Sanda Lenzholzer & Marialena Nikolopoulou, Foreword to the Special Issue on Subjective Approaches to Thermal Perception, *International Journal of Biometeorology*, **64,** 167–171 (2020) https://doi.org/10.1007/s00484-019-01857-0

Title Editorial/ Foreword: Subjective approaches to thermal perception

Sanda Lenzholzer[1], Marialena Nikolopoulou[2]

1. Wageningen University, Landscape Architecture Group, P.O. box 47, 6700 AA Wageningen, The Netherlands. E-mail: sanda.lenzholzer@wur.nl

2. University of Kent, Kent School of Architecture and Planning, Canterbury, CT2 7NR, UK. E-mail: M.Nikolopoulou@kent.ac.uk

The last few years have seen an increasing amount of research in a relatively new area of biometeorology, the intersection of outdoor thermal comfort studies with environmental psychology. Focusing on people not as mere recipients of the complex radiation exchanges outdoors and processes aiming to reach equilibrium with the internal thermoregulatory processes, but actively engaging with the perception of these thermal processes has revealed a new perspective of understanding outdoor thermal experience, enriching the scientific discourse internationally.

This new focus on the more subjective human parameter has provided a complimentary paradigm, highlighting the importance of personal, behavioural and psychological factors in outdoor thermal perception (Nikolopoulou et al. 2001, Nikolopoulou 2011). These new approaches have been increasingly adopted across the world at different geographic and climatic contexts (e.g. Stathopoulos et al. 2004; Nikolopoulou and Lykoudis 2006; Knez and Thorsson 2006; Thorsson et al. 2007a Knez and Thorsson 2008; Knez et al. 2009; Lin 2009, Lenzholzer 2010; Lenzholzer and Koh 2010; Lenzholzer and van der Wulp 2010, Aljawabra and Nikolopoulou 2010; Klemm et al. 2015b; Klemm et al. 2015a; Cortesão et al. 2016; Shih et al. 2017; Shooshtarian and Rajagopalan 2017) and a lively interdisciplinary field of research has emerged.

This Special Issue has been developed to reflect on these developments, specifically the subjective side of outdoor thermal perception and comfort, addressing a range of suitable methods for such investigations.

Why now?

The reasons to shed light on these aspects are manifold. First of all, in recent years the research paradigms to study human perception have increasingly included constructivist approaches that reflect a subjective perspective of human perceptions (Creswell 2014). A main approach within this paradigm is phenomenology that sees human multisensory sensations and the subjective interpretation of these as central themes of ‘perception’ (Heschong 1979; Husserl 1960; Merleau- Ponty 1992). In line with these developments embracing such phenomenological approaches seems necessary to supplement the predominantly positivist discourse in thermal perception studies.

Secondly, environmental psychology has significantly advanced in the past years and provided new ways of collecting data on people’s experience of their environment, including the thermal environment (Knez 2005; Lenzholzer and van der Wulp 2010). These recent developments had significant repercussions in the disciplines that shape human environments and thus the thermal environment (e.g. architecture, urban design, landscape architecture, etc.), as they aim at creating environments that respond to these perceptions. Phenomenological and psychological approaches have become leading approaches to support design decisions in these disciplines (Pallasmaa 2005). In line with these developments, phenomenological and psychological perspectives have gained importance and been taken into account in recent research on thermal perception.

Finally, the rapid development of social media and internet of things provide new approaches to collecting information from different populations which would not have been possible 20 years ago. Such progress in disparate fields have suggested it is timely to provide an overview of these recent developments through this special issue and provide an outlook into promising future concepts and methods.

Contents and highlights

The Special Issue includes a range of methodological approaches in the field of outdoor thermal comfort, as well as geographical spread and climatic zones (Figure 1).

Table 1: Authors and titles of articles in the current special issue

Authors	**Title**	**doi**
J. Cortesão, F.B. Alves and K. Raaphorst	Photographic comparison: a method for qualitative outdoor thermal perception surveys	10.1007/s00484-018-1575-6
T. Sharmin and K. Steemers	Effects of microclimate and human parameters on outdoor thermal sensation in the high-density tropical context of Dhaka	10.1007/s00484-018-1607-2
Pantavou, S. Lykoudis, M. Nikolopoulou and I.X. Tsiros	Thermal sensation and climate: a comparison of UTCI and PET thresholds in different climates	10.1007/s00484-018-1569-4
L. Giuffrida, H. Lokys and O. Klemm	Assessing the effect of weather on human outdoor perception using Twitter	10.1007/s00484-018-1574-7
H. Leng, S. Liang and Q. Yuan	Outdoor thermal comfort and adaptive behaviors in the residential public open spaces of winter cities during the marginal season	10.1007/s00484-019-01709-x
E. Sharifi and J. Boland	Passive activity observation (PAO) method to estimate outdoor thermal adaptation in public space: case studies in Australian cities	10.1007/s00484-018-1570-y
F.B. Faustini, J.R. Gomes de Faria and M.S.G. de Castro Fontes	The influence of thermal comfort conditions on user's exposure time in open spaces	10.1007/s00484-019-01749-3
S. Manavvi and E. Rajasekar	Semantics of outdoor thermal comfort in religious squares of composite climate: New Delhi, India	10.1007/s00484-019-01708-y
L. Klok, N. Rood, J. Kluck and L. Kleerekoper	Assessment of thermally comfortable urban spaces in Amsterdam during hot summer days	10.1007/s00484-018-1644-x
A. Lemonsu, A. Amossé, D. Chouillou, N. Gaudio, S. Haouès-Jouve, J. Hidalgo, J. Le Bras, D. Legain, S. Marchandise and B. Tudoux	Comparison of microclimate measurements and perceptions as part of a global evaluation of environmental quality at neighbourhood scale	10.1007/s00484-019-01686-1
C. Vasilikou and M. Nikolopoulou	Outdoor thermal comfort for pedestrians in movement: thermal walks in complex urban morphology	10.1007/s00484-019-01782-2
F. Aljawabra and M. Nikolopoulou	Thermal comfort in urban spaces: a cross-cultural study in the hot arid climate	10.1007/s00484-018-1592-5
S. Lenzholzer and S. de Vries	Exploring outdoor thermal perception—a revised model	10.1007/s00484-019-01777-z

Out of the 13 papers, seven focus in cities outside Europe; from the winter city of Harbin (Leng et al.), to the continental Northeasst USA (Giuffrida et al), and the more temperate city of Adelaide (Sharifi

and Boland), to the more tropical cities of Sao Paolo (Faustini et al.), New Delhi (Manavvi and Rajasekar), Dhaka (Sharmin and Steemers) and the drier conditions of Phoenix and Marrakesh (Aljawabra and Nikolopoulou). The European context is analysed in five papers focusing on the cities of Amsterdam (Klok et al.); Toulouse (Lemonsu et al.), Porto (Cortesão et al.), Rome and London (Vasilikou and Nikolopoulou) and Athens, Thessalonica, Milan, Fribourg, Kassel, Cambridge and Sheffield (Pantavou et al.). This international coverage confirms the global reach and importance of the remit of outdoor thermal comfort.

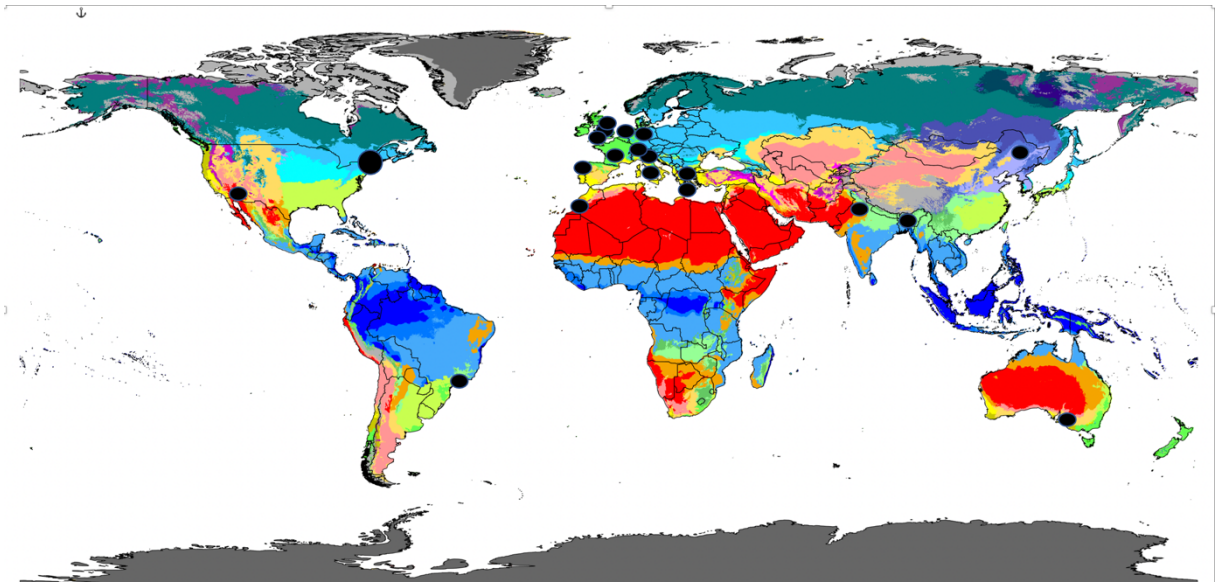

Fig. 1: Köppen climate zone map depicting the geographic and climatic distribution of the cities and regions investigated in the current special issue

The work submitted to this Special Issue reflects a methodological variation, focusing on different aspects of thermal perception and comfort. The work includes mixed methods, some more established than others for the specific cognate area. Phenomenological and ethnographic approaches complement more traditional methods collecting data and comparing subjective with objective methods to draw relevant conclusions. Innovative social media platforms such as twitter (twitter.com) are also included (Giuffrida et al.), highlighting potential next steps in capturing large scale subjective data from multiple areas, surpassing the difficulties of traditional comfort surveys; as well as theoretical position papers aiming to construct an extended model of thermal perception (Lenzholzer and de Vries).

The different contributions ultimately aim to understand thermal perception, the driving forces behind it and how these can be employed in design and planning of our cities, as well as different prediction and warning systems for the public. The notion of adaptation and environmental diversity becomes integral for health and well-being under the unprecedented global warming our cities phase.

Methodological approaches

Integral to all the approaches presented in the different studies is the need to triangulate evidence from the different surveys studying human perspectives (whether through interviews, or observations) with meteorological measurements available at different scales, from the microclimate participants experience to weather stations. Such work continues to provide bridges between the different disciplines of architecture, design and planning with geography, meteorology and climatology enabling the dialogue, essential for the cross-disciplinary approaches.

Portable meteorological stations have been employed, usually accompanying structured surveys with members of the population in transverse surveys. In studying the subjective perspective, different

approaches have been followed; from passive activity observations to estimate thermal adaptation in Adelaide (Sharifi and Boland) to the use of photographic comparisons in Porto (Cortesão et al.), and photographic records in Sao Paolo to estimate exposure times (Faustini et al.).

To overcome the need for collecting wider samples to represent a population, two studies used longitudinal methods with structured walks with small groups. Lemonsu et al. consider thermal perception as one of the components of environmental perception in Toulouse, while Vasilikou and Nikolopoulou organised a series of thermal walks in London and Rome in different seasons, to evaluate the variation of thermal perception in the urban fabric, highlighting the role of walking in thermal diversity.

At the regional scale, Giuffrida et al. demonstrate how twitter can provide meaningful information on linking tweets containing weather-associated words with thermal perception, while linking with real-time meteorological data. This feasibility study successfully paves the way for further employment of social media platforms and Internet of Things in the wider thermal comfort debate.

Regarding evaluation methods, in many of the studies, there is an attempt to link subjective indicators of thermal sensations as collected from the surveys with different indicators from literature, predominantly developed for outdoor use. From the range of theoretical indicators presented in the special issue, the most widely used have been the Physiologically Equivalent Temperature (PET) and Universal Thermal Comfort Index (UTCI), employed by Sharifi and Boland, Manavvi and Rajasekar, as well as Pantavou et al.; while Klok et al. and Leng et al. use PET. All these studies are aiming to quantify different aspects of adaptation, whether through linking with thermal sensation, or thresholds as a function of different climatic parameters. Another useful approach highlights the use of existing datasets and the need for developing open-access data. With the increasing occurrence of outdoor comfort surveys across the world, this can become an important resource which can allow further analysis in the future. One such study is the paper by Pantavou el al., who use meta-analysis of the largest publically available dataset on outdoor thermal comfort to-date, that of project RUROS (CRES 2004), to quantify the contribution of climate to the long-term thermal adaptation.

Many authors discuss the effect of design-related parameters on thermal comfort; however, Klok et al., succeed in also quantifying such influence, linking the cooling effect of green, shade and water with thermal comfort based on measurements as well as surveys. Shading appears to be the most influential parameter during hot weather, and such information is critical for urban planners and other professionals who may be tasked with reducing urban heat.

Activities

Outdoor spaces can support a range of activities and can play an important role for health and well-being both directly, allowing outdoor activities to take place, including walking and exercising, as well as indirectly, supporting informal activities, socialising, to providing suitable conditions for cooling when the indoor environment becomes unhospitable. Different authors discuss activity across a wide spectrum from essential to optional, static to dynamic.

In the winter city of Harbin, Leng et al., focusing on residential open spaces, highlight the low thermal threshold value of 10.2 ºC for outdoor activities and how design can be employed to increase the marginal season.

Similarly, Sharifi and Boland, differentiating between social and necessary activities highlighted the wide range of thermal conditions between the two types. Once again thermal adaptation varied widely between different sites, depending on supportive land use, as well as spatial and landscape features.

These are also the results of Faustini et al., who investigate time of exposure in two different areas in the zoo of Baaru, Sao Paolo. Although use of different areas was similar in relation to the number of

people visiting the different areas, people spent longer time in the spaces with more favourable microclimatic conditions, i.e. better shading.

One typology of open spaces that had not been investigated before, but where outdoor comfort conditions have a considerable influence is religious spaces. These provide the framework for the analysis of Manavvi and Rajasekar, in two religious squares is New Delhi. Adaptation elements such from solar exposure and landscape, as well as implicit physiological factor such as intent of visit and thermal history have a significant effect on thermal perception. Particularly for those visiting the squares for religious purposes, neutral PET was 2.7 ºC higher than those visiting for non-worship purposes, once again highlighting the importance of psychological adaptation.

Social construct?

Socio-economic and cultural backgrounds are rarely investigated in outdoor comfort surveys. It is generally acknowledged that outdoor space is predominately accessible to all. Although there is specific mention to spaces drawing people from different economic backgrounds and social hierarchies in the special issue, such as the religious squares, this is explicitly discussed by Aljawabra and Nikolopoulou. Focusing on a similar hot-arid climate of Marrakech in Morocco and Phoenix in Arizona, they highlight the effect such factors can have on thermal comfort. Due to the prevalence of air-condition in Phoenix, people were more sensitive to changes in air temperature and solar radiation, demonstrating a narrower comfort zone. Interestingly, in both cities, people from lower socio-economic background were found to be comfortable at a wider range of temperatures. Given the financial and environmental expense of using air-conditioning, comfortable outdoor spaces can thus provide suitable alternatives supporting outdoor activities for different population groups.

What for the future?

The special issue concludes with a position paper by Lenzholzer and de Vries. They assess the recent literature on outdoor thermal perception, aiming to develop an extended model of thermal perception that explicitly includes the subjective approaches, identifying knowledge gaps and suggesting new methods to study outdoor thermal perception. From refinement of the development or thermal indices to multisensory perception or technological developments, and immersive experiences, whether physical or digital, we are still in the infancy of fully articulating and quantifying the psychologically aspect of thermal perception. Although the model still remains speculative, the evidence provided throughout this special issue has highlighted a number of important issues.

Where personal data is not available, predictive models can be useful to inform comfort conditions and justify the efforts using publicly available data sources. The recurrent theme across the submissions highlights the important role of adaptation in supporting human activities. In this framework, design can be viewed as integral to increase environmental diversity and enhance adaptive capacity. This requires collaboration between different disciplines and understanding of semantics of different fields; from land use to urban morphology, to natural or other design interventions, all highlighting the importance of the network of open spaces. This aligns with the findings from a recent Special Issue from the built environment, which demonstrated that the fabric-first approach focusing on buildings as isolated entities needs to be revisited (Emmanuel and Steemers 2018).

Undoubtedly, we foresee a need for further research in the field. Focusing on the most densely populated regions, such as southeast Asia, Africa and south America can provide evidence for the critical role of open spaces, as well as health and well-being. In a changing climate, thermal perception is paramount to the development of comfortable open spaces, which not only increase resilience but also enable social justice ensuring access to comfortable environments to the wider population.

Acknowledgements

The editorial work on this Special Issue was partly funded by the Research fellow fund of the Wageningen Institute for Environment and Climate Research (WIMEK)

References

Aljawabra F, Nikolopoulou M (2010) Influence of hot arid climate on the use of outdoor urban spaces and thermal comfort: Do cultural and social backgrounds matter? Intelligent Buildings International 2 (3):198-217. https://doi.org/10.3763/inbi.2010.0046.

Cortesão J, Alves FB, Corvacho H, Rocha C (2016) Retrofitting public spaces for thermal comfort and sustainability. Indoor and Built Environment 25 (7):1085-1095. https://doi.org/10.1177/1420326x16659326

CRES, Centre for Renewable Energy Sources (2004) RUROS project & database, http://alpha.cres.gr/ruros.

Creswell JW (2014) Research design : qualitative, quantitative, and mixed methods approaches. SAGE Publications, Thousand Oaks, California

Emmanuel R, Steemers K (2018) Connecting the realms of urban form, density and microclimate. Building Research & Information 46 (8):804-808. https://doi.org/10.1080/09613218.2018.1507078.

Heschong L (1979) Thermal delight in architecture. Mass, MIT Heschong L (1979) Thermal delight in architecture. Mass, MIT Press, Cambridge

Husserl E (1960) Cartesian Meditations- an introduction to phenomenology (trans: Cairns D). Martinus Nijhoff, Den Haag.

Klemm W, Heusinkveld BG, Lenzholzer S, Jacobs MH, Van Hove B (2015a) Psychological and physical impact of urban green spaces on outdoor thermal comfort during summertime in The Netherlands. Building and Environment 83:120-128, https://doi.org/10.1016/j.buildenv.2014.05.013.

Klemm W, Heusinkveld BG, Lenzholzer S, van Hove B (2015b) Street greenery and its physical and psychological impact on thermal comfort. Landscape and Urban Planning 138:87-98, https://doi.org/10.1016/j.landurbplan.2015.02.009.

Knez I (2005) Attachment and identity as related to a place and its perceived climate. Journal of Environmental Psychology 25 (2):207-218, https://doi.org/10.1016/j.jenvp.2005.03.003.

Knez I, Thorsson S (2006) Influences of culture and environmental attitude on thermal, emotional and perceptual evaluations of a public square. International Journal of Biometeorology 50 (5):258-268. https://doi.org/10.1007/s00484-006-0024-0.

Knez I, Thorsson S (2008) Thermal, emotional and perceptual evaluations of a park: Cross-cultural and environmental attitude comparisons. Building and Environment 43 (9):1483-1490. https://doi.org/10.1016/j.buildenv.2007.08.002.

Knez I, Thorsson S, Eliasson I, Lindberg F (2009) Psychological mechanisms in outdoor place and weather assessment: towards a conceptual model. International Journal of Biometeorology 53 (1):101-111. https://doi.org/10.1007/s00484-008-0194-z.

Lenzholzer S (2010) Engrained experience-a comparison of microclimate perception schemata and microclimate measurements in Dutch urban squares. International Journal of Biometeorology 54 (2):141-151. https://link.springer.com/article/10.1007%2Fs00484-009-0262-z.

Lenzholzer S, Koh J (2010) Immersed in microclimatic space: Microclimate experience and perception of spatial configurations in Dutch squares. Landscape and Urban Planning 95:1-15. https://doi.org/10.1016/j.landurbplan.2009.10.013.

Lenzholzer S, van der Wulp NY (2010) Thermal experience and perception of the built environment in Dutch urban squares. Journal of Urban Design 15 (3):375-401

Lin T-P (2009) Thermal perception, adaptation and attendance in a public square in hot and humid regions. Building and Environment 44 (10):2017-2026. https://doi.org/10.1016/j.buildenv.2009.02.004.

Merleau- Ponty M (1992) The phenomenology of perception. Routledge, London Nikolopoulou M (2011) Outdoor thermal comfort. Frontiers in Bioscience 3:1552-1568. https://doi.org/10.2741/245.

Nikolopoulou M, Baker N, Steemers K (2001) Thermal comfort in outdoor urban spaces: Understanding the human parameter. Solar Energy 70 (3):227-235. https://doi.org/10.1016/S0038-092X(00)00093-1.

Nikolopoulou M, Lykoudis S (2006) Thermal comfort in outdoor urban spaces: Analysis across different European countries. Building and Environment 41 (11):1455-1470. https://doi.org/10.1016/j.buildenv.2005.05.031

Pallasmaa J (2005) The Eyes of the Skin- Architecture and the Senses. Wiley and Sons, Chichester

Shih W-M, Lin T-P, Tan N-X, Liu M-H (2017) Long-term perceptions of outdoor thermal environments in an elementary school in a hot-humid climate. International Journal of Biometeorology61(9):1-10 https://link.springer.com/article/10.1007%2Fs00484-017-1345-x

Shooshtarian S, Rajagopalan P (2017) Study of thermal satisfaction in an Australian educational precinct. Building and Environment 123:119-132. https://doi.org/10.1016/j.buildenv.2017.07.002.

Stathopoulos T, Wu H, Zacharias J (2004) Outdoor human comfort in an urban climate. Building and Environment 39 (3):297-305. https://doi.org/10.1016/j.buildenv.2003.09.001

Thorsson S, Honjo T, Lindberg F, Eliasson I, Lim EM (2007) Thermal comfort and outdoor activity in Japanese urban public places. Environment and Behavior 39 (5):660-684. https://doi.org/10.1177/0013916506294937

Twitter https://twitter.com