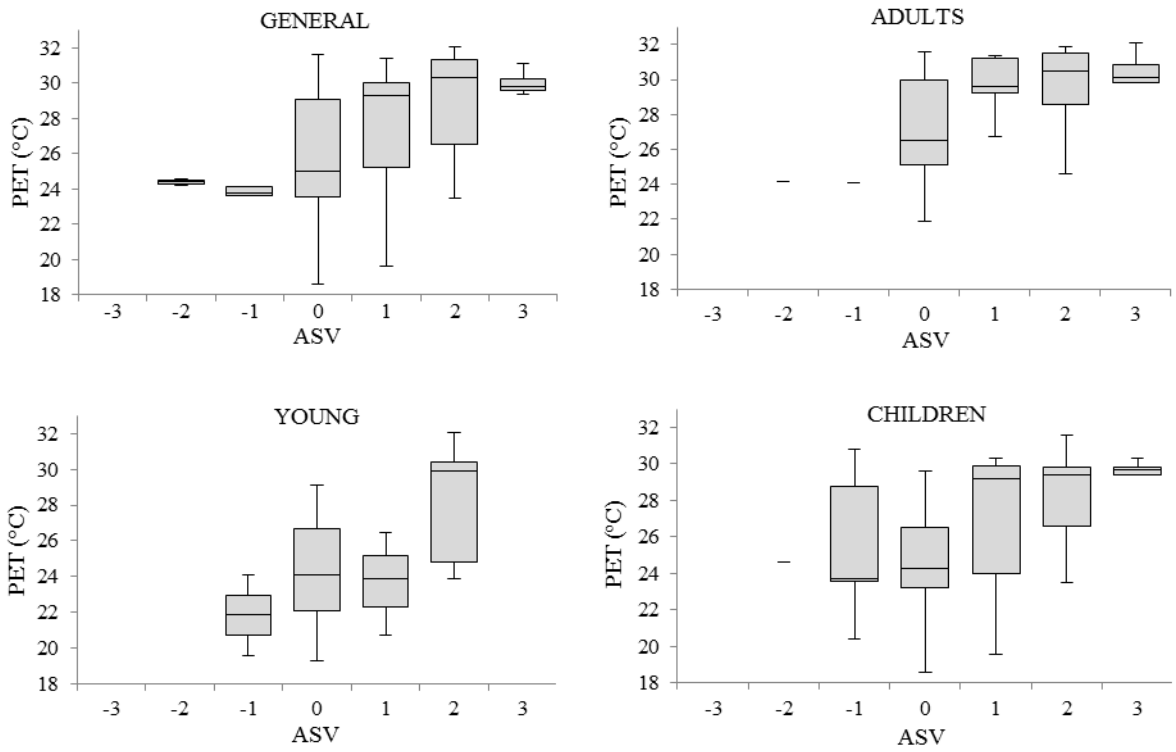

Figure 8 *Range of PET related to ASV range of the users, and separated by age group: children, teens and adults/elderlys. In the general graph, the percentage of respondents to ASV value to "Neither cool nor warm" is 26%.*

CONCLUSION

The evaluation of the thermal environment of open spaces is important to create design guidelines que can help to improve the comfort and consequently the quality of life of users. In this study, developed in warm wheather conditions, it was found que users of the park have little tolerance for direct solar incidence. Thus, for these weather conditions, future interventions shouldnt prioritize site shading, either through afforestation and / or built covers, not only in places of greater permanence, but Also in the circulation spaces.

The assessment of the Actual Sensation Votes (ASV) pointed a variation between the thermal sensation" neither cool nor warm", "little warm", "hot" and "very hot". Regarding thermal preference, most users preferred colder temperatures, specifically in the afternoon, when the air temperatures were very high (above 28 °C) and relative humidities were lower (around of 55%). The percentage of users who preferred the same local temperature was also significant.

In the microclimatic conditions evaluated, the range of thermal comfort found to PET index was 23.5 to 29.1°C for the total sample. This range shows minimum and maximum limits above those previously found by Fontes et. al (2012) for the city of Bauru (16-27 °C). In Both studies were there superposition que indicate ranges of comfort/discomfort, difficulty in proving the establishing clear limits of thermal comfort in open spaces, those already established in the literature. Regarding the analysis of the limits of thermal comfort by age groups, the differences between children and young people ranges were not significant (23.2-26.5 °C, 22.1-26.7 °C to children and young people respectively). However the differences between those thermal comfort limits and of the adult/elderly group (25.1-30.0 °C) were higher. This result shows higher tolerant to heat for that age group.

For being a pilot study, the field survey carried out in just two days was sufficient to test the methodology for the larger project that aim analyse the user thermal comfort by age group. This reasearch is unusual in surveys conducted in open spaces and can be used in architectural design in order to prioritize the needs of the largest portion of users. Thus, in the case of Bauru Zoo, an environment comfortable for children´s recreation may prevail over the other, creating more pleasant spaces and encouraging the permanence of that public.

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