Thermal Walks:
Identifying pedestrian thermal comfort variations in the urban continuum of historic city centres

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ABSTRACT: The paper investigates the impact of urban morphology on the thermal comfort of pedestrians as they move in the urban continuum of historic city centre neighbourhoods. Primary fieldwork carried out in two different European locations, investigated the differentiation in the thermal sensation of pedestrians, during their walking activity in a dense urban continuum. The new methodology, thermal walks, involved simultaneous environmental and human monitoring. A series of structured walks with participants carried out in the summer and winter, took place in parallel with measurements of climatic conditions in the different spaces of the designated route. Following the walks, a sequential analysis identifies the variations that are perceived by users between spaces with different geometrical characteristics, forming part of the urban continuum. The research provides a new analytical tool to identify the diversity of thermal sensations that could be provided by a complex urban morphology.
Keywords: environmental diversity, pedestrian movement, thermal comfort, urban microclimate

INTRODUCTION

Walking is the most widespread mode of transport [1]. As a crucial link between intermodal transfers, pedestrian activity helps to fulfil recreational and utilitarian trips. Urban design and transport studies have established the importance of thermally comfortable outdoor spaces, which enhance vitality and liveability of cities, for use by pedestrians [1, 2, 3].

This paper presents the initial results of a primary fieldwork on pedestrian perception of the thermal environment in the urban continuum. The wider aim of the study is to provide an understanding of the dynamic thermal comfort of pedestrians as they walk in differentiated urban spaces and the impact of complex morphology on their perception.

Two pedestrian routes in different European locations were selected. They were situated in the historic city centres of London, UK (51˚30'N, 0˚08'W) and Rome, Italy (41˚54'N, 12˚30'E), representing popular everyday walking routes and covering the range of the temperate climate. This enabled the comparison of two urban morphologies with similar sequential geometric variations, at the scale of the neighbourhood, in a different cultural and climatic context. The fieldwork was carried out during summer 2012 and winter 2013 in both cities to assess seasonal variations. This paper presents initial findings of work in progress, focusing on perceived thermal variations in the thermal sensation of pedestrians as they walk in the urban continuum.

WALKING AND THERMAL VARIATION

Pedestrians, in contrast with vehicular movement, can only adapt to the circulation facilities provided for them. In this context, walking satisfies the needs for the smallest scale of transport and gives pedestrians a unique capability for flexible and small scale movements. People's activities on foot involve a substantial amount of meandering, sudden changes of direction and stop and go movements. People often walk consciously or unconsciously along places where it is attractive and comfortable, be it in the shade in the summer, or choosing a route with other people.

The way pedestrians experience the thermal environment outdoors is based largely on the sensory cues they pick up during their movement in the urban continuum [4]. Microclimatic conditions and environmental diversity seem to influence pedestrian experience and perception of open spaces especially in high density urban fabrics [2, 5]. The act of walking itself can be analysed in a sequence of different spatial and thermal experiences, with various intensities. The variations between sequential urban spaces are distinguished here in a) spatial, i.e. different urban morphology, b) microclimatic, i.e. fluctuations in temperature, wind speed, solar radiation, etc. and c) perceived, i.e. the subjective experience and psychological variables of pedestrians on assessing the above physical variations.

METHODOLOGY

Previous studies have focused on the thermal sensation of users standing or sitting in outdoor spaces [6]. This study investigates variations in thermal comfort during the dynamic state of pedestrian movement in a comparative analysis of the thermal experience between different urban spaces in a continuum. The sensitivity of walkers for their environment and the effects of the weather on their activity have to be taken into account when assessing thermal perception. For this purpose, the methodology used includes sense-walking techniques [7] along with environmental and human monitoring.

Thermal Walks

The fieldwork was organised in structured walks with participants walking along selected pedestrian routes in the two cases study city centres. In each route, a walking distance of approximately 500m or 20-25 minutes was covered. Participants were briefed in a pre-walk meeting for the nature of the research, in order to provide climate-conscious responses. The thermal walks were repeated twice a day, at 12 noon and 2pm, to record the diurnal variation at the time of the day were pedestrian frequentation has been recorded through observations as more elevated (lunch time). The duration of each session in summer and winter was 5 days for each location.

Environmental Monitoring

During the thermal walks, a portable weather station (*Thelonius*) was used to record the urban climate at street level. It was comprised of a CR800 Campbellsci datalogger on a lightweight trolley with five sensors mounted and a telescopic pole at 1.75m, to simulate the average walking person's height. The environmental parameters monitored were a) air temperature and relative humidity (CS215 probe with white radiation shield), b) globe temperature (CT100 probe), c) wind speed (ultra-sonic two-dimensional anemometer), d) lux levels (Skye lux meter), and e) carbon dioxide levels. *Thelonius* monitored and recorded the variation in microclimatic conditions continuously throughout the given routes, with six focus points of recording.

Human Monitoring

Pre-walk observations were used to record patterns of pedestrian movement along the selected case studies, as well as frequentation times, through video recording, people following techniques and people counting. In the context of the thermal walks, participants were asked to record their thermal sensation, preferences and satisfaction by completing a structured questionnaire. Walking simultaneously with the portable weather station, participants focused on six points along the route to record variations in their thermal sensation (in a 5-point scale: *colder, cooler, none, warmer, hotter*) and comfort state. Participants were randomly selected and included inhabitants, people working in the area and visitors of all age.

The questionnaire included a section dedicated to general observation data, such as age, gender, clothing, etc. The second part consists of seven questions that evaluate the thermal conditions, sensation, preference and satisfaction of subjects. It also includes an evaluation of the surrounding urban morphology. Four sections followed, designed to provide a comparative evaluation between the focus points of the walk. The final part of the questionnaire provided an overall assessment of the walk, aiming to link variations in climatic conditions with different spaces along the route.

Tale of two cities: London and Rome

Two pedestrian study areas with similar variations in their geometric descriptors were carefully selected in two different latitudes (London, UK and Rome, Italy) to represent respectively the cool and temperate climate zone. Each route is characterised by three urban squares that are connected with short segments of streets, with a sequential differentiation in their geometric descriptors (aspect ratio and sky view factor).

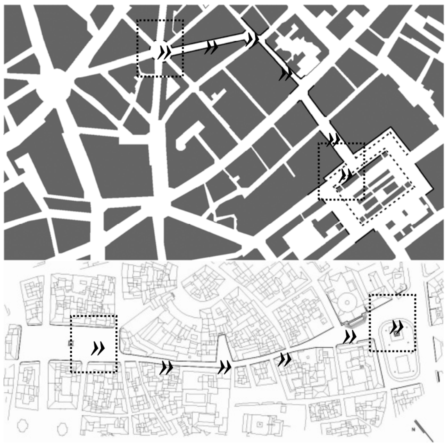


Figure 1: The two »case study routes in London (top) and Rome (bottom).

The case study in London is the route from Seven Dials junction to Covent Garden square, walking through Neal and James Street (Fig. 1, top). It is a commercial area with shops at the ground floor and offices, with little or no vegetation. People meeting and walking through are the most frequent activities, with Covent Garden being one of the main destinations of pedestrians. The case study is the longest continuous semi-pedestrian route in the historic city centre of London.

The selected route in Rome commences from *Campo dei Fiori*, usually an open air market until noon, and ends in *Piazza Cairoli*, one of the few urban squares with vegetation in the historic core of the city (Fig. 1, bottom). *Via dei Giubbonari* that connects the two squares is one of the historic commercial streets of Rome, with continuous use since the sixteenth century. The street is intersected in the middle of the route by a small fully enclosed square, *Largo dei Librari*. Similar activities as with the London case study take place. The urban morphology is characterised by dense, compact blocks of buildings and narrow street segments with frequent intersection of paved open squares.

RESULTS

This study presents initial results from the analysis of the data collected in summer 2012 and winter 2013 in Rome and in summer 2012 in London. The data from the last fieldwork session in winter 2013 in London are currently being processed in parallel with writing this paper. Overall 314 questionnaires were completed during the thermal walks in both locations. In Rome, summer thermal walks involved 90 interviews and 90 in winter, whereas in London 66 questionnaires were collected in summer and 68 in winter.

Table 1: Average measured microclimatic conditions for the two locations, Rome and London.

		Tair (°C)	Tglobe (°C)	RH (%)	Ws (m/s)	Light (lux)
Rome	**summer**	**31.9**	**32.6**	**41**	**0.6**	**16310**
	winter	**9.1**	**9.9**	**52**	**1.2**	**10649**
London	**summer**	**19.3**	**21.1**	**40**	**1.1**	**12900**
	winter	**6.2**	**7**	**57**	**0.9**	**8900**

The weather conditions that occurred during the fieldwork are presented in Table 1. There is a significant difference in air temperature for both Rome and London, with mean summer air temperature of 31°C and 19°C respectively. Winter mean temperature is more similar for both locations, at 6-9 °C. Relative humidity is similar for both locations, at 40% during summer and 52-57% during winter. Thermal preferences (Fig. 2) differ between case studies and seasons. During summer, participants in Rome prefer to be cooler (78%), whereas in London, 56% of participants prefer to be warmer and 40% prefer no change. In winter Rome, 67% of participants prefer to be warmer.

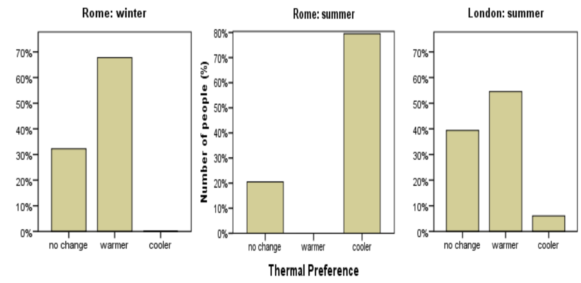


Figure 2: Thermal preferences in Rome (winter and summer) and London (summer).

Variations in Thermal Perception

The thermal walks were iterated during five days (including weekends), while, when possible, same participants were interviewed for more than one day and for both seasons. The focus of this longitudinal study of thermal variations is on the link between three parameters of the outdoor urban continuum: urban morphology, microclimatic conditions and perception of pedestrians.

Figure 3 presents a matrix of graphs and DEMs that show a holistic view of the three parameters for the walks taking place in Rome summer 2012. Graphs (a) and (b) show the variation in the Actual Sensation Vote (ASV) of participants as they walked from focus points A to F at 12 noon and 2 pm respectively. It is shown that at 12 noon the most thermally pleasant variation (approx. 60% of participants) occurred in spaces D (H/W=6, SVF=0.18) and F (H/W=0.4, SVF=0.36). At 14pm, more than 60% of the same participants recorded space B (H/W=8, SVF=0.11) as the space with the thermally pleasant variation. These results can be related to the actual climatic conditions that were monitored in parallel (Graphs (c) and (d) in Figure 3 show the climatic conditions for the 12 noon and 2 pm walks). As expected, air temperature and relative humidity remain homogeneous throughout the walks. Wind speed and solar radiation / light intensity have the greatest impact on the changes in ASV of participants for each focus point.

Finally, the Digital Elevation Model (DEM) for the Rome case study (Fig. 3, maps i and ii) show the positioning of participants during the monitoring. Due to the urban morphology and solar angle, at 12 noon 40% of participants were positioned in the sun (even in spaces with H/W>2.5), while at 2 pm 93% of participants walk in shade. The black-and-white band in the middle of Figure 3 illustrates the sun-shade pattern at the two different times of the walks.

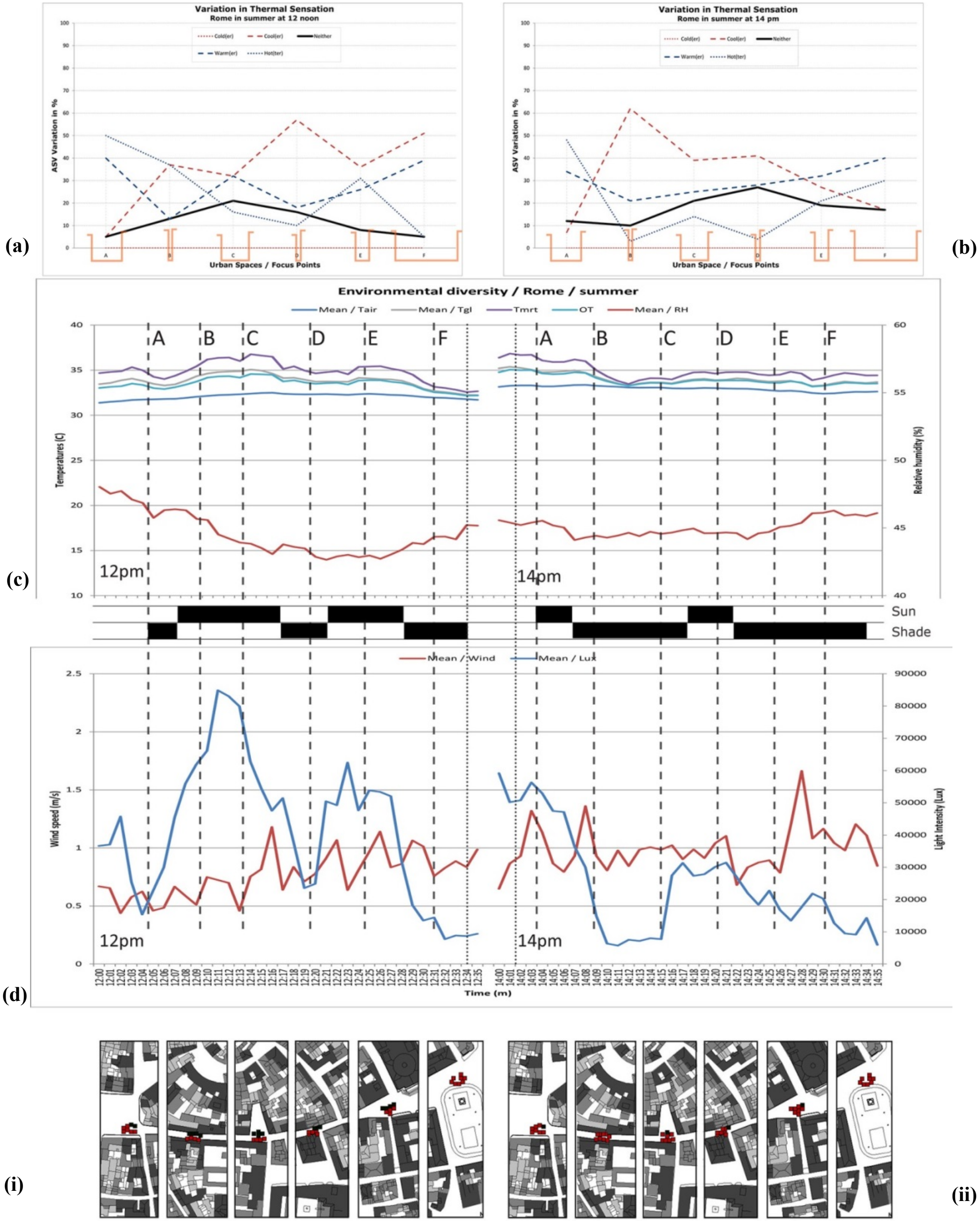
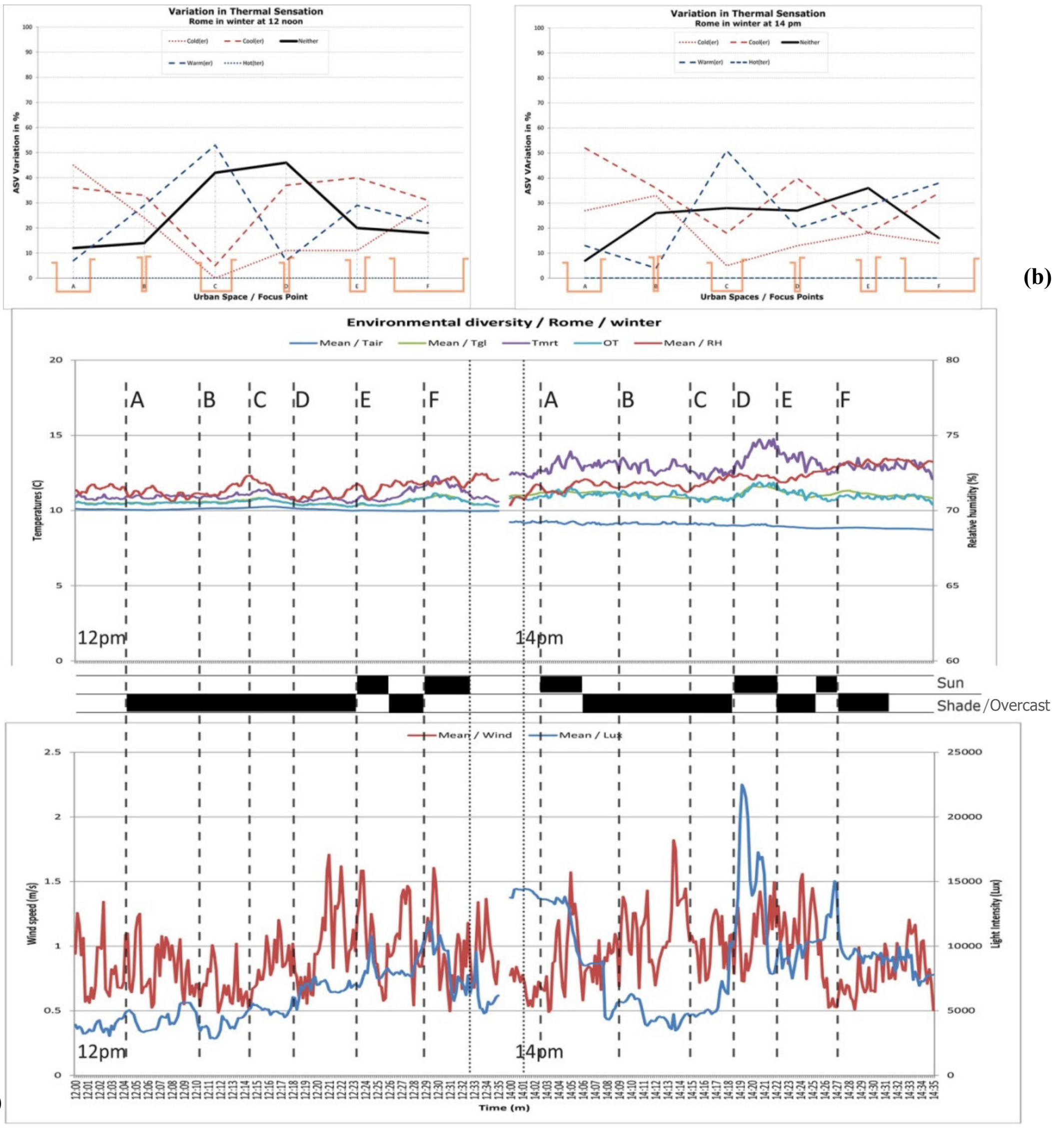


Figure 3: Matrix of the three parameters shows the relation between the ASV, actual climatic data and geometric descriptors of the summer thermal walks in Rome. Graphs (a) & (b) show the variation in the ASV and H/W ratios, graphs (c) & (d) show the Tair, MRT, RH, Wind speed and light intensity data and maps i and ii show the DEMs with positioning of participants.

Similar analysis is carried out for winter thermal walks in Rome. Figure 4 shows focus point C (H/W=0.9, SVF=0.35) as one or the more thermally-pleasant for both 12 noon and 2 pm walks.

At the same time, in winter there is an increase in the number of participants (max. of 50%) that record no variation in their thermal sensation throughout the walk (compared with a max. of 25% during the summer).



(a) (b) (c) (d)

Figure 4: Multi-parametric matrix shows the relation between the ASV, actual climatic data and geometric descriptors of the winter thermal walks in Rome. ASV variation in winter Rome at 12 noon is related to the H/W ratio of each focus point.

As shown, temperature and RH remain fairly stable throughout the walks. Light intensity data are used for indicating sunny, shady or overcast conditions. Compared wind and light intensity mean data (summer and winter respectively) with thermal sensation votes in Rome suggest that transitions from H/W>2.5 to H/W<2.5 increase non-homogeneous (either *warmer* or *cooler*) variations in ASV. Low wind speed seems to allow for more homogeneous thermal sensation votes (for example, in summer Rome at 12 noon 67% of participants found the transition from H/W=0.9 to H/W=6 as thermally cooler, while wind speed reduced from 1.6 to 0.6 m/s).

During the London summer walks (Fig. 5), variation in ASV seems to be non-homogeneous (i.e. distributed between *cooler* and *warmer* for the duration of the walk), for both the 12 noon and 2 pm walks. Space C, a small square in a crossroad (Earlham and Neil street; H/W=1.1, SVF= 0.41) shows the highest thermally-pleasant variation (72% of participant recorded a *warmer* thermal sensation at 2 pm walk). Wind speed and sunny or shady/overcast conditions (not shown here) were the main climatic parameters of this variation. Transition from H/W=2.6 to H/W=1.1 at 2pm was recorded as thermally-more-pleasant, *warmer*, during fairly overcast conditions and while wind speed reduced from 1.5 to 0.8 m/s).

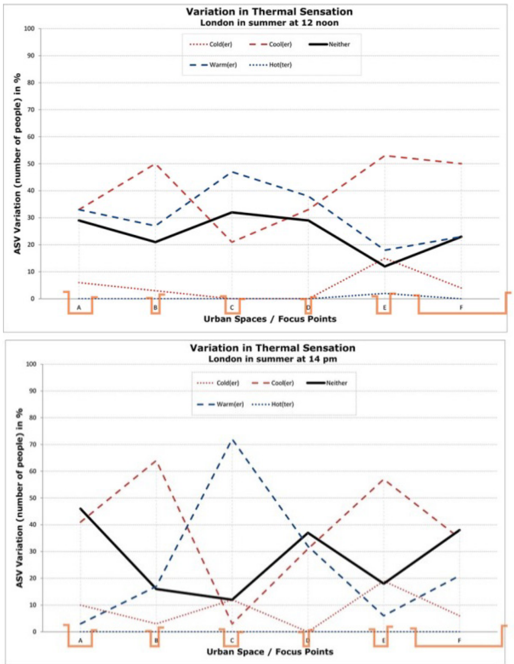


Figure 5: ASV variation during walks in London (summer).

Urban Spaces of Thermal Preference

Part of the interviews addresses the way participants perceived the change in the surrounding spaces as they moved from one focus point to following one. At the end of the walk, an overall evaluation was included. Each participant was asked to record the most pleasant and unpleasant climatic variable and to identify the space in which they experienced it. For example, Figure 6 shows the spaces that were *thermally*-more-pleasant in summer and winter in Rome.

In Rome, *Piazza Cairoli* (point F), the square with vegetation and water features, was voted as the space with the most pleasant thermal aspect for both seasons (Fig. 6). The results of the end-of walk evaluation of thermally-pleasant spaces seem to correspond to the findings from the multi-parametric matrix analysis of the thermal walk and the variation in ASV (Fig. 3 & 4).

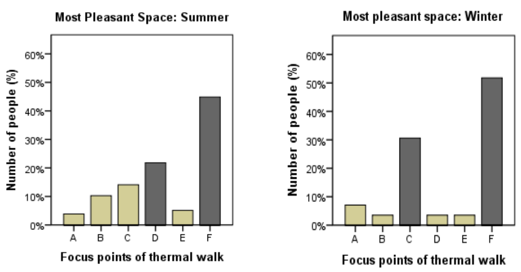


Figure 6: Thermally-most-pleasant spaces according to participants in Rome during summer and winter walks.

CONCLUSION

This paper presents initial findings from the study of environmental diversity and pedestrian thermal comfort in the continuum of complex urban spaces. The fieldwork presented shows a tendency for pedestrians to be able to perceive and identify consciously the variations of microclimatic conditions, while walking. Participants seemed to associate climatic variables with specific urban spaces along their given walking route. Initial findings suggest that thermally-pleasant spaces do not share a specific geometric characteristic and may vary between seasons (for example, in summer Rome, H/W=6-8, whereas in winter, H/W=0.4-0.9).

Further analysis that will quantify this differentiation using climatic simulation is currently under way. Predicted climatic models, based on the complex urban morphology under consideration will be compared with the findings of the primary research. Further conclusions will provide a detailed understanding of the perceived variations in the thermal experience of pedestrians walking in a complex urban continuum.

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