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Impact of site-specific morphology on outdoor thermal perception: A case-study in a subtropical location

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ABSTRACT

The paper addresses to what extent site-related factors affect the perceptual assessment of microclimate by users of outdoor spaces. Testing of this hypothesis was based on data normalization approaches in order to align thermal sensation data gathered during field surveys at monitoring points with differing urban morphologies, thereby looking at differences found between predicted and observed thermal responses. Outdoor thermal comfort surveys took place during 2009 over different seasons in pedestrian areas of downtown Curitiba (25.5°S, 49°W, 910 m amsl), a subtropical location in Brazil. Monitoring points were defined in respect of urban geometry attributes. For the measurements, a pair of HOBO Onset weather stations was used. The outdoor index Universal Thermal Climate Index and the derived Dynamic Thermal Sensation were used for comparisons to subjective thermal sensation and thermal preference data collected from 1685 respondents over 14 campaigns. Results showed visible differences in linear regression lines between sites with different Sky View Factor, which were later confirmed by ANOVA tests. Relative differences in binned data in terms of prediction errors were found to be nonlinear between groups, which points to the need for further investigations. Results thus suggest that a given point's overall appearance affects the way people thermally perceive it.

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1. Introduction

In assessments of thermal perception of users of outdoor spaces, a perfect match between thermal expectations of pedestrians and design strategies should be sought. Only from the starting point of a locally calibrated outdoor thermal comfort index, a given set of strategies can be adequately proposed by means of climate-responsive urban design. Yet, a great deal of subjectivity is involved as far as questionnaire-based thermal perception assessment is concerned. Indeed, it has been argued that a purely quantitative approach is insufficient for correctly describing comfortable conditions in outdoor spaces (Nikolopoulou and Steemers, 2003). As pointed out by Höppe (2002), psychological aspects are also part of the three different approaches to thermal comfort: the psychological, the thermophysiological and the one based on the heat balance of the human body. The psychological approach has been explored by authors such as Rohles (2007), who ran experiments with subjects in a climate chamber in the 1970s, finding out that the room's appearance can create an impact on the thermal assessment as reported by the respondents.

In outdoor urban areas, in particular among buildings, contextual aspects such as the site's appearance, presence/absence of vegetation, noise and traffic and the overall environmental quality of it play a role in how one actually "feels" the thermal environment. Perceived thermal sensation can be affected by a particular site's attribute, such as green infrastructure, which has been shown by Klemm et al. (2015a) to be responsible for increases in thermal comfort levels in a temperate climate. Upon investigating pedestrians' long-term thermal perception on warm summer days in three Dutch cities by means of questionnaire-aided surveys, such authors found out that people evaluated green urban spaces as the most thermally comfortable spaces in summer. This was aligned with subsequent physical measurements of relevant microclimate variables. The question posed by Klemm et al. (2015a) and by the same author in another paper (Klemm et al., 2015b) 'how people actually perceive thermal comfort related to urban green spaces?' is explored in the present paper, however in terms of morphology attributes and with a right-here-right-now survey approach. The underlying research topic is thus related to outdoor thermal comfort both from a psychological and from a physical perspective.

Chen and Ng (2012) further link such aspects to improvements in the quality of urban living. The subjectivity involved in studying behavioral aspects in urban settings lead both authors to conclude that the use of outdoor space is determined not only by the "state of body" but also by the "state of mind". The statement corroborates the traditional definition of thermal comfort as described by the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) (1966) "the condition of mind which expresses satisfaction with the thermal environment". For urban planning, the implication is that urban design should not only address the "real" but also the "perceived" problems (Lenzholzer, 2010).

On one hand, we know for a fact that microclimatic parameters are affected by urban morphology (Ali-Toudert and Mayer, 2006; Bourbia and Boucheriba, 2010; Krüger et al., 2010; Makido et al., 2012; Erell et al., 2014; Nonomura et al., 2014; Buccolieri et al., 2015; Jihad and Tahiri, 2016), on the other hand, and reversely, the resulting morphology might affect perceived/reported thermal sensation. In this respect, the following hypothesis can be tested: if one could ensure same, equivalent microclimatic conditions, expressed as an index value, for monitoring sites with different urban morphologies, then perhaps certain aspects of the sites' appearance will in a certain extent affect reported thermal sensation votes. The momentary response to a typical thermal assessment question 'how do you feel at this exact moment?' might thus contain experienced thermal sensation (general perception) as regards a given site's outlook. Lenzholzer (2008) argues, based on findings from environmental psychology that people develop cognitive "schemata" about the physical settings they are exposed to. In this context, interpretations and judgements of a given location are in part dependent on spatial cues. If one could identify such influencing spatial cues, then user-oriented urban design guidelines could be traced to more adequately address them.

Differently as in the studies reported by Klemm et al. (2015a, 2015b), the questionnaire used in our surveys did not comprise specific questions regarding the affective impression of the respondents to urban morphology attributes. Thus, a second objective of this paper is to evaluate whether a standard comfort questionnaire, administered at different sites throughout a number of outdoor comfort campaigns would be able to capture context-related influences on reported thermal sensation. This could further aid the process of standardizing protocols for outdoor thermal comfort research (Johansson et al., 2014).

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