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Thermal perception of outdoor urban spaces in the hot arid region of Cairo, Egypt

Mohamed H. Elnabawi*, Neveen Hamza, Steven Dudek

School of Architecture, Planning and Landscape, Newcastle University, UK

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ABSTRACT

Urban microclimatic conditions affect the human body energy balance and individuals' thermal perception; which in turn influences their usage of outdoor spaces. This study investigates users' thermal comfort in an urban street in a hot arid climate of Cairo, Egypt. The investigation was carried out in two different climatic conditions; summer and winter, using subjective surveys on the perception of the thermal environment applying the seven-point ASHRAE 55 thermal sensation votes (TSV). The survey is complimented by a one week of field measurements in both seasons to examine the main climatic parameters affecting thermal comfort in term of psychological and personal factors. The thermal acceptability by means of thermal sensation votes was assessed based on physiologically equivalent temperature (PET). Analytical results indicate that the thermal comfort ranges were between 23 and 32 °C PET while the preferred temperatures were 29 °C PET in summer and 24.5 °C PET in winter. These values were higher than that of the temperate climates and European scale, confirming the existence of thermal adaptation and indicating that the physical environment and the psychological adaptation is argued to be complementary rather than contradictory, and consideration of this duality could increase the use of the city's open spaces.

1. Introduction

Thermal comfort as a term has been defined in numerous ways based on how it has been examined. For instance, Fanger's (1972) definition links thermal comfort and the rate of energy gains and losses by the human body, describing the state of comfort when all heat flows to and from the body in equilibrium. In this definition, Fanger's (1972) studies were mainly based on the rational model, which accounts for environmental conditions and physiological regulation of body temperature within a limited range. According to British standard BS EN ISO 7730 (2013) and ASHRAE (2009), thermal comfort is defined as "the state of mind that expresses satisfaction with the surrounding environment". This means that comfort is not a state condition, but rather a state of mind, which in turn highlights the social and psychological dimensions. Although this description suggests psychological influences, thermal comfort was approached from a purely physical perspective for a long time. Accordingly, the first attempts made to assess thermal perception and grade thermal stress consisted of the simply measurable physical variables like air (dry-bulb) temperature (Parsons 2003). Later, thermal indices included wet-bulb temperature and air velocity, like the indices based on 'Effective Temperature'(Parsons 2003; Gagge et al., 1986). In 1926, Macpherson defined the following six factors affecting thermal sensation: air temperature, air speed, humidity, mean radiant temperature, metabolic rate, and clothing levels (Goldman, 1999; Berglund, 1978). Since then, a range of other indices for thermal comfort, which included more personal parameters like clothing degree and metabolic rate, were later developed with the 'Predicted Mean Vote' (PMV) by Fanger (1972), 'physiological equivalent temperature' (PET) (Höppe, 2002; Höppe & Mayer, 1987; Mayer, 1993; Matzarakis, Mayer, & Iziomon, 1999) and the COMFA index (Brown & Gillespie, 1995). All these indices reasonably produce near accurate predictions of occupant thermal sensation; however, their sole focus on the physiological and physical dimensions was increasingly criticized, as the climatic chamber method used to underpin these indices failed to include many subjective, social and cultural real world situations (Han, 2007). Moreover, these indices are almost exclusively designed on theoretical analyses of human exchange in mid-latitude climatic in North America and Europe, such as ASHRAE standards and the ISO (Han, 2007). Other studies in different climatic regions have refuted this hypothesis and indicated a wider range of adaptation and tolerance to local conditions. Lin (2009), for example, studied outdoor thermal perception and adaption in a hot and humid subtropical

* Corresponding author. Tel.: +4407550233393.
E-mail address: melnabawi@aucegypt.edu (M.H. Elnabawi).

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climate of Taiwan, and reported that the thermal acceptance range for the entire year was 21.3–28.5 °C PET, significantly higher than the European scale of 18–23 °C PET (Lin, 2009). Another study in the hot summer Mediterranean climate of Tel Aviv found the PET values were higher by 3 °C PET than the European scale and lower by 5 °C PET than the lower boundary of Taiwan (Cohen, Potchter, & Matzarakis, 2013). Additionally, Mahmoud (2011a,2011b) investigated people's thermal comfort in an urban park of Cairo, Egypt. The study argued that the comfort range of PET for the urban parks in Cairo is 22–30 °C in summer and 21–29 °C in winter, which is also higher than the European scale.

These results revealed that a purely physiological approach is inadequate to characterize thermal comfort conditions outdoors, and thermal adaptation, which involves behavior adjustment (personal, environmental, technological or cultural), physiological factors (genetic adaptation or acclimatization), and psychological factors (habituation or expectation) as playing an important role in the assessment of thermal environments (Brager and de Dear 1998;; Knez, Thorsson, Eliasson, & Lindberg, 2009; Lin, 2009; Nikolopoulou, Baker, & Steemers, 2001; Nikolopoulou & Steemers, 2003; Thorsson et al., 2004; Yang, Nyuk Hien Wong, & Kardinal, 2013). Thus, different scholars such as Nikolopoulou and Lykoudis (2006), Lin and Matzarakis (2008), Kántor, Égerházi, and Unger (2012), Kántor, Unger, and Gulyas (2012) and Cohen et al. (2013) suggest that calibration should be carried out using local subjective comfort data conducted from field surveys to provide a broader perspective to assess thermal comfort in urban spaces. Thus, the present study provides empirical data from field survey coupled with in-situ measurements conducted in outdoor urban street during the summer and winter of the year 2012 in the hot arid climate of Cairo, Egypt, where a very rare outdoor questionnaire surveys have been published in such a climate.

The main objectives of this study are as follows:

1. To evaluate the pedestrians' thermal comfort perception and preference in outdoor urban spaces of Cairo.
2. To calibrate the boundaries of the human thermal sensation scale under the hot arid climate in comparison to other climatic zones.
3. To investigate the impact of thermal adaptation and behaviors on human thermal sensation in outdoor spaces.

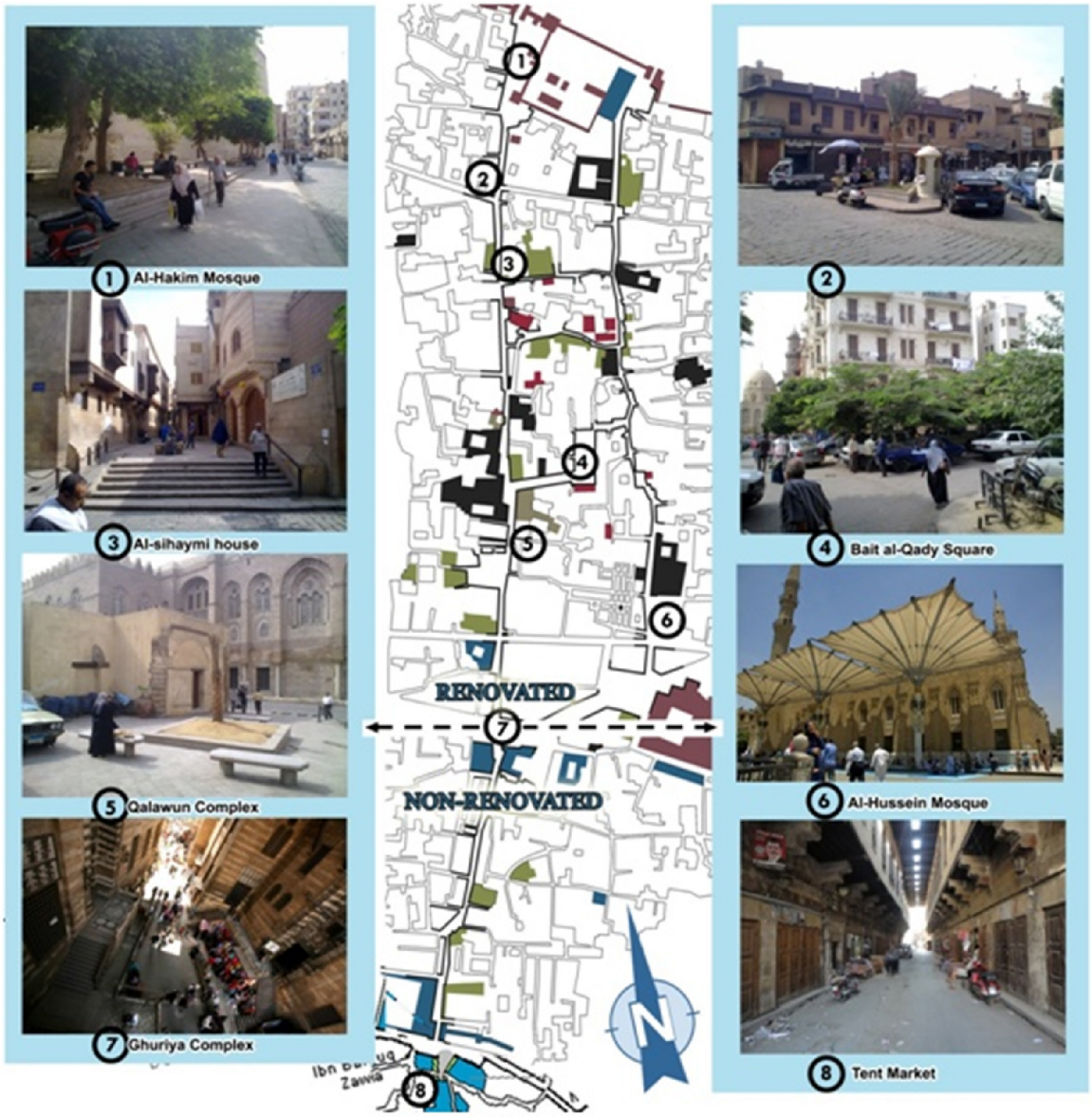

Fig. 1. A-Muizz Street runs from North to South across the middle of what scholars refer to as Islamic or Medieval Cairo.