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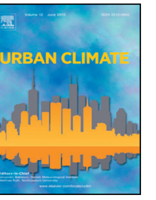

Qualitative methods to explore thermo-spatial perception in outdoor urban spaces

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To be able to design thermally comfortable urban spaces, designers require design guidelines that respond to people's thermal and spatial perception. This thermo-spatial perception is influenced by a range of dimensions: the nature and scale of spatial contexts, the kinetic state of the people and the time scale of their perception ('now' or 'the past'). Recently, novel qualitative methods have been developed to link thermal and spatial information of people's perception. To attain an overview of these methods we conducted an extensive literature review. The results show that these qualitative methods respond to the different dimensions by combinations of momentary and long-term thermal perception research in stationary mode and in motion in varying spatial environments. These qualitative methods deliver explicit combination of thermal and spatial information. Based on that evidence, new knowledge relevant to urban design of thermally comfortable urban spaces can be generated.

1. Introduction: Concepts and methods in outdoor thermal perception research

Careful climate-responsive design of urban spaces is needed to solve existing urban climate problems and face the challenges induced by climate change. To design thermally comfortable urban environments, designers need design guidelines that combine thermal and spatial matters. Such guidelines should be based

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on evidence about how urban spatial characteristics (e.g. shapes of buildings and open spaces, materials, distribution and type of vegetation) affect human thermal perception. Methods to study this connection between thermal and spatial perception are novel and need to be discussed and compared. Hence, the main aim of this paper is to give an overview of the new methods to investigate outdoor thermal perception and cast light on their usability for different research objectives.

Since the 1920s studies were conducted on human thermal environments (Houghten and Yaglou, 1923) and different thermal indices (mainly based on air temperature and relative humidity) were developed. A classical concept to describe thermal perception was given by Fanger in the 1970s. He described 'thermal comfort' as 'the human satisfaction with its thermal environment'. Fanger defined this concept for indoor environments and also developed a physiological index (PMV) to describe 'thermal comfort' quantitatively (Fanger, 1972). Since that time, various other physiological indices, e.g. the physiological equivalent temperature PET (Matzarakis et al., 1999; Mayer and Höppe, 1987) and lately the universal thermal climate index UTCI (Höppe, 2002), were developed to describe 'thermal comfort' (also see the reviews of Chen and Ng (2012) and Knez et al. (2009)). All studies that dealt with these indices included micrometeorological measurements of the thermal environments and human physiological responses.

Auliciems (1981) critically discussed these physiological thermal indices and decided to sharpen the use of terms. He described the physiological responses of the human body to thermal states with 'thermal sensation' (p. 110) and argued that the common use of the term 'thermal comfort' in the literature is not apt to describe uncomfortable thermal stimuli that humans are often exposed to. Moreover, he called for an adequate consideration of psychological influences (e.g. expectations, climate accommodation, etc.) in the description of thermal experience. He suggested a neutral and inclusive term to describe physiological and psychological influences together: 'thermal perception' (p. 119). We will use Auliciems' terminology throughout this paper because his work was seminal for the approaches to thermal perception and gained increasing acceptance throughout the past decade. Nikolopoulou et al. further questioned the purely physiological approach. They demonstrated that a physiological approach only accounts for about 50% of the variation between objective and subjective outdoor thermal perception (Nikolopoulou et al., 2001). The other part of the variation is mainly influenced by psychological factors (Nikolopoulou et al., 2001; Nikolopoulou and Lykoudis, 2006; Nikolopoulou and Steemers, 2003). Apart from that, Aljawabra and Nikolopoulou (2010) as well as Knez and Thorsson indicated that many other factors such as culture or the climate people are used to, affect thermal perception (Knez and Thorsson, 2006; Knez et al., 2009).

Rohles (1980), Auliciems (1981) and later also Nikolopoulou and Steemers introduced concepts from environmental psychology into the discourse to describe outdoor thermal perception. One major concept that relates to the temporal and ephemeral character of urban climate concerns the duration of experience: short- and long-term memory. They described how short-term experience was involved in thermal perception: "Short-term experience is related to the memory and seems to be responsible for the changes in people's expectations from one day to the following" (Nikolopoulou and Steemers, 2003, p. 97). Later on Knez and his colleagues specified the interpretation of 'short-term' and 'memory', introducing the scale of the long-term perception. It seems meaningful to differentiate momentary and longer term experience (Knez et al., 2009) (Fig. 1).

Momentary experience describes thermal perception at a specific moment in a specific place ('here and now'). The duration of such experience is in the range of seconds (Knez et al., 2009). A person could, for example, express momentary thermal perception this way: 'I feel cold right now, here in the shade of the building'. Typical studies on this momentary thermal perception entailed interviews of people in outdoor spaces such as the studies of Nikolopoulou et al. on the 'Actual Sensation Vote' (Nikolopoulou et al., 2004; Nikolopoulou and Lykoudis, 2006). An indirect way to acquire insights into people's immediate behavioral response to a thermal environment was the use of observations in urban spaces (Kántor and Unger, 2010; Katzschner, 2004; Katzschner et al., 2002). Based on Nikolopoulou's indications (Nikolopoulou and Steemers, 2003; Aljawabra and Nikolopoulou, 2010), Knez et al. (2009) and Lenzholzer (2010b) extended the concept of thermal perception to longer time scales based on so-called 'perception schemata'. These schemata are either based on experiencing a repetition of similar stimuli or they can sometimes also be biased through salient incidences that get 'engrained' in people's memory (Eysenck, 2006; Lenzholzer, 2010b; Neisser, 1976; Nikolopoulou and Steemers, 2003). Perception schemata help to 'pre-sort' information on

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