Thermal notations as a design tool - evaluating the thermal comfort of pedestrians moving in spatial sequences

Carolina Vasilikou, Marialena Nikolopoulou
Centre for Architecture and Sustainable Environment, University of Kent, Kent School of Architecture, Marlowe Building, Canterbury CT2 7NR, UK
K.Vasilikou@kent.ac.uk
M.Nikolopoulou@kent.ac.uk

dated: 10 June 2015

1. Introduction

Thermal perception plays a major role in the experience of pedestrians in complex urban environments, because of the continuous change in spatial, microclimatic and comfort qualities. When moving in spatial sequences, the ability to measure thermal comfort forms a vital part of the design of comfortable urban spaces. This raises the question regarding of using an efficient and accurate way to evaluate changes in thermal perception and comfort state in spatial sequences. How can this evaluation be transformed into an efficient urban design tool, readily accessible by architects and urban designers?

Outdoor thermal comfort studies based on fieldwork tend to evaluate thermal comfort with an emphasis on the static experience of people in disconnected, separate urban spaces. The impact of pedestrian movement and passage from one space to another on thermal perception, comfort and its subtle variations has not been sufficiently analysed. The author's recent work has attempted to fill this gap by developing the methodology of thermal walks (Vasilikou & Nikolopoulou, 2014; Vasilikou, 2015). This provided an efficient tool for evaluating thermal comfort along spatial sequences through the combination of microclimatic measurements and people surveys. The present study aims to focus on the critical task of making the results of "thermal walks" accessible to architects and urban designers. This is achieved with the creation of a tool of notation that codifies a wide range of objective and subjective measurements and facilitates their interpretation and use by the non-expert.

2. Background

2.1 Thermal walks

The methodology of thermal walks was developed because of the need to understand how walking and moving between interconnected spaces may affect the thermal perception and thermal comfort of the pedestrian. This approach is based on a comparative method based on sequential experiences. This comparative approach was initially developed for the analysis of visual perception and architectural studies (Cullen, 1969) but also for indoor thermal comfort studies (Houghton in Givoni, 1976). Thermal walks consist of a sense-walking technique that analyses the urban climate, the morphology of spaces and the way people perceive their combined effect, through a series of structured walks with simultaneous environmental and human monitoring. This new process is based on point-to-point evaluation of the thermal perception and spatial variation. Its particularity is the combination of objective microclimatic and spatial data with subjective responses by pedestrians at street level.

2.2 Sensory notation

Sensory notation has been used extensively by social sciences to explore the experience of users and represent it in quantifiable terms (Lucas, 2009; Lucas & Romice, 2010; Henshaw et al., 2009). According to Cedric Price, 'mental, physical and sensory well-being is required' (in Zardini, 2005) , as improving the quality of the urban environment becomes now more than ever a necessity. It is a visual representation, based on radar diagrams that provide a holistic analysis of the sensory experience. Its merit lies in recording quantitative aspects of qualitative data, such as prioritisation of one sensory experience over another, intensity of sensory experience and corroboration. Originated from social sciences, researchers from across disciplines utilise sensory walking, soundwalks, thermal walks and smell walks as a means to focus on particular sensory experiences and express personal and intimate relationships with a place. During the walks participants are involved in discussions, interviews, photo-surveys, mapping, sound recordings, climatic measurements as well as other innovations according to the specificity of place. However, sensory notation cannot combine the objective (measured) with the subjective (perceived). The development of thermal notation tries to fill this gap, focusing on thermal perception and comfort.

3. Thermal notation

3.1 Methodology

During spring and summer 2014, the author had the opportunity to apply the methodology of thermal walks in a project of redevelopment, in collaboration with the City of Paris and the Urban Pedestrian Mobility Group (*Groupe MUP Labex Futurs Urbains* in *Universite Paris-Est*). The aim was to assess the quality of walking in a specific spatial sequence in the historic city centre and the potential of the specific urban entities of this sequence for future pedestrianisation (Vasilikou, 2014). The location consisted of *Rue du Faubourg du Temple* in the area of *Place de la Republique*. The data collection followed the methodology of thermal walks, using microclimatic monitoring and simultaneous people surveys (fig 1).

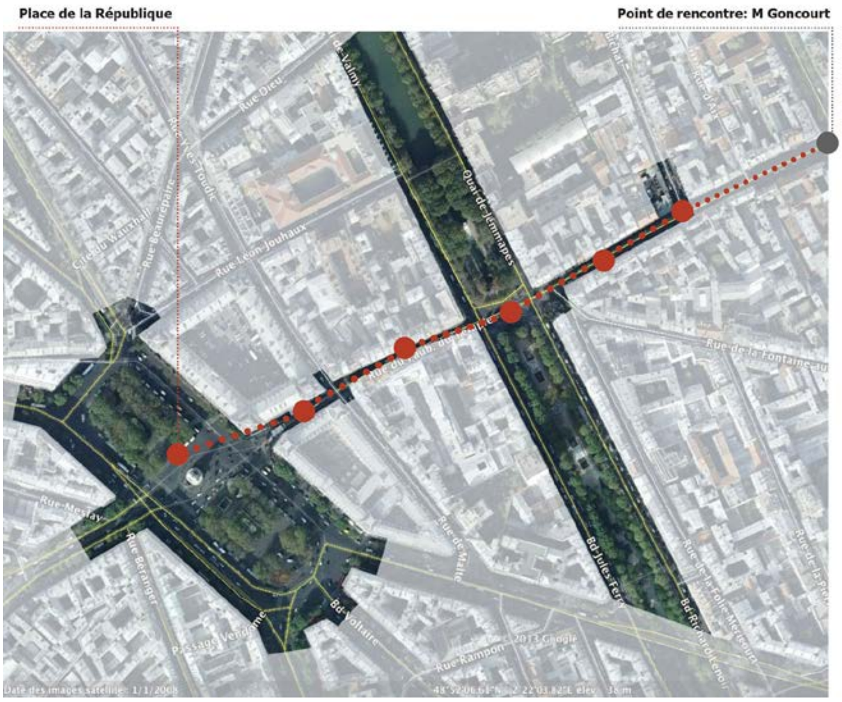

Fig. 1 Rue du Faubourg du Temple in Paris and the six focus points of the thermal walk, dividing the walk in six distinct interconnected spaces (distinguished by different geometric descriptors).

To carry out the thermal walks, the author designed a new portable weather station, which was built at Université Paris-Diderot 7 (in collaboration with Martin Hendel). Based on a tripod (fig 2), three sensors were connected to a DeltaOhm datalogger recording measurements every 15 seconds. Sensors included a hot-wire anemometer, a PT100 combined air temperature and Relative Humidity probe and a PT100 grey globe probe (constructed by the author). These recorded air temperature, relative humidity, wind speed and direction, and globe temperature (conforming to ISO 7726, 1998).

Fig. 2 Participants completing the first part of the questionnaire in Rue du Faubourg du Temple during the commissioned thermal walks in Paris city centre.

In terms of monitoring the thermal perception, thermal comfort and sequential variations in both during movement from one point of the walk to the other, the design of the questionnaire was developed so that a benchmark of Actual Sensation Vote would be recorded for every focus point. This facilitates the comparative analyses of ASVs between points, but also the recording of the perceived differential ASV (dASV) that records the variation in thermal sensation. The questionnaire used for thermal walks was re-designed to include, among others, monitoring of the following parameters of thermal perception:

- Thermal sensation (ASV),
- Wind vote
- Sun Vote
- Perceived Thermal Comfort, and
- Differential thermal sensation (dASV).

A richer analysis of the thermal sensation is conducted recording wind and sun votes, analysing the thermal perception in terms of microclimatic parameters (Nikolopoulou et al., 2001). Questions for each focus points included among other the following evaluations (using a 5-point-Likert-scale) based on the comparative approach:

1) How do you find the thermal environment at this precise moment?
a) Temperature: Cold / Cool / Neither warm nor cool / warm / hot [ASV]
b) Wind: no wind / breeze / OK / windy / too windy [Windvote]
c) Sun : would like more / OK / too much sun [Sun vote]
2) Do you feel a thermal variation in relation to your previous sensation?
Colder Cooler No variation Warmer Hotter [dASV]
3. You find this:
Uncomfortably cold uncomfortably cool Comfortable uncomfortably warm uncomfortably hot [PTC]

3.2 Thermal notation used as a design tool

As thermal walks are conducted with simultaneous objective and subjective data collection, the notation takes the form of a radar diagram method (fig 3). The diagram is structured in a way so that ASV, Sun votes and Wind votes are evaluated on the lower vertical and diagonal axis. These are directly juxtaposed with the respective comfort temperature and wind speed and radiant temperature. The horizontal axis provides the assessment of thermal comfort and the variation of Actual Sensation Vote. In this way, the use of thermal notation provides a way to represent thermal perception as an active process of climate-conscious walking.

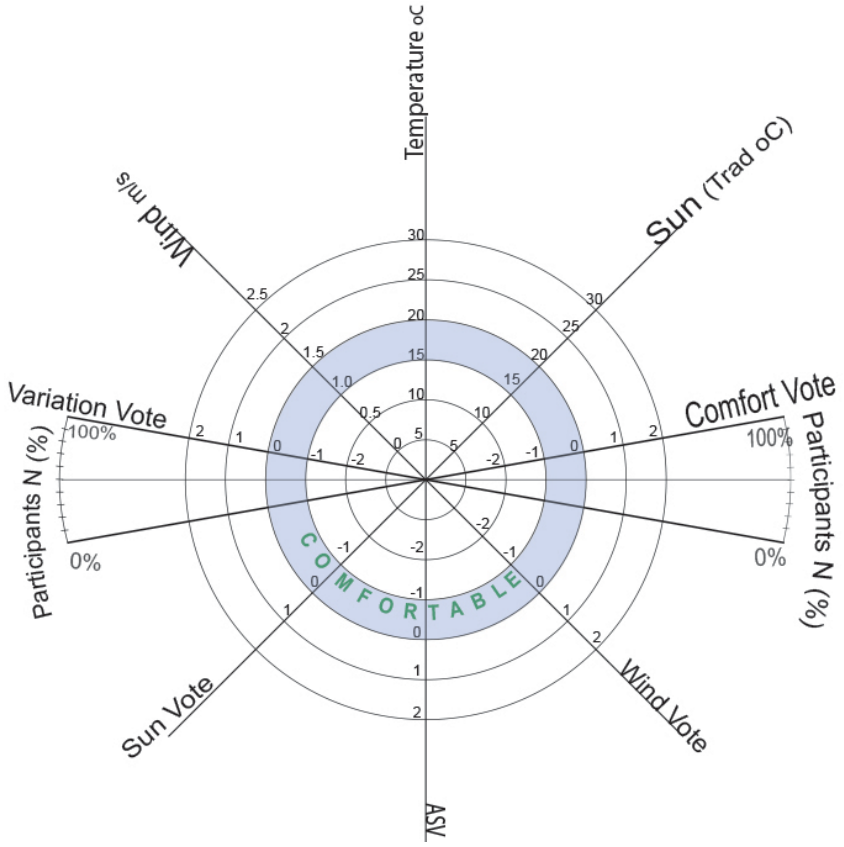

Fig. 3 Thermal notation is a new graphic representation of data collected during the evaluation of thermal perception in movement, combining all investigated parameters.

The notation progresses during the analysis of data and includes location (spatial specificity based on focus points along a spatial sequence), a descriptor (objective or subjective measurements that involve the juxtaposition between temperature, wind and solar radiation conditions and thermal sensation, wind and sun vote) and the evaluation (thermal comfort and thermal variation assessment for each focus point by participants). This provides the opportunity for the researcher and designer to juxtapose objective and subjective data in the same diagram (fig 4).

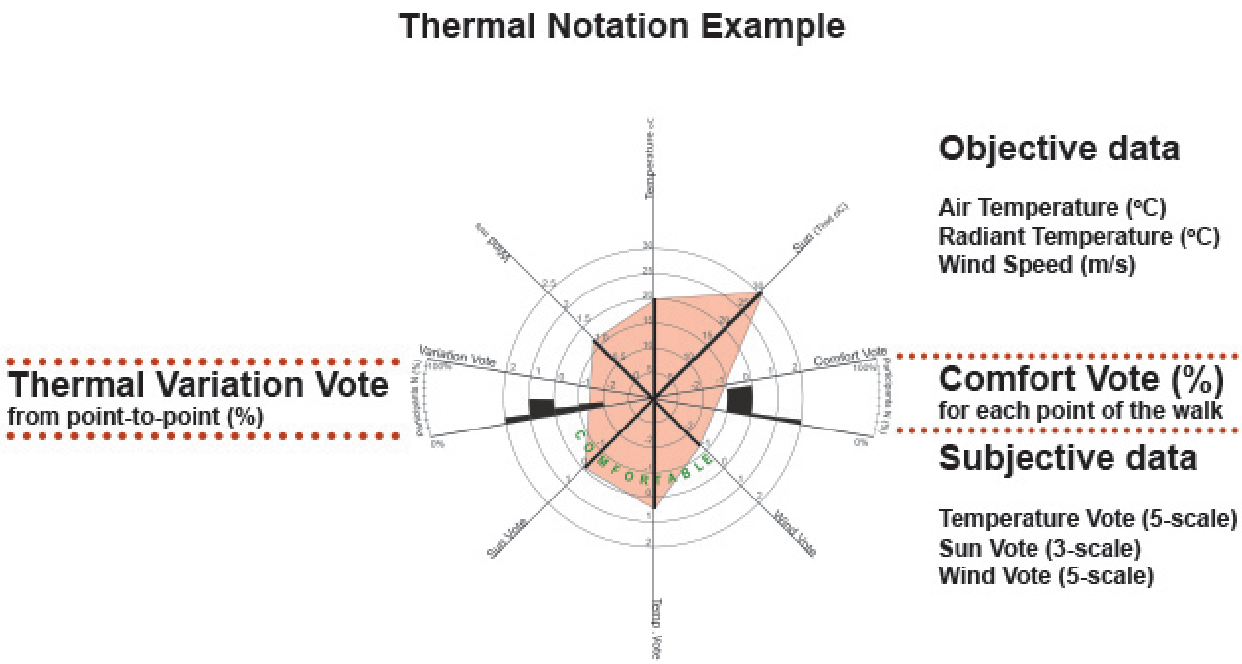

Fig. 4 This is an example of a Thermal Notation for a specific sample of people in a specific focus point of the walk, depicting both objective of microclimatic conditions and subjective data of their effect on thermal perception in a spatial sequence.

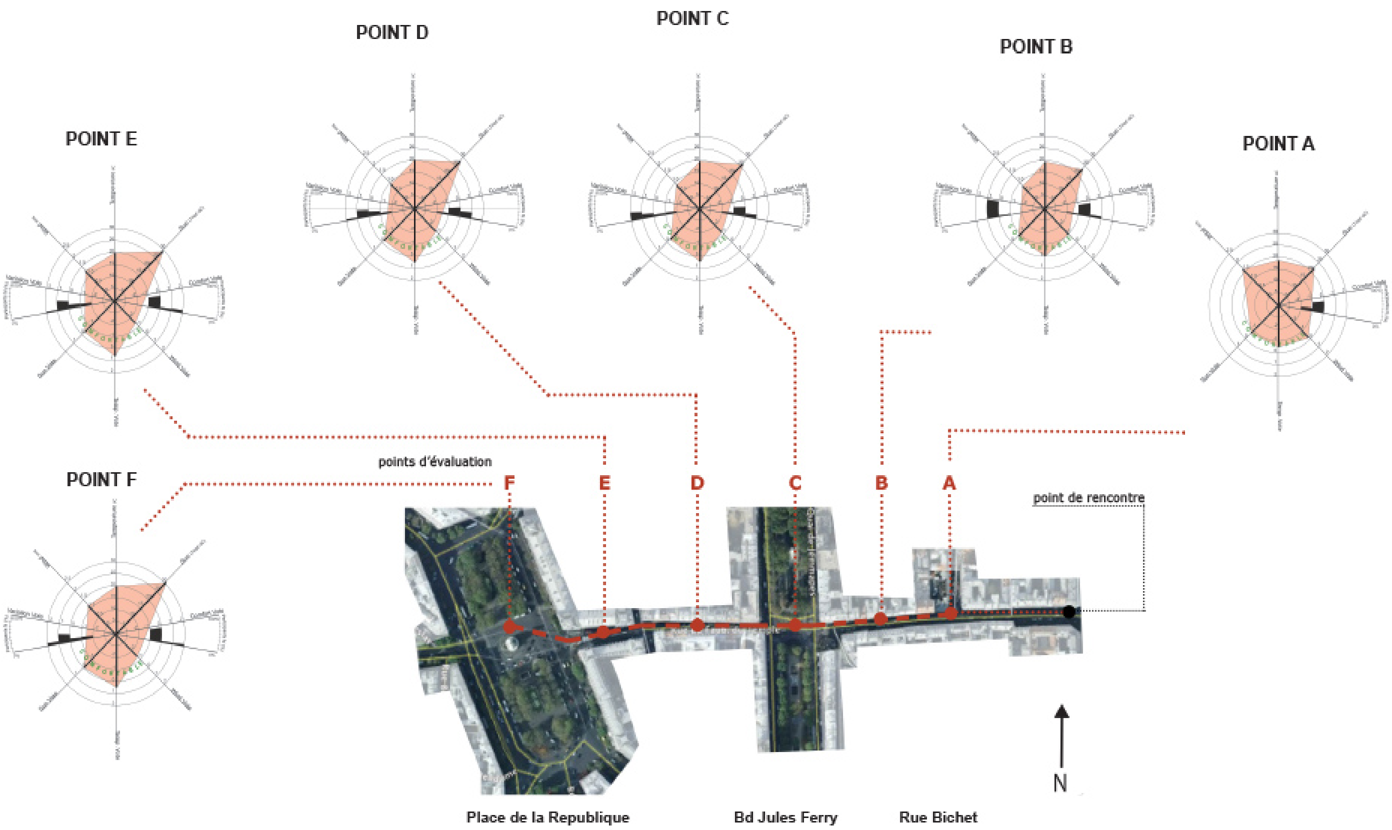

Fig. 5 Presenting the evaluation of the thermal walks in one sequence with six thermal notations for the sample of participants during the 2014 monitoring.

By locating the spatial sequence on a plan or a section, the notational scheme can be understood as a layer of transparency added to traditional modes of depicting urban spaces. The descriptors provide a measured value of each microclimatic parameter. At the same time, subjective descriptors record the pedestrians' perception of each parameter, allowing for an indication of increased influence between temperature, wind and solar radiation. Finally, this method of graphic representation provides a strong distinctive image for each thermal environment and the basis for a comparative thermal analysis between spaces. The comfort state is depicted on a 5-scale basis with comfort placed at zero, while extreme discomfort at -2 and 2. Finally, Fig 5 shows the application of thermal notation to the overall evaluation of a spatial sequence. The designer may use this tool to identify spaces of discomfort and find ways to improve them.

4. Conclusions

The project findings contributed in developing design guidelines for proposals of partial pedestrianisation and climate-sensitive intervention in specific parts of the spatial sequence in *Rue du Faubourg du Temple*. This necessitated the communication of outdoor thermal comfort to designers and policy-makers through technical reports. The evidence-based comparative approach shows the importance of pedestrians as generators of data, in the evaluation of outdoor thermal comfort. Correctly interpreted, their contribution is vital and needs to be taken into account in the design of pedestrian networks identifying design improvements in spaces of movement and lingering. This opens the way towards the broad use of thermal notation and its effective integration in the design process. The thermal representation of urban space may lead to significant results about projects of pedestrianisation and spatial quality in everyday walking environments.

The study of thermal variations in spatial sequences has produced valuable information about the effect of the form of spatial sequences in their microclimate. In addition, walking activity provided a framework of evaluating thermal comfort while in movement. The complexity of the research provides opportunities for application towards numerous directions. The interpretation of complex thermal perception in a scientific way, accessible to the urban designer, is challenging. Finally, this method of graphic representation provides a strong distinctive image for each thermal environment and the basis for a comparative thermal analysis between spaces. Thermal notation can be applied to the overall evaluation of a spatial sequence and the designer may use this tool to identify spaces of discomfort and propose design solutions that are climate-sensitive.

Acknowledgment

The author would like to thank the *Ville de Paris* and *Groupe MUP (Labex Futurs Urbains)* for the collaboration in this project, Martin Hendel (EIVP) and Prof. Laurent Royon from Université Paris Diderot 7 for providing access and technical support to the microclimatic equipment used during the fieldwork.

References

Cullen G., 1961: *The concise townscape*. London: Architectural Press.

Givoni B., 1976: *Man, climate and architecture*. NY: Van Nostrand Reinhold Publishers.

Henshaw V., Adams M. and Cox T. J., 2009: Route Planning a Sensory Walk: Sniffing out the Issues. In: *The 2009 Royal Geographical Society Annual Conference Proceedings*, 26-28 August 2009. Manchester: University of Manchester.

ISO 7726, 1998: Ergonomics of the thermal environment: instruments for measuring physical quantities. Geneva: International Standards Organisation.

Lucas R. & Romice O., 2008: Representing Sensory Experience in Urban Design, *Design Principles and Practices: an International Journal*, **2**, 4, pp.83-94.

Lucas R., 2009: Designing a Notation for the Senses, *Architectural Theory Review*, **14**, 2, p173-182.

Nikolopoulou M., Baker N. and Steemers K., 2001: Thermal comfort in outdoor urban spaces: understanding the human parameter, *Solar Energy*, **70**, 3, pp. 227-235.

Vasilikou C., 2015: *The role of urban morphology and pedestrian movement in the perception of thermal comfort in historic city centres*, University of Kent, Canterbury: PhD Thesis.

Vasilikou C. & Nikolopoulou M., 2014: Degrees of environmental diversity for pedestrian thermal comfort in the urban continuum, a new methodological approach. In: Edgerton E., Romice O. & Thwaites K. (eds.), *Bridging the boundaries: Human experience in the natural and built environment and implications for research, policy and practice*, Hogrefe Publishing, Gottingen.

Vasilikou C., 2014 : Le confort thermique de la marche. In : J.Monnet & E.Hernandez (coord.), La place de la marche dans le fonctionnement de la rue du Faubourg du Temple à Paris, compte-rendu d'une étude réalisée par le Groupe "Mobilités Urbaines Pédestres" (Labex Futurs Urbains, Université Paris-Est) pour la Mairie de Paris (Agence de la Mobilité, Direction de la Voirie et des Déplacements), 26 novembre 2014, 35 pages.

Zardini M., ed. 2005: *Sense of the City: an alternative approach to urbanism*. Toronto: Lars Muller Publishers.