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Seasonal Variations in Thermal Perception of Urban Environments: Summer and Winter In-situ Assessment from a Central European Town

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KEYWORDS

- urban place
- thermal environment
- perception
- sketch mapping
- adaptation measures
- Czechia

ABSTRACT

Growing urbanisation, together with extreme weather events, negatively affects urban populations worldwide. Recent urban climate studies demonstrate that people-oriented approaches are needed to effectively target adaptation measures and thus improve urban populations' well-being. In this study we used the in-situ approach of sketch mapping to identify thermally pleasant and unpleasant places during two seasons, summer and winter, in Ústí nad Orlicí, a Czech town. Generally, places perceived as the most thermally unpleasant, regardless of season, are parking lots near shopping centres, and these require priority attention from urban planners. Respondents consistently identified the planting of high greenery and the construction of shelters as preferred adaptation measures across both seasons. Our findings also point to a clear preference for more enclosed places.

Introduction

Manifestations of climate change combined with accelerating urbanisation significantly impact both the physical and mental health and well-being of urban populations worldwide, and this requires urgent and effective solutions (IPCC, 2023). In the broader context of climate change, urban climate research is gaining increased attention (Nazarian et al., 2024). Traditionally, such studies have focused on analysing Urban Heat Islands (UHI) and Surface Urban Heat Islands (SUHI) respectively, as well as the numerical modelling of thermal exposure (Lehnert et al., 2023a). However, recent paradigm shifts in urban climate studies increasingly emphasise human-oriented approaches. Researchers nowadays advocate holistic and personalised approaches that consider how people experience diverse urban environments, with the aim of developing more effective adaptation and mitigation strategies that directly enhance urban dwellers' quality of life (Auliciems, 1981; Chen & Ng, 2012; Kuras et al., 2017; Schnell et al., 2021; Guzman-Echavarria et al., 2022). Within this holistic framework, local knowledge is essential for contextual understanding, and effective planning of climate adaptation measures demands site-specific analyses that take into account the unique geographic, geometric, and especially the microclimate characteristics of each (urban) neighbourhood or location (Lenzholzer & van der Wulp, 2010; Fagerholm et al., 2021; Lehnert et al., 2023a).

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Both heat and cold extremes can negatively affect human health, leading to increased morbidity and mortality rates (Urban et al., 2014; Son et al., 2019; Masselot et al., 2025). Mortality and morbidity rates can particularly increase in urban environments with higher thermal exposure (Huang et al., 2022; Arsenović et al., 2019; 2024). Nevertheless, human thermal comfort is affected not only by thermal exposure (such as air temperature, radiation, humidity, and wind speed), but also by psychological, physiological, and social/behavioural aspects (Nikolopoulou & Steemers, 2003).

Thermal perception, which can never be separated from the overall perception of the environment (Knez et al., 2009; Lenzholzer, 2010), is of crucial importance in this context. People perceive places differently (Siwek, 2011), as Tuan (1974:45) notes, outward physical variations among individuals are striking yet relatively minor when compared to internal differences. Various environmental factors also influence individual thermal perception. From this perspective, it is essential to understand how the urban environment shapes thermal perception, as such knowledge is vital for designing thermally comfortable spaces that respond to human needs (Lenzholzer et al., 2018; Lai et al., 2020).

The urban environment is inherently structured into places. Place is one of the two or three fundamental geographical concepts that has long been studied; however, as Cresswell (2015) points out, this has often occurred with very little understanding of what the concept actually means. For the purposes of this paper, we draw on the conceptualisations of authors such as Tuan (1976) and Relph (1976), understanding place as something created through location, physical structure and, above all, individuals' relationships to these places. This approach allows places to be attributed with subjective dimensions, which may underlie attempts to answer questions concerning how people form relationships with places, their intentions and experiences within them, the meanings that places carry and, not least, the emotional bonds people develop with them.

The nature of emotional bonds between people and place is closely linked to two fundamental concepts: topophilia and topophobia. Topophilic places are those that evoke positive emotional responses and are therefore often understood as safe, pleasant, desirable, or well-liked (Tuan, 1974). The dichotomous counterpart to topophilic places are topophobic places—those associated with negative emotions (Ruan & Hogben, 2007). As a result of forming such negative attachments, people may perceive these places as unsafe, unpleasant, or repellent, and may deliberately avoid them. However, people do not necessarily form purely positive or purely negative emotional connections to specific places. It is evident that many places can elicit both types of emotional response. Beyond topophilia and topophobia, it is therefore useful to analytically distinguish topo-ambivalence—a situation in which a place is perceived simultaneously in both positive and negative terms. In the urban context, parks are frequently cited as examples of such ambivalent spaces (Daniel & Jirmus, 2023). Topophilic places may typically include urban greenery (Capineri et al., 2018), historical centres (Brisudová et al., 2020), and places featuring blue infrastructure (Völker & Kistemann, 2013; Doležal et al., 2024; Grzyb, 2024). In contrast, topophobic areas often encompass vacant and neglected urban places or buildings, high-traffic corridors or public transport hubs, areas of social disorder, and poorly lit alleys (Cucu et al., 2011; Brisudová et al., 2020; Šimáček et al., 2020; Doležal, 2022).

It should be noted that topophilia and topophobia are based on inherently subjective experiences shaped by cultural backgrounds and individual differences (Hashemnezhad et al., 2013). What one person finds appealing, another might perceive as threatening or uncomfortable. The same is also true specifically for thermal perception (Knez & Thorsson, et al. 2006; Květoňová et al., 2024). These perceptions are further modulated by temporal factors such as time of day (Lehnert et al., 2023a), seasonal variations (Lenzholzer & van der Wulp, 2010; Wei et al., 2022), prevailing weather conditions (Knez et al., 2009), culture (Aljawabra & Nikolopoulou, 2010), social dynamics, an individual's personal history and associations with similar environments (Knez, 2005), and the resulting thermal expectation (Nikolopoulou et al., 2001). Understanding these nuanced responses to urban spaces can significantly inform human-oriented approaches (not only) in urban planning (Brown et al., 2019).

Current research unfortunately does not adequately reflect the role that thermal (dis)comfort may play in shaping topophilia, topophobia, and topo-ambivalence. For this reason, the aim of this paper is to contribute new insights to the relationship between thermal (dis)comfort and urban places. Hence, the main objectives of this study are: i) to identify the seasonal variations in human perception of thermal comfort in urban environments based on in situ assessments of urban places during representative summer and winter days; ii) to explore and contextualise spatial aspects of urban places in which thermal (dis)comfort was perceived. By meeting these objectives, the study also contributes to a holistic understanding of the effect of urban environments on human thermal comfort and related cold and heat stress.

Data and methods

Study area

Ústí nad Orlicí is a town located in Eastern Bohemia, Czechia, situated in the Orlické Mountains foothills (49°58'N, 16°24'E) (Fig. 1). The town covers an area of approximately 36 km² (CZSO, 2017) and supports a population exceeding 14,000 inhabitants (CZSO, 2024), classifying it as a medium-sized town. This town serves as a district town and is characterised by regional importance, a functional typology classification as diversified, and the embodiment of characteristics typical of Czech settlements. For this study, the cadastre of Ústí nad Orlicí was selected.

The climate of Ústí nad Orlicí is classified as a temperate oceanic (Cfb), characterised by moderate summers and cold winters (Kottek et al., 2006). The elevation of the town centre ranges from 320 to 379 metres above sea level (ČÚZK, 2024). Located at the confluence of the Tichá Orlice and Třebovka Rivers, the town's topography and hydrological setting significantly influence its local climate. Historically, Ústí nad Orlicí served as an important agrarian centre before evolving into an industrial hub, earning the nickname "East Bohemian Manchester". Over recent decades, the town has undergone further transformation from its industrial heritage to become a contemporary administrative and service centre, featuring a distinctive blend of historical architecture and modern urban development. The surrounding landscape is characterised by rolling hills, forests, and agricultural lands, providing a scenic backdrop to the urban environment.

Methodology of this study and research methods used

This study employed participatory mapping as the primary research approach. The rationale behind this methodological approach lies in the feasibility and effectiveness of participatory mapping in gathering data related to research into residents' perceptions of urban environments and their local knowledge (see Šerý et al., 2025a). Apart from that, participatory approaches and community involvement are crucial for effective urban planning and the improvement of public urban environments. Implementing these approaches lays the foundation for more sustainable solutions. Participatory mapping encompasses three distinct approaches: Public Participation Geographic Information Systems (PPGIS), mental mapping, and sketch mapping (Brown & Kyttä, 2018; Denwood et al., 2022). For this investigation, we utilised sketch mapping, which involves data collection on paper with a base map. The re-

Figure 1. Location of the study area, map background: © MapTiler © OpenStreetMap contributors
A = public transport hubs; A1 = bus station, A2 = railway station
B = main square
C = parks; C1 = Park by the Theatre, C2 = Park by the Church, C3 = Kociánka Park, C4 = Czechoslovak Legions Park, C5 = Smetana Gardens, C6 = Park by the railway station
D = parking lots; D1 + D2 = Parking lots at the shopping zone, D3 = Parking lot near the hospital

search employed the *SketchMap Tool* developed at Heidelberg University (https://sketch-map-tool.heigit.org/). This tool integrates analogue data collection with digital processing via OpenStreetMap, allowing participant-marked sketch maps to be georeferenced automatically upon upload. The data can then be downloaded for use in GIS. The tool may be combined with questionnaires to provide contextual participant information and remains accessible to users with limited technical expertise due to its automated processes. As open-source software, it is particularly suitable for resource-constrained communities, though users must adhere to data protection regulations and ethical standards (Klonner & Norze, 2023).

The data collection took place in situ, allowing for real-time perception data while participants were physically present at locations ("here and now"). This method yields more precise data by capturing participants' spontaneous cognitive and emotional responses with minimal external influence. This contrasts with retrospective methods, where responses may be coloured by accumulated experiences, second-hand information, emotional states, or contextual variables at recall time (Brisudová et al., 2024).

Data collection

In this study, we performed three thermal walks with the same 10 participants (5 women and 5 men) aged between 18 and 28, all physically fit with no health issues, who were not residents but were familiar with the town as occasional visitors, ensuring they were not directly influenced by strong previous experiences with specific places. Thermal walks provide a method for pedestrians to analyse, identify, and perceive thermal conditions as they move through complex (urban) environments (Vasilikou & Nikolopoulou, 2013; Dzyuban et al., 2022; Květoňová et al., 2024). The first walk was conducted on 20 August 2023, a tropical day that was mostly cloudless and windless, with a mean daily air temperature of 22.9 °C and a maximum daily air temperature of 31.0 °C (according to the Ústí nad Orlicí station; WMO ID 11679). This thermal walk took place from 1:15 p.m. until 3:15 p.m., chosen as the time of the most extreme and simultaneously stable weather conditions. Before starting the walk, short-term thermal history was controlled with a half-hour acclimatisation period, during which respondents were acquainted with the methodology, which was adapted from Květoňová et al. (2024). The second and third thermal walks were held on 28 January 2024, a frost day that was mostly cloudless and almost windless, with an average daily temperature of -0.7 °C and a daily minimum of -3.0 °C (according to the Ústí nad Orlicí station; WMO ID 11679). Since research of this nature had not been previously conducted in winter, the authors organised two walks: one in the early morning (from 7:15 a.m.) when cold conditions are most extreme, and the second at the same time as the summer walk (from 1:15 p.m.). These thermal walks also lasted 2 hours, with the same acclimatisation procedure. For all walks, respondents were instructed to walk through the entire study area and visit several varied locations. No specific route was prescribed, enabling participants to explore the area according to their preferences, though they were specifically directed to visit key places, such as the main square, public transport hubs, parks, parking lots, main streets, etc. Research has shown that a two-hour duration is adequate to cover the study area comprehensively. Participants marked polygons on two maps – one for thermally unpleasant locations (in summer, "hot" locations marked in red; in winter, "cold" locations marked in blue) and another for thermally pleasant locations (in summer, "cool" locations marked in blue; in winter, "warm" locations marked in red). After each walk, an hour-long discussion was conducted with respondents about all the polygons they had marked, their reasons for selecting these locations, and the improvement measures they would suggest for each location.

Data processing and visualisation

Once the paper maps were collected, the SketchMap tool was used to automatically digitise the responses into a georeferenced vector layer. The polygons were then edited (topology check) in QGIS and converted into a hexagonal grid (10 m grid size) by calculating the number of overlapping polygons for each hexagonal cell. Isolines representing 50% overall agreement and the boundaries of all responses were created, simplified, and smoothed for final visualisation. The follow-up discussions with respondents were subjected to thematic analysis to identify key patterns in terms of thermal perception of the marked polygons, reasons for respondents' selection, and suggested measures.

Results

Winter thermal perception

At least half of the respondents identified several places which they perceived to be cold during winter, including both public transport hubs (Fig. 1,2 – A1, A2), the main square (B), various parks (C1, C3, C4), and the parking lots (D1–D3). The primary reasons (Fig. 3) for perceiving these places as cold were related to them being "open spaces". Additionally, all respondents mentioned that parking lots are too open and thus unpleasant. Squares, public transport hubs, and parking lots were perceived as cold due to their "cold and concrete" surfaces, while public transport hubs and parks were considered draughty areas. Respondents also described public transport hubs and parking lots as depressing places. To reduce topophobia in these places, at least half of the respondents suggested planting high greenery, building shelters, and enclosing them with barriers.

Conversely, during winter, respondents also reported feeling thermally pleasant at the same public transport hubs (Fig. 1,2 – A1, A2), the main square (and part of the street leading to the main square) (B), and the parking lot near the hospital (D3), making these areas thermally ambivalent during winter. Sunlight and the presence of people contributed to thermal comfort at the square and the parking lot (Fig. 3). The square was also more pleasant due to its arcades and its compactness. The public transport hubs were more pleasant due to their shelters. Respondents who marked parks as thermally pleasant during winter attributed this to the presence of high greenery.

Summer thermal perception

Respondents identified several thermally unpleasant places where they perceived heat during summer, including both public transport hubs (Fig. 1,2 – A1, A2), the main square (B), the parking lots (D1–D3), and some parks (C3–C5); however, two parks (C3–C4) were also perceived as thermally pleasant during summer, rendering them thermally ambivalent. The primary reasons for perceiving all these places as thermally unpleasant were the absence or lack of shade and direct sunlight (Fig. 3). Furthermore, the square was considered unpleasant due to its overheated surface, lack of greenery, smell, and overcrowding. The public transport hubs were deemed unpleasant for the same reasons, plus the presence of homeless people, heavy traffic, and heat from vehicles and buildings. Parking lots were also characterised by overheated surfaces, overcrowding, absence of greenery, and openness. All respondents (10) suggested planting high greenery to improve thermally unpleasant areas. Half suggested building shelters and gazebos. Some respondents also suggested establishing blue elements, using less impervious surfaces, enclosing more space, and implementing water sprinkling on roads.

Thermally pleasant places during summer included almost all the parks (Fig. 1,2 – C1–C4, C6) due to their high greenery, shade, blue elements, and low greenery (Fig. 3). Respondents also noted that the square could sometimes be pleasant during summer due to its arcades, while public transport hubs could be perceived as pleasant due to the shade provided by buildings.

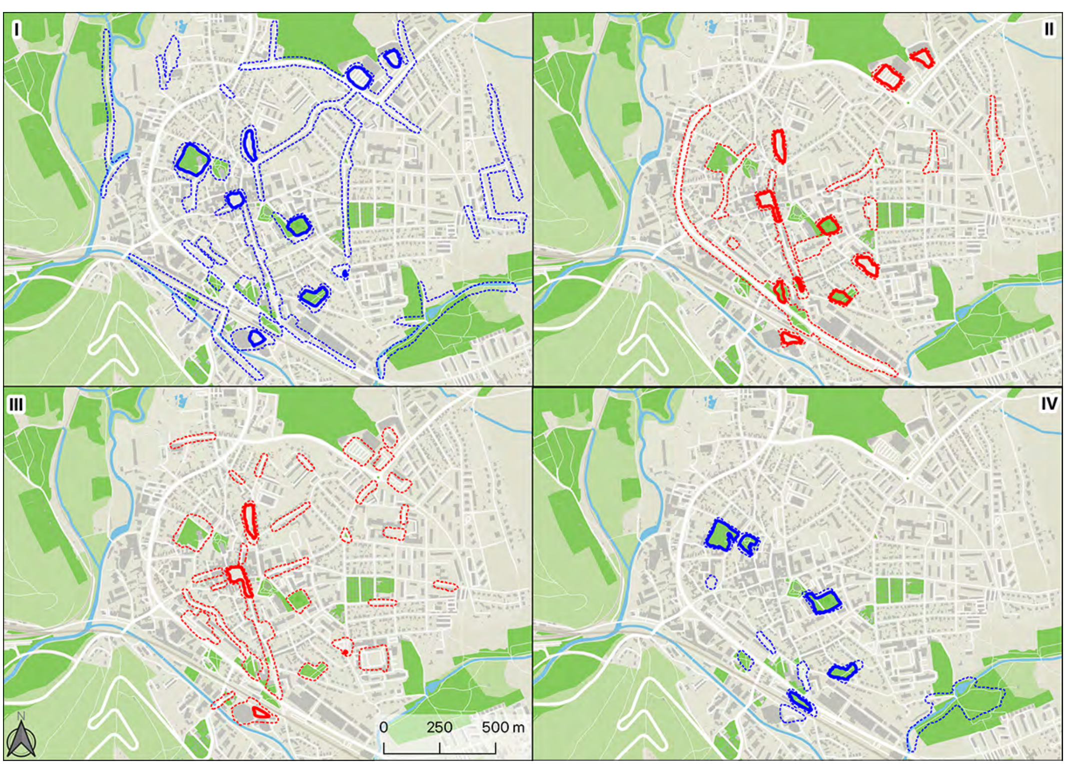

Figure 2. Thermally pleasant, resp. thermally unpleasant places in summer and winter in the study area, map background: © MapTiler © OpenStreetMap contributors

I = winter, blue colour = thermally unpleasant locations ("cold"),
II = summer, red colour = thermally unpleasant locations ("hot")
III = winter, red colour = thermally pleasant locations ("warm"), IV = summer, blue colour = thermally pleasant locations ("cool")
Solid lines indicate places identified by ≥5 participants; dotted lines indicate places identified by 1–4 participants.

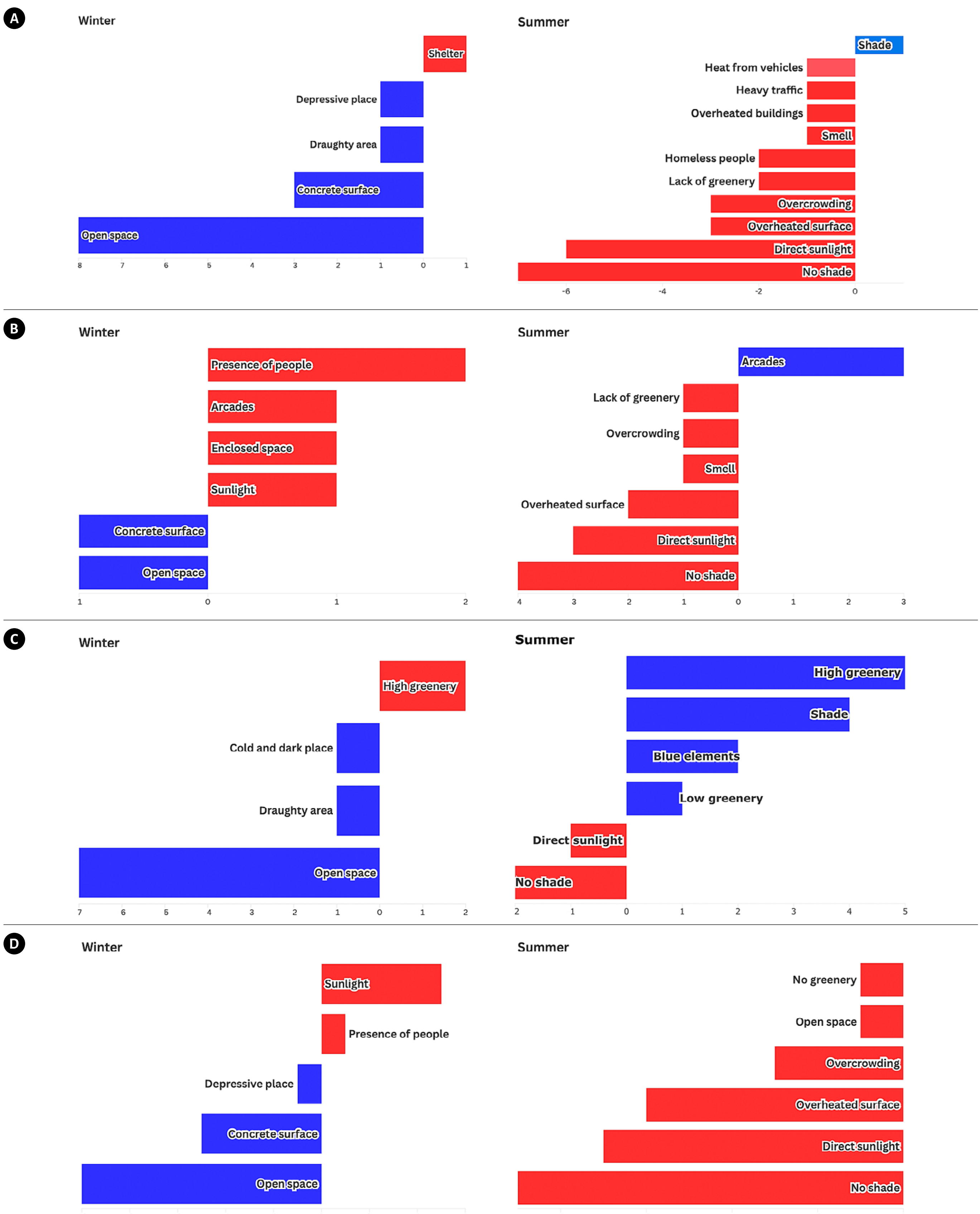

Figure 3. Reasons for perceiving places as (un)pleasant in summer and winter;
A) public transport hubs; B) main square; C) parks; D) parking lots;
Winter, blue colour = thermally unpleasant ("cold") locations, red colour = thermally pleasant ("warm") locations;
Summer, red colour = thermally unpleasant ("hot") locations, blue colour = thermally pleasant ("cool") locations.

Interseasonal differences in thermal perception

In terms of thermal perception, places have been generally categorised as thermally pleasant (comfortable), thermally unpleasant (uncomfortable), or thermally ambivalent. Our study examined the marked places and how they were perceived across two seasons, investigating whether the perception of thermal (dis)comfort in specific places remains consistent across seasons and whether any patterns emerge (Fig. 4).

The results reveal several distinct patterns. First, places perceived as unpleasant during both summer and winter include parking lots in the shopping zones (D1, D2). The second category consists of places that are thermally unpleasant during summer but are perceived as thermally ambivalent during winter, and this includes both public transport hubs (A1, A2), the main square (B), and the parking lot near the hospital (D3). One park was perceived as thermally pleasant during summer but unpleasant and cold during winter (C1), while some parks (C3, C4) were perceived as cold in winter but were perceived ambivalently during summer. Some places were marked only during summer, such as the park near the church (C2) and the park near the train station (C6), both perceived as pleasant, and Smetana Gardens (C5), which were perceived as unpleasant. Notably, no places were perceived as thermally pleasant during both summer and winter (Fig. 4).

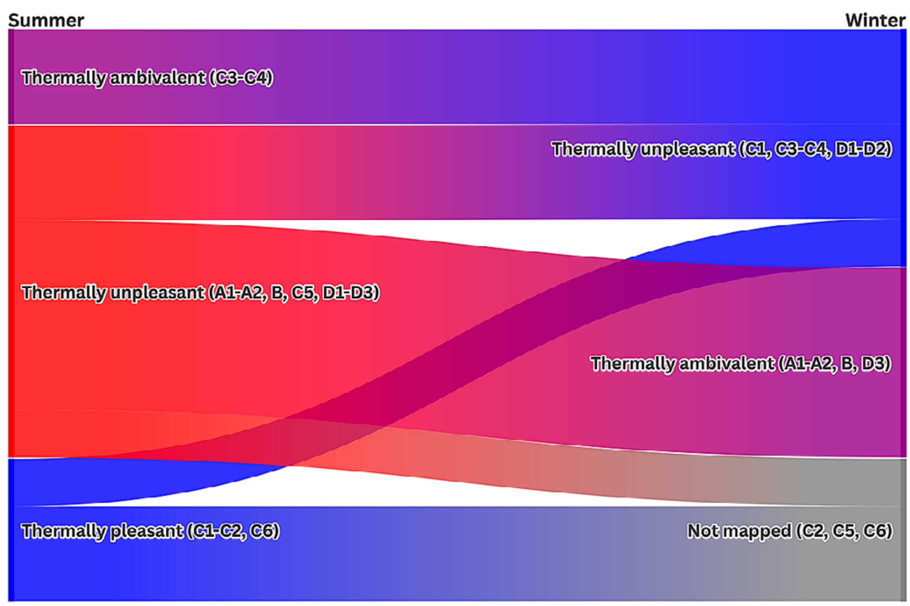

Figure 4. Interseasonal differences in the perception of thermally (un)pleasant places in the study area

A = public transport hubs; A1 = bus station, A2 = railway station
B = main square
C = parks; C1 = Park by the Theatre, C2 = Park by the Church, C3 = Kociánka Park, C4 = Czechoslovak Legions Park, C5 = Smetana Gardens, C6 = Park by the railway station
D = parking lots; D1 + D2 = Parking lots at the shopping zone, D3 = Parking lot near the hospital

Discussion

This study is unique in investigating the seasonal differences in thermal perception across different urban places in Ústí nad Orlicí, revealing spatial patterns of thermal (dis)comfort that extend beyond traditional urban climate research methods, such as temperature measurements, LST analyses, and numerical modelling. Our findings demonstrate that thermal perception is highly context-dependent, with significant differences between types of urban places and across seasons, as well as among individuals with varying (thermal) backgrounds and physiological characteristics (Aucliems, 1981; Tseliou et al., 2017; Schweiker et al., 2018). In this context, future research could investigate whether and how people with strong previous experiences of specific places may develop distinct patterns of (thermal) perception.

In this study, we suggest that certain urban places may be considered fundamentally problematic from a thermal comfort perspective, regardless of seasonal conditions. The most striking pattern to emerge from our approach was the consistent thermal discomfort associated with parking lots in shopping zones; these were perceived as thermally unpleasant places in both summer and winter. Květoňová et al. (2024), using the example of Prague, suggest that parking lots are considered unpleasant during hot summer days. In this study we found that parking lots are perceived as thermally unpleasant not only during hot summer days, but also during winter days. Persistently experienced thermal discomfort may contribute to the year-round presence of negative associations individuals have with these places, thereby reinforcing the reproduction of topophobia associated with them. Therefore parking lots deserve considerably more attention from urban planners and local policymakers. Solutions could include, for instance, implementing more greenery with appropriate spacing and crown shape (Milosević et al., 2017). Furthermore, in accordance with previous studies from Czech cities (Lehnert et al., 2021; 2023b), public transport hubs during summer were perceived as thermally uncomfortable. However, by focusing on winter in this study in Ústí nad Orlicí, we found that transport hubs can be thermally ambivalent; this is in contrast to a simultaneous study carried out in Olomouc (Czechia) (Květoňová et al., 2025), where some transport hubs were even considered thermally comfortable by most respondents. With regard to urban squares, in this case study from Ústí nad Orlicí, we found ambivalent thermal perception in winter, similar to Květoňová et al. (2025) in Olomouc. Parks demonstrated the most pronounced seasonal dependency in thermal perception, being generally pleasant during summer but unpleasant during winter, particularly in more exposed locations. This finding aligns with previous research by Klemm et al. (2015), who noted the significant role of vegetation in creating pleasant microclimates during warmer months, while potentially exacerbating thermal discomfort during colder periods through increased shading and wind channelling effects. It should also be noted that the predominant type of deciduous trees could contribute to this perception.

The findings of our research highlight the ambiguous role of perceived thermal comfort and discomfort in the reproduction of people's topophilic and topophobic relationships to urban places. This role varies both in relation to the specific places unveiled in the study and in accordance with seasonal dynamics. This initial insight should serve as a rationale for further research aimed at achieving a deeper understanding of this ambiguity.

Concerning the reasons for their choices, respondents indicated that, especially in winter, some places were perceived as unpleasant due to their openness and sometimes due to the presence of "cold and concrete surfaces", which aligns with Lenzholzer & van der Wulp (2010). However, open spaces can also be perceived positively when there is, for example, sunlight in a pleasant place (Krüger et al., 2017; Lehnert et al., 2021). Furthermore, it should be emphasised that some places perceived as thermally unpleasant are unpleasant for other reasons beyond thermal perception, as seen in this study in the case of public transport hubs where participants cited the "presence of homeless people," suggesting that social stress could serve as a more significant stressor than the thermal load. Similarly, the commonly mentioned "heavy traffic" can negatively affect both thermal comfort (Schnell et al., 2016) and overall perception (Brisudová et al., 2020; Šerý et al., 2023).

Regarding the measures to improve their perceptions of places, in summer respondents most often suggested planting tall greenery, which is in line with Lehnert et al. (2023), while in winter, to improve thermal conditions, at least half of the respondents suggested, in addition to greenery, more enclosure of the places and the construction of shelters, which is consistent with the study by Květoňová et al. (2025). However, it should be taken into account that greenery should be appropriately placed in the environment (Geletič et al., 2023; Janků et al., 2024).

The results obtained have the potential not only to enrich existing knowledge on thermal (dis)comfort in urban environments, but also to be applied in urban planning policies aimed at mitigation measures. Indeed, all the identified proposed measures may serve as a basis for the deliberate evidence-based re-design of the physical settings of places with regard to mitigation. In this context, reconfiguring the spatial arrangements of problematic places could strengthen those aspects that render such places considerably more topophilic. In other words, as Šerý et al. (2025b) state, only such guided placemaking efforts can meaningfully contribute to shaping public places that effectively meet the needs of 21st-century urban residents.

Limits of the study

The study is based on the same homogenous group of 10 respondents across all three thermal walks. While this qualitative method is inherently subjective and the sample size is relatively small, we suggest using methods based on qualitative data as supplementary assessment in combination with quantitative data analysis. Future research could employ alternative methods, such as participatory mapping based on long-term thermal experiences or another in-situ approach, such as the analysis of thermal sensation votes using a mobile app (Květoňová et al., 2024). When conducting such research, care must be taken as respondents may become overly preoccupied with the research itself, such that the results might not accurately reflect reality (Lewis & Gutzwiller, 2023). Additionally, when mapping public spaces, the underlying research reason partially reveals itself through the mapping process (McLean, 2017). Moreover, the resulting map may differ when based on responses from local residents (Koukal, 2025). This research was specifically conducted during afternoon hours in summer and winter, with an additional morning session in winter to capture extreme weather conditions; however, it is important to note that the effects of blue(grey)green infrastructure can vary throughout the day (Lehnert et al., 2021).

Conclusion

The present study addressed the perception of urban environments across two different seasons, identifying key places with thermal (dis)comfort. Our findings indicate that parking lots are consistently perceived as the least thermally pleasant urban places, regardless of the season. Public transport hubs and the main square were perceived as thermally unpleasant during summer, but thermally ambivalent during winter. Furthermore, the research demonstrates a clear preference for more enclosed places over open places. Thermally pleasant places during summer included almost all the urban parks; however, most of these same parks were perceived as cold during winter. This seasonal contrast may be attributed to the species composition of the trees, which are predominantly deciduous. Nonetheless, respondents suggested several adaptation measures, with the most frequently mentioned being the planting of high greenery and the construction of shelters, regardless of season. This study contributes to a complex understanding of seasonal variations in human thermal comfort and the related cold and heat stress. Additionally, our findings emphasise the practical significance of considering seasonal thermal perception in the planning of urban places, particularly in the context of climate change and the creation of more liveable urban environments.

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