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The effect of personal and microclimatic variables on outdoor thermal comfort: A field study in Tehran in cold season

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ABSTRACT

Outdoor thermal comfort condition is examined through field surveys in Tehran, Iran, during five days of winter. Environmental monitoring has been carried out in parallel to human surveys using interviews and questionnaires with space users. Examining the climatic data in relation to subjective thermal sensation, this study confirms the significant effect of personal (age and gender) and climatic (air temperature, solar radiation, and air velocity) variables. It also determines the outdoor acceptable thermal range utilizing the index Ta, with the neutral air temperature of 14.2 °C for cold season, which is then compared and justified with its indoor associated study. Finally, this research endorses environmental stimulation and expectations as two major parameters of psychological adaptation influencing thermal perception in this study.

1. Introduction

Outdoor thermal comfort issues have recently gained a considerable attention in context of urban microclimate studies for a variety of reasons. Initially, microclimate is an important issue in determining the quality of outdoor spaces, since people's sensation of thermal comfort is critically affected by local microclimate. Also, microclimate influences decisions on whether or not to use the space. Different studies have confirmed that thermal, and by implication, comfort conditions, affect people's use of outdoor spaces and its frequency (Chen & Ng, 2012; Eliasson, Knez, Westerberg, Thorsson, & Lindberg, 2007; Givoni et al., 2003; Katzschner, 2006; Mayer, 2008; Nikolopoulou, Baker, & Steemers, 2001; Zacharias, Stathopoulos, & Wu, 2001). Furthermore, indoor thermal condition of the buildings is affected by the surrounding outdoor environment. Thus, modifying outdoor conditions can improve indoor thermal condition and affect building energy consumption by reducing the energy demands for creating comfortable indoors (He, Hoyano, & Takashi, 2009; Hoppe & Seidl, 1991; Zhu et al., 2007). Finally, climate is one of the key factors influencing development in the tourism sector, and different studies have shown that climate is a pervasive factor in tourism decision-making (de Freitas, 2003; Lin & Matzarakis, 2007; Matzarakis, de Freitas, & Scott, 2004). A study by Murphy, Pritchard and Smith (2000) indicates that the destination environment −the climate of which is a major factor- is a highly significant predictor of destination quality. Likewise, trips to summer and winter resorts − in order to avoid the unpleasant climatic situation confirm this notion (Tsutsumi, Nakamatsu, & Arakawa, 2005).

Accordingly, extensive research on outdoor thermal comfort issues in various climates around the world have been conducted in recent decade. A comprehensive review of these studies has been conducted by Chen and Ng (2012) and Nikolopoulou (2011). Some aimed to study outdoor thermal comfort zone in different climates in order to investigate people thermal sensation in different outdoor spaces under different climatic conditions (Ahmed, 2003; Givoni et al., 2003; Hwang & Lin, 2007; Krüger, 2011; Lin, 2009; Moreno, Labaki, & Noguchi, 2008; Spagnolo & de Dear, 2003; Thorsson, Honjo, Lindberg, Eliasson, & Lim, 2007; Thorsson, Lindberg, Eliasson, & Holmer, 2007), with different adaptive behaviors (Lin, 2009; Nikolopoulou et al., 2001; Nikolopoulou & Steemers, 2003a, 2003b; Thorsson, Honjo et al., 2007; Thorsson, Lindberg et al., 2007). These studies and some other (Zhao, Zhou, Li, He, & Chen, 2016) revealed that outdoor thermal comfort zones and levels of perception vary according to geographical, characteristic, and cultural differences. This fact elucidates the need to investigate outdoor thermal comfort (and key microclimatic and personal variables) within different climates and geographical regions independently. Personal variables studied so far are mainly focused on psychological aspects of the issue (Lin, 2009; Nikolopoulou et al., 2001; Nikolopoulou & Steemers, 2003a, 2003b; Thorsson, Honjo et al., 2007; Thorsson, Lindberg et al., 2007). While various studies have investigated effect of gender on indoor thermal comfort, a comprehensive review of which has been provided by Karjalainen (2012), few studies have focused on age and gender as effective variables on outdoor thermal sensation (Krüger & Rossi, 2011;

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Tung et al., 2014).

Outdoor thermal comfort in urban spaces has not been an issue in Iran; and the few research studies have been limited to urban parks, in warm season of the year (Monam, 2011). Therefore, this study investigates how microclimate and personal variables affect human thermal sensation in geographical, cultural, and climatic context of Tehran, Iran. Among microclimate variables, the effect of air temperature, solar radiation, and air velocity on human thermal perception is studied, which is combined with age and gender as personal variables. The latter two factors are among those personal variable which need more investigation in various climates and cultures, which is the reason this study addresses the issue. A research study has been carried out in Tehran −the capital city of Iran- in winter. It mainly consists of a fieldwork involving objective measurement (through key climatic parameters) along with subjective assessment, which examines the thermal sensation of individuals present in the urban area.

2. Field study

The study site is located in the city of Tehran, for the longitude 51_19′ E and latitude of 35_41′ N. Tehran features a semi-arid climate (Köppen climate classification: BSk), and can be generally described as mild in the spring and autumn, hot and dry in the summer, and cold in the winter. Average annual temperature in Mehrabad station reaches 17.5 °C, which ranges from 3.8 °C in January to 29.5 °C in August. Minimum and maximum temperatures of −15 °C and 44 °C have been recorded in this station for last sixty years. The annual precipitation in Tehran is around 220 mm, with the highest amount in January, and summers without precipitation. Average relative humidity varies from 25 to 46 percent in different months of the year. Fig. 1 indicates a 60-year record of meteorological data of Tehran, which is achieved through data archives of Islamic Republic of Iran Meteorological Organization (IRIMO).

The fieldwork was carried out in five days of January, between the hours 9:00 in the morning to 5:00 in the evening. A section of Valieasr Avenue (Fig. 2), a south-north street −the longest street in Tehran- was chosen for data record and interview. Due to its diversity of use and significant role in communication network, a wide range of people with different aims of presence in the street were interviewed.

2.1. Physical measurements

The objective climatic parameters investigated in the fieldwork were air temperature in shade (Ta, °C), relative humidity (RH, %) and air velocity (WS, m/s). The climatic measurements were recorded in 37 test area using a mobile system. The devices were installed on a tripod at the height of 1 m (corresponding to the average height of centre of gravity for adults); but in order not to be affected by people's movements, the anemometer was installed at the height of 2 m (Mayer, & Höppe, 1987; Thorsson, Honjo et al., 2007; Thorsson, Lindberg et al., 2007; Yang at al., 2017). Air temperature, relative humidity and air velocity were recorded at intervals of 2 min automatically (corresponding to the 4 min interview period). The characteristics of applied measurement devices are illustrated in Table 1.

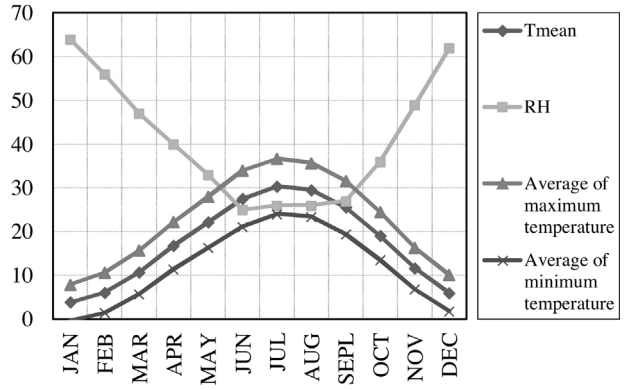

Fig. 1. Averages mean daily, maximum and minimum temperature and relative humidity of Tehran (IRIMO).

2.2. Questionnaire survey

Along with climatic measurements, a questionnaire survey was administered in order to record the corresponding subjective responses simultaneously. The questionnaire collected information in two separate parts; the first part collected information such as time, type of exposure to the sun, activity level, and clothing which was completed by the interviewers, while the second part was performed by the interviewee. The latter included demographic data (e.g. age and sex) and information such as reason and duration of presence in the street; however, it mainly asked subjects to rate their current thermal comfort and also preference (Table 2). Thermal experience was rated on ASHRAE 7-point thermal sensation vote (TSV) scale (including cold, cool, slightly cool, neutral, slightly warm, warm, and hot).

Records of subjective perception of thermal condition, wind, and sun exposure together with some additional questions of this section provided the subjective data needed. The whole questionnaire process was designed to take less than 5 min to complete, and the only personal information about the subjects recorded was gender and age. Both features were intended to reduce the rejection rate.

The subjects' group consisted of 410 persons randomly picked out, while trying to maintain an almost equal portion between male and female subjects (206–204 respectively), ranging from 13 to 76 years old. Yet, the majority of subjects (96%) are 20–65 years old.

3. Results and discussion

3.1. Summary table

Summary of the recorded climatic data in their means, ranges and standard deviation are depicted in Table 3 for the period of work. It should be noted that air temperature values recorded are quite higher than the climatological data for Tehran. Values of clothing value −as physical data with a great effect on thermal comfort- can be also seen in the table.

Outdoor air temperatures ranged from a low of 9 °C to a high of 15 °C. Mean of air velocity was 0.28 (m/s) and the mean of relative humidity was around 51%. Mean clothing value of subjects was 1.10 clo, ranging from the low of 0.50 to the high of 1.76.

3.2. Thermal sensation vote: data and analysis

As previously stated, thermal experience was rated on ASHRAE 7-point thermal sensation vote (TSV) scale (i.e., 3- as cold; 2- as cool; 1- as slightly cool; 0 as neutral;1 as slightly warm; 2 as warm; and 3 as hot). Table 4 displays the distribution percentage of number of TSVs of all subjects in the study, while mean of TSV equals −0.48 and standard deviation is 0.65.

The percentage of people feeling neutral (TSV = 0) was highest (56%), while the percentage of people who felt slightly cool (TSV = −1) was the next high vote (38%). Assuming the TSV range of (-1, +1) as the thermal acceptable range −which will be further discussed in section 3.5- and according to Tables 2 and 3, it could be suggested that with total mean value of air temperature of 11.87 °C (ranging between 9.0 °C and 15.0 °C), more than 90% of reported votes lie in thermal comfort conditions.

Fig. 3 illustrates the number of TSVs in ASHRAE scale along with mean value of Ta in each set. As could be predicted, the mean value of