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Original Research Article

Thermal Comfort Based on Climate Identity
A Phenomenological Explication of Collective Sympathetic Thermal Perception (CSTP) in the Historic Bazaar of Naqsh-e Jahan Square, Isfahan

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Abstract

Problem statement: Thermal comfort in urban open and semi-open spaces arises from the interaction between microclimatic variables and occupants' physiological and perceptual responses. Conventional thermal comfort indices, by reducing the body to numerical quantities and relying on standard assumptions of clothing insulation (clo) and metabolic rate (met), have under-addressed the role of climatic–cultural contexts and collective lived experience in modulating thermal perception. As thermal experience is not merely a by-product of physical conditions, its explanation requires attention to thermal sensation, heat and cold stress, seasonal memory, behavioural adaptation patterns, social norms, and the cultural meanings of place. Focusing on the historic *bazaar* of Naqsh-e Jahan Square, Isfahan -a mediating space between architecture and the city- this study conceptualizes "Collective Sympathetic Thermal Perception" (CSTP) as an analytical framework for explaining how context-bound thermal perception and shared thermal experience are constituted within a socio-historical and climate-conditioned setting.

Research objective: Given the dominance of quantitative approaches, this study distinguishes "index" from "experience," positioning CSTP as a framework for analysing the gap between quantitative measurement and qualitative monitoring, and examines collective thermal tolerance in relation to seasonal memory, social norms, and place identity through a descriptive phenomenological approach.

Research method: A descriptive phenomenological approach was adopted within a qualitatively dominant mixed-methods design. Field data were collected through a cross-sectional approach at the third level of thermal comfort studies (Nicol & Humphreys) from 100 bazaar occupants in summer and winter 1403 SH (2024–2025); concurrently, air temperature, relative humidity, and thermal stress indices were recorded. Instruments comprised a semi-structured questionnaire and 30 in-depth episodic interviews. Qualitative analysis followed Colaizzi's method, with trustworthiness ensured through member checking, thick description, and peer debriefing; the quantitative component's validity and reliability were assessed through content validity, a pilot study, and internal consistency. Questionnaire data were then analysed in SPSS using descriptive statistics and comparative tests to corroborate the qualitative patterns.

Conclusion: From 487 significant statements, three principal themes were extracted: seasonal thermal memory and alliesthesia; individual adaptation and group norms; and the cultural and seasonal meaning of temperature. These were organized into an intertwined three-layer model of CSTP: (1) thermal anthropocentrism, comprising social norms, local physiology, behavioural adjustment, and social interaction; (2) sensory integration, comprising alliesthesia, seasonal memory and expectation, embodiment, contrast perception, thermal pleasure, and gradual adaptation; and (3) lived experience, comprising the cultural and seasonal meaning of temperature, climatic identity, place memory, sense of belonging, and collective experience. The concept shows that occupants' thermal appraisal is shaped by bodily sensation, collective presence, norms, activity type, and the cultural meaning of place, while behavioural synchronisation, thermal silence, and social affirmation render difficult conditions more tolerable. Accordingly, in historic socio-spatial open and semi-open spaces, the design objective is not necessarily absolute thermal comfort but the enhancement of acceptability, tolerance, and duration of stay -requiring occupants to be recognized as active agents in adaptation and enabling choice, behavioural adjustment, and gradual adaptation. Thermal assessment must therefore complement environmental metrics with perceptual, social, and cultural variables. By bridging the literature on thermal expectation, acceptability, and preference, the model offers a context-specific framework for analysing user thermal behaviour and underpins human-centred design, context-sensitive energy management, and thermal justice in historic and contemporary public spaces.

Keywords: *Collective sympathetic thermal perception, Phenomenology of thermal comfort, Multisensory coherence, Lived experience, Naqsh-e Jahan Square, Isfahan*

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Introduction and Problem Statement

Today, urban public spaces, particularly historic fabrics, are recognized as vital hubs of social, cultural, and economic interaction. Traditional Iranian bazaars, and especially the historic bazaar of Isfahan, are understood as more than commercial structures; rather, they are socio-spatial settings with high physical and social resilience that have preserved their urban vitality and dynamism despite structural transformations over time (Shirani et al., 2017). This historical continuity indicates a profound adaptation between architectural form and the environmental and social needs of users within this historic context. In light of climate change, global warming, and the intensification of urban heat islands, the provision of desirable thermal comfort has become one of the central concerns of designers, architects, and urban planners (Johansson et al., 2018; IEA, 2021). This is while Iranian vernacular architecture, composed of open and enclosed spaces, has long provided a setting for users' thermal comfort under critical climatic conditions through passive physical strategies and the use of environmental capacities (Mas'oudi-nejad et al., 2018). In this regard, understanding the governing relationships between the physical components of space and the ways users perceive thermal conditions in semi-open and historic structures is key to re-reading the climate identity of these environments.

Classical and conventional models of thermal comfort assessment, largely developed on the basis of static models under controlled indoor laboratory conditions, reduce occupants' thermal perception to physical exchanges and the heat balance between the human body and the environment (Fanger, 1970). Although early attempts were made to explain thermal comfort in urban spaces through steady-state heat balance equations, pioneering studies demonstrated a substantial discrepancy between physical-mathematical descriptions and users' actual perceptions in urban open and semi-open spaces (Nikolopoulou & Lykoudis, 2006). Extensive empirical and field evidence accumulated over recent decades has shown that rigid mathematical models lack the capacity to accurately predict occupants' thermal perception and tolerance in open and semi-open environments characterized by dynamic microclimatic conditions (de Dear & Brager, 2002; Nikolopoulou & Steemers, 2003). Thus, although many existing studies on outdoor thermal comfort have been limited to microclimatic physical measurements and statistical analyses of standardized questionnaires, neglecting the deeper semantic, cultural, and phenomenological dimensions of the research context (Chen & Ng, 2012), attention to human, behavioral, and psychological variables is of considerable importance in evaluating the quality of public spaces. In complex open urban environments, occupants actively engage with climatic conditions. As an intelligent being, the human possesses capacities that make adaptation and adjustment to varying thermal conditions possible (Tahbaz, 2017).

This adaptive process encompasses not only behavioral responses, such as changing clothing, altering activity levels, or seeking shade, and physiological responses, such as climatic acclimatization, but is also strongly influenced by psychological factors, mental expectations, short- and long-term thermal memory, and occupants' spatial identity (Nikolopoulou et al., 2001; Knez & Thorsson, 2006). This phenomenon, referred to as psycho-thermal adaptation, indicates that sense of place, attachment to space, and the aesthetic perception of architectural form can significantly increase occupants' thresholds of thermal acceptance and tolerance (Lenzholzer, 2012). Accordingly, thermal adaptation in traditional open environments is a dynamic and multidimensional process that extends beyond the physiological thermal exchanges of the human body (Nikolopoulou & Lykoudis, 2020). In diverse climates and valuable historic fabrics such as traditional Iranian bazaars-which may serve as a clear example of a stable microclimate-thermal perception transcends a merely individual experience and manifests as a collective perception shaped by shared collective memory, social dynamics, and climate-responsive behavioral patterns. Nevertheless, based on the authors' review, few studies have explained the relationship between physical-climatic identity and occupants' thermal perception in semi-open spaces from a qualitative and phenomenological perspective.

The historic bazaar of Naqsh-e Jahan Square in Isfahan, with its distinctive physical features such as semi-open spatiality, shade-producing geometry, and indigenous materials with high thermal capacity, represents a prominent archetype of

adaptation among form, climate, and environmental, social, and economic patterns of life. Accordingly, the central question of this study is how the climatic and physical identity of a historic semi-open space influences occupants' subjective thermal perception and adaptive behaviors, including those of local shopkeepers and visitors. In response to this question, the present study seeks, through a mixed-methods approach aligned with standard methodologies for assessing thermal comfort in open spaces, to develop a model entitled Collective Sympathetic Thermal Perception in relation to climate identity, as a complementary context-sensitive explanatory layer for the climate-based interpretation of thermal stress tolerance thresholds and for generating insight into energy management.

Literature Review

Over the past five decades, thermal comfort research has evolved from purely physiological approaches toward adaptive, perceptual, and socio-cultural perspectives. The earliest dominant frameworks in this field were grounded in the body's thermal balance and laboratory-based measurements. Among these, the PMV-PPD model proposed by Fanger is regarded as one of the most influential models for predicting thermal comfort, estimating comfort conditions on the basis of a combination of environmental and personal variables (Fanger, 1970). This approach, which became the foundation of many international thermal standards, largely treated comfort as a physiological and generalizable phenomenon. However, as scholarly attention shifted toward urban spaces, the inadequacy of such models for accurately predicting occupants' thermal sensation became increasingly evident. In response to this limitation, specialized thermodynamic and physiological outdoor indices, such as the Physiological Equivalent Temperature (PET) and the Universal Thermal Climate Index (UTCI), were introduced to simulate the and heat exchange of the human body with radiation and wind variables in outdoor environments (Chen & Ng, 2012).

From the 1990s onward, extensive field studies across different climates exposed the limitations of static models and led to the development of adaptive thermal comfort theory. Studies by Brager & de Dear (1998) & de Dear & Brager (2002) , as well as Nicol & Humphreys (2002), demonstrated that occupants of naturally ventilated buildings accept a wider range of thermal conditions and that their thermal preferences are associated with outdoor climatic conditions and their adaptive capacity. Within this framework, thermal adaptation was introduced as a dynamic process encompassing physiological, behavioral, and psychological dimensions. This theoretical shift transformed the concept of thermal comfort from a fixed and universal state into a context-dependent phenomenon shaped by climate, behavior, and human experience.

As this line of inquiry progressed, from the 2000s onward, researchers paid increasing attention to the role of social, cultural, and perceptual factors in shaping thermal experience. A substantial body of research showed that occupants' thermal evaluations are not determined solely by the physical conditions of the environment, but are also influenced by expectations, climatic memory, lifestyle, social norms, and lived experience (Nikolopoulou et al., 2001; Knez & Thorsson, 2006). In this regard, studies of urban open spaces demonstrated that there is not always a complete correspondence between quantitative thermal indices and individuals' perceptual experience, and that users may experience different thermal perceptions under similar physical conditions (Nikolopoulou & Lykoudis, 2006; Thorsson et al., 2007a,2007b). These findings gradually paved the way for the emergence of human-centered approaches in thermal comfort research. Table 1 summarizes other relevant studies in the literature concerning the research topic.

In parallel with this trajectory, some scholars criticized the limitations of purely quantitative approaches and emphasized the need to attend to the perceptual and contextual dimensions of thermal experience (Auliciems, 1981; Westerberg & Glaumann, 1990/91). In these studies, thermal perception was understood not as a passive reaction to physical conditions, but as a multidimensional experience shaped by mental and social processes. The development of psychological studies of thermal comfort and the growing attention to occupants' subjective preferences can also be interpreted within this line of inquiry (Heijs & Stringer, 1988). Gradually, more recent research underscored that thermal experience emerges from the simultaneous interaction of physiological,

Table 1. Review of research background relevant to the present study

Researcher	Location	Methods and Tools	Key Findings	Relevance to the Present Study
Knez & Thorsson (2006)	Sweden and Japan	Questionnaire plus measurements of air temperature, radiation, and wind speed	Thermal perception and preference are influenced by thermal memory, expectations, and sense of place.	Provides a conceptual basis for "Collective Sympathetic Thermal Perception."
Jendritzky et al. (2012)	Germany (UTCI model development)	UTCI model development and field validation	Limited examination of acclimatization; the UTCI model performs better than PMV in open and semi-open spaces.	Justifies the use of thermal assessment models better suited to open spaces in the present research.
Lenzholzer (2012)	The Netherlands (urban squares)	In-depth interviews plus recording of thermal behaviors	Users interpret thermal conditions based on sense of place and collective memories.	Reinforces the theoretical framework of collective thermal perception.
Lai et al. (2014)	Global review (China and the United States)	Systematic literature review	Cultural and psychological factors in open spaces have largely been overlooked.	Highlights the research gap regarding the collective and cultural dimensions of thermal experience.
Tahbaz et al. (2014)	Kashan, historic fabric	Field measurements; UTCI analysis	Microclimatic moderation reduces thermal stress to a more acceptable level.	Provides physical support for the concept of thermal stress mitigation in a historic setting.
Potchter et al. (2018)	Hot-arid climate	Field measurements plus numerical modeling	In hot-arid climates, shading geometry and surface materials exert a dominant influence on thermal comfort.	Demonstrates climatic similarity with Isfahan and its historic bazaar context.
Schweiker et al. (2020)	Indoor and outdoor spaces	Laboratory and field studies	Offers an in-depth examination of acclimatization and thermal acceptability, emphasizing their significance.	Supports attention to human variables in the present study.
Heidari (2019)	Various climates of Iran	Questionnaire plus field measurements	Developed localized thermal comfort equations for different Iranian climates.	Underscores the importance of examining differences based on climate identity in achieving collective thermal perception.
Majidi et al. (2022)	Open spaces of residential neighborhoods in Isfahan	Field survey plus PMV and SET indices	Identified differences in heat tolerance between residents of two neighborhoods.	Provides a domestic precedent with climatic similarity and methodological relevance for open-space assessment.

perceptual, behavioral, and environmental factors and therefore cannot be adequately explained solely through engineering models.

In recent years, with the intensification of the energy crisis, climate change, and the growing urgency of sustainable development, thermal comfort studies have become increasingly linked to climate resilience, energy efficiency, and environmental adaptation. In this regard, research has shown that a precise understanding of occupants' thermal behavior and perception can contribute significantly to improving building energy performance and developing effective thermal control strategies (Schweiker, 2022a). Some recent studies have also demonstrated that even within a fixed climate, seasonal variations and lived experiences can alter thermal preferences and desired temperatures, thereby revealing the limitations of approaches based on fixed temperature setpoints (Jain, 2024; Sanchez, 2025).

Alongside human factors, numerous studies have examined the role of the physical and spatial characteristics of the built environment in shaping thermal perception. Features such as spatial form, solid-to-void ratio, material type, degree of openness, presence of vegetation, and the quality of natural elements are among the variables that can influence occupants' thermal experience (Lenzholzer & van der Wulp, 2010; Klemm et al., 2015). Moreover, research has shown that situational and psychological factors-such as the purpose of being in a place, the possibility of controlling thermal conditions, mood, and mental expectations-also play a meaningful role in individuals' thermal evaluations (Lin, 2009; Johansson et al., 2018). Thermal perception, therefore, should be regarded as a multilayered phenomenon dependent on the reciprocal interaction among human beings, the environment, and the socio-cultural context. Although research on thermal comfort in urban open spaces has grown substantially in recent decades, the systematic and comprehensive review by Zhao et al. (2026) of studies conducted between 2015 and 2025 identifies three major gaps in this field: first, most studies have concentrated on temperate and cold climates, while hot-arid climates remain

underrepresented; second, human dimensions, including cultural characteristics and psycho-behavioral adaptation, have received limited attention in prevailing formulations; and third, research methods have largely relied on one-dimensional physical measurements, while integrated tools for assessing behavior and subjective perception have generally been neglected. Accordingly, by focusing on the historic bazaar of Naqsh-e Jahan in Isfahan within a hot-arid climate, the present study seeks to establish a systematic connection among physical variables, collective adaptive behaviors, and cultural-identitarian contexts through a three-layer model of Collective Sympathetic Thermal Perception.

In Iran, too, numerous studies have been conducted in the field of thermal comfort, most of which have focused on the evaluation of thermal indices, the localization of comfort models, and energy-consumption management (Tahbaz, 2017; Nasrollahi et al., 2017; Heydari, 2019). Some of these studies have addressed qualitative factors affecting thermal comfort in relation to thermal adaptation and adaptive capacity in open spaces (Khayraldin & Zabetian, 2016; Zabetian & Khayraldin, 2018; Mortaheb & Heidari, 2022, 2023; Mortaheb, 2026). However, based on the authors' review, the majority of domestic studies still remain within the framework of quantitative models and physical measurements, and only a limited number have examined the phenomenological, perceptual, and lived dimensions of occupants' experience.

A review of the thermal comfort literature in Iran and internationally reveals three key points. First, research in this field has moved from static physiological models toward adaptive and perceptual approaches in open spaces. This shift indicates that thermal perception is not determined solely by physical heat balance; rather, such factors as expectation, preference, acclimatization, acceptability, mood, and lived experience also play a role in shaping it. Second, the principal gap in the literature lies not in the theoretical foundations or the identification of psychological variables per se, but in the phenomenological investigation of how these variables become manifest within specific historical and cultural settings. Since previous studies, with their predominantly quantitative and physical approaches, have overlooked the analysis of lived experience as a collective phenomenon, the present research draws on classical theoretical frameworks and a mixed-methods methodology-including instrumental microclimatic measurements and qualitative inquiry into lived experience-to explain the relationship between the physical-climatic identity of the historic bazaar of Isfahan and the formation of Collective Sympathetic Thermal Perception among both permanent occupants (shopkeepers) and temporary occupants (visitors). Drawing upon studies regarding thermal comfort, Fig. 1 conceptualizes the framework and purpose of the "Collective Sympathetic Thermal Perception" concept.

Theoretical Framework

This study is based on the assumption that occupants' thermal perception in historic bazaars and semi-open spaces emerges from the interaction of microclimatic conditions, individual characteristics, prior experiences, behavioral patterns, multisensory engagement with space, and bodily awareness. Since this perception extends beyond the classical measurements of thermal comfort, the theoretical framework of the article focuses on explaining thermal adaptation, preference, and expectation within the lived experience of occupants.

In this research, the concept of Collective Sympathetic

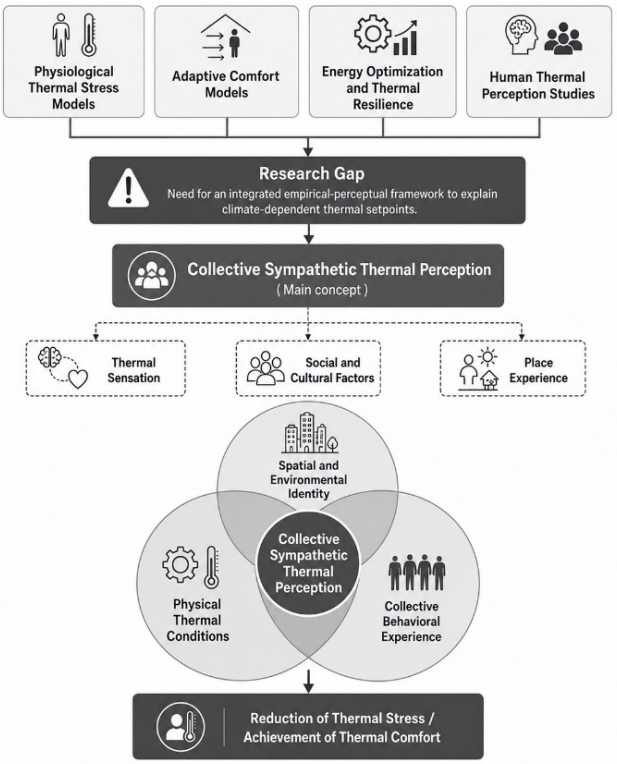


Fig. 1. Evolution of longitudinal thermal comfort studies and the conceptual positioning of "Collective Sympathetic Thermal Perception" within the integrated research framework. Source: Authors.

Thermal Perception is used as an interpretive framework and refers to a social, context-dependent, and experience-based process in which occupants' thermal evaluations are shaped not only by the physiological state of the body, but also by the presence of others, the spatial qualities of the environment, and a shared perceptual memory. In this sense, the occupant is not a passive receiver of thermal conditions; rather, through embodied perception, adaptive behaviors, and the interpretation of spatial situations, the occupant participates in the construction of the thermal meaning of place.

The term sympathetic in this study is an explanatory concept describing a form of sensory-behavioral alignment between body, space, and the presence of others. This alignment emerges from the intersection of two complementary concepts: thermal empathy and collective adaptation. Thermal empathy refers to the occupant's sensitivity to the thermal condition of the environment in relation to the presence of others. In this state, the occupant does not experience heat only through the body alone, but also in relation to other bodies, the type of activity, the rhythm of presence, clothing, age, gender, and the degree of familiarity with the space. Collective adaptation refers to the process through which a group of occupants within a specific microclimate gradually becomes accustomed to a tolerable range of thermal conditions. This adaptation is not merely physiological; it is also shaped by behavioral patterns such as choosing shaded routes, pausing in cooler spots, reducing walking speed, modifying clothing levels, selecting places to sit, and adjusting the timing of presence in the bazaar.

Accordingly, Collective Sympathetic Thermal Perception is a social, contextual, and experiential process through which occupants' temperature preferences emerge from the interaction of three main layers: thermal human-centeredness, multisensory coherence, and the occupant's lived experience. The first layer emphasizes individual and group differences in thermal perception. The second layer shows that the sensation of heat is linked to light, shade, sound, movement, crowd density, and spatial quality. The third layer refers to the role of climatic memory, spatial habits, and the occupant's familiarity with the bazaar.

To clarify this relationship further, this article also draws on the concept of body-behavior congruence. This concept, known in environmental psychology as synomorphy, derives from Barker's studies (1968) and refers to the correspondence between spatial characteristics and human behavioral patterns. However, in this research, the concept is not used only at the level of physical compatibility between space and behavior; it is extended to the perceptual-sensory level. In this reading, bazaar corridors are not merely containers of behavior, but active contexts for regulating thermal perception, directing behavioral patterns, and shaping the shared experience of occupants.

From this perspective, empirical indicators of outdoor space such as physiological equivalent temperature (PET) can explain the microclimatic condition of the bazaar, but they may not be sufficient for a full understanding of thermal comfort. These indicators acquire more precise meaning when interpreted alongside perceptual, behavioral, and lived data from occupants. Therefore, this study explains the relationship between bodily conditions, thermal perception, collective behavior, and bazaar microclimate in relation to the spatial realities of the historic Naqsh-e Jahan Bazaar.

- **Thermal human-centeredness**

One of the most significant theoretical shifts in contemporary thermal comfort studies involves moving away from static and universal approaches toward a "human-centered" explanation of thermal perception. This approach demonstrates that thermal experience is not merely a function of physical environmental conditions; rather, it is shaped by individual characteristics, cultural contexts, situational factors, and the occupants' lived experiences. Consequently, exposing occupants to identical environmental conditions does not necessarily lead to a uniform perception of thermal acceptability (Nakano et al., 2002).

In this framework, perceptual differences are explained at two levels: "intra-individual" and "inter-individual." Intra-individual variability refers to changes in a single occupant's perception across different times and psychological-environmental states, whereas inter-individual variability illustrates the diversity of thermal responses among different occupants under similar environmental conditions. Fountain et al. (1996) and de Dear & Fountain (1994), by critiquing models based on the mean of group responses, argue that such models cannot adequately represent the actual experience of occupants, since perceptual responses exhibit considerable dispersion even within a single environment.

Humphreys and Nicol, confirming these differences, have further highlighted the limitations of standardized approaches and the necessity of attending to occupants' perceptual diversity (Humphreys & Nicol, 2002).

To explain the origins of this variability, researchers emphasize the simultaneous role of physiological, behavioral, social, and cultural factors. Rupp et al. (2015) categorize these factors into two major axes: first, "physiological factors," including metabolic characteristics and biological regulation of the body; and second, "cultural-behavioral factors," including clothing patterns, adaptive strategies, and climate-social norms. In this regard, literature reviews indicate that although there is no fixed pattern of preferred temperature across different groups, thermal sensitivity and the manner in which environmental conditions are evaluated differ among demographic groups. These differences, rather than being mere functions of biological traits, are linked to adaptive practices and cultural contexts (Wang et al., 2018).

Following these developments, the concept of "thermal resilience" has gained significant importance in recent studies. This perspective does not view the human as a passive entity subject to environmental stressors; instead, it recognizes the individual as an adaptive and learning agent capable of recalibrating their perception. Schweiker explains resilience in connection with the flexibility of the "human-environment system," defining it as the capacity to maintain performance and restore equilibrium when faced with thermal stress (Schweiker, 2022b). On this basis, as its pictorial expression is also illustrated in Fig. 2, the greater the adaptive capacity of a dwelling or its occupants, the higher the threshold of thermal resilience becomes.

This theoretical framework is of twofold importance for analyzing historic and semi-open spaces, particularly the "Naqsh-e Jahan Bazaar in Isfahan." In these spaces, the issue is not merely achieving a static comfort setpoint; rather, due to the dynamic and semi-open nature of the environment, the occupants' ability to tolerate, regulate, and interpret variable thermal situations is the decisive factor in their satisfaction. Therefore, thermal comfort in this historic context must be analyzed as a context-dependent phenomenon contingent upon the interaction between the built form, climate, and human experience.

- **Multisensory coherence**

The second layer of this theoretical framework rests on the premise that thermal perception is not an experience independent of other sensory domains; rather, it is shaped in organic connection with vision, touch, audition, and the spatial quality of the environment. Adopting a phenomenological approach, Heschong (1979) analyzed the "thermal sense" as an independent sense-one that, although overlooked in traditional classifications, plays a fundamental role in environmental perception and the richness of spatial experience. From this perspective, temperature is not merely a physical variable, but a component of the perceived quality of a place, linking environmental changes to pleasure and awareness through sensory nerve endings.

This approach aligns with Merleau-Ponty's theory of "embodiment"-a perspective positing that the inception of world perception is fundamentally rooted in the body; it does not decouple mind from body, arguing instead that humans experience the world not through abstract mentality, but through a lived body engaged with its environment (Monshizadeh, 2022). In this framework, the body serves as an active medium of perception, constructing the quality of spatial experience through continuous interaction with the environment. Consequently, thermal perception is not a static phenomenon; rather, it is a dynamic process dependent on how the body inhabits space. In this sense, the thermal experience while sedentary differs from the dynamic experience induced by movement, changing paths, pausing, or transitioning from shade to sun (Chen & Ng, 2012). This dynamic provides the context for a multisensory connection with the environment, in which the body, as a "corporeally-aware" entity, integrates with space.

The thermal perception of occupants in dynamic urban spaces, such as traditional bazaars, cannot be assessed solely through traditional static indices. Complementing this discussion, the concept of alliesthesia (Cabanac, 1971) demonstrates that the pleasantness or unpleasantness of a physical stimulus is not necessarily dependent on the stimulus itself, but is linked to the internal state of the body and the context of perception. Recent studies, such as Li et al. (2026), indicate that thermal comfort during movement is strongly influenced by the phenomenon of thermal alliesthesia. This phenomenon transforms the

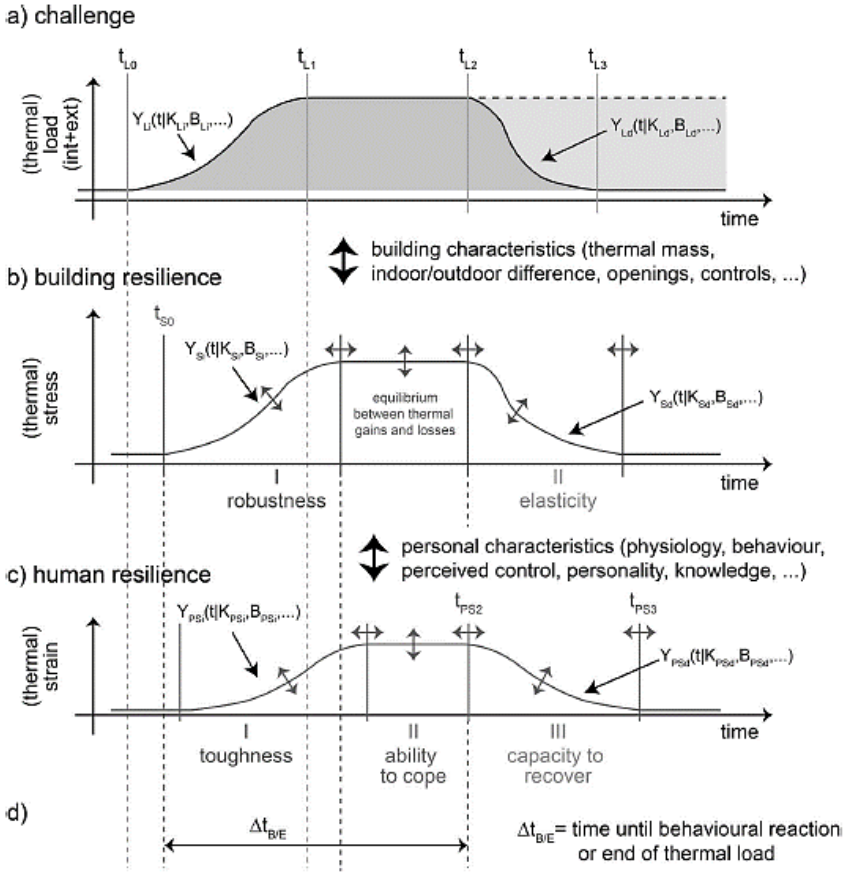


Fig. 2. Dimensions and components of human and building resilience. The arrows indicate that the curve's position depends on building characteristics and individual traits. Source: Schweiker, 2022b.

thermal experience of pedestrians along urban walking paths, creating fleeting feelings of pleasure or discomfort in response to microclimatic variations.

This principle clarifies the distinction between "thermal sensation" and "thermal perception": thermal sensation is limited to registering the direction and intensity of a physical stimulus, whereas thermal perception encompasses the interpretive, semantic, and evaluative layers of the experience. Thus, a specific thermal stimulus can create a pleasurable or tedious experience depending on the occupant's internal state. Recent studies have confirmed the view that "variety is the spice of life". Liu et al. (2017) demonstrated that mild thermal stimuli outside the neutral range can lead to increased thermal pleasure and spatial satisfaction. This finding proves that a controlled diversity of environmental stimuli does not necessarily lead to dissatisfaction but rather enriches the quality of the experience. In the semi-open and historic space of the bazaar, such diversity can be experienced through the dynamic interplay of light, shade, airflow, and the characteristics of the materials. Therefore, thermal comfort in this context is the product of "multisensory coherence" and the interaction between controlled thermal challenges and the occupant's perceptual responses.

- **Lived experience**

The third layer of this framework emphasizes the role of lived experience in shaping thermal perception. From this perspective, occupants' thermal responses are not merely reflections of the immediate environmental state; rather, they constitute an experience-based process that acquires meaning through its connection with memory and prior patterns of environmental encounter. According to the findings of Knez et al. (2009), thermal experiences affect occupants at two levels: short-term experiences, which are linked to everyday memory and modify thermal expectations over limited time spans, even from one day to the next; and long-term experiences, which, in the form of more stable patterns, provide the basis for thermal judgments and the regulation of adaptive behaviors.

In developing a revised model of thermal perception,

Lenzholzer et al. (2018, 2020) distinguish between immediate perception-the here-and-now condition-and accumulated experiences. These long-term experiences are transformed in the occupant's mind into "mental schemas," that is, cognitive frameworks that enable individuals to anticipate thermal conditions and regulate their responses accordingly. Such responses encompass a wide spectrum of adaptive actions, ranging from physiological and clothing-related adjustments, such as modifying clothing insulation, to behavioral patterns, such as route selection, changes in walking speed, seeking shade, and moving between open and enclosed spaces.

In the historic Naqsh-e Jahan Bazaar, this experiential dimension is manifested through variables such as being local or non-local, the degree of prior familiarity with the bazaar's spatial configuration, the type of activity, and the occupants' seasonal memories. For example, a local occupant, relying on their "climatic memory," is better able to anticipate the thermal qualities of the passageways and semi-open spaces, and thus adapt their behavior more intelligently to the bazaar's microclimate. Accordingly, thermal perception in this study is understood as a contextual phenomenon, simultaneously shaped by the physical conditions of the environment and the occupant's experiential lifeworld.

- **Conclusion of the theoretical framework**

The synthesis of the three layers -thermal human-centeredness, multisensory coherence, and lived experience- demonstrates that thermal comfort and thermal perception in historic semi-open spaces cannot be explained solely through physical indices or standard models. Such indices are indispensable for describing microclimatic conditions and the intensity of thermal stress; however, the central concern of this study is to understand how occupants evaluate, tolerate, and interpret thermal conditions within the context of a specific historic environment. On this basis, thermal comfort in the present research is conceived not as a static and merely physiological state, but as a perceptual, embodied, contextual, and experience-based process.

Within this framework, the human-centered layer foregrounds individual and inter-individual differences in thermal perception; the multisensory coherence layer shows that the body, in encountering thermal stimuli, acts as an interpretive and multisensory agent; and the lived experience layer, by adding the dimensions of time, memory, and place familiarity, explains thermal perception in relation to both short-term and long-term experiences. The combined outcome of these three layers constitutes the theoretical foundation of the concept of Collective Sympathetic Thermal Perception in the present study. This concept refers to a process in which patterns of thermal perception, evaluation, and tolerance emerge in relatively convergent or comparable forms among occupants as a result of the interaction among individual characteristics, embodied experience, place memory, and a shared spatial context.

In this regard, the distinction among thermal sensation, thermal perception, and thermal adaptation is of fundamental importance. Thermal sensation refers to the registration of the direction and intensity of thermal experience along a continuum from cold to hot. Thermal perception, however, is a broader concept that encompasses such dimensions as satisfaction, preference, acceptability, tolerability, and the overall interpretation of environmental conditions (de Dear, 2011; Parkinson et al., 2012, 2015; Gandhi & Brager, 2016). Thermal adaptation, in turn, refers to the behavioral, cognitive, and bodily processes through which individuals respond to environmental conditions. Therefore, the aim of this research is not to establish a fixed point of thermal comfort, but rather to understand the relationship between the microclimatic conditions of the Naqsh-e Jahan Bazaar and the ways in which occupants sense, perceive, evaluate, and adapt to them.

From this perspective, the historic Naqsh-e Jahan Bazaar is not merely a physical setting for passage, shopping, or pausing; rather, through its patterns of shade, the sequence of open and semi-open spaces, airflow, crowding, materials, rhythm of movement, and collective memory, it becomes an environment that organizes occupants' thermal perception at both the individual and collective levels. Accordingly, thermal comfort in this study is understood as a perceptual-experiential product, formed at the intersection of body, senses, memory, behavior, and spatial context, and serving as the basis for the empirical analyses of the present research (Fig. 3).

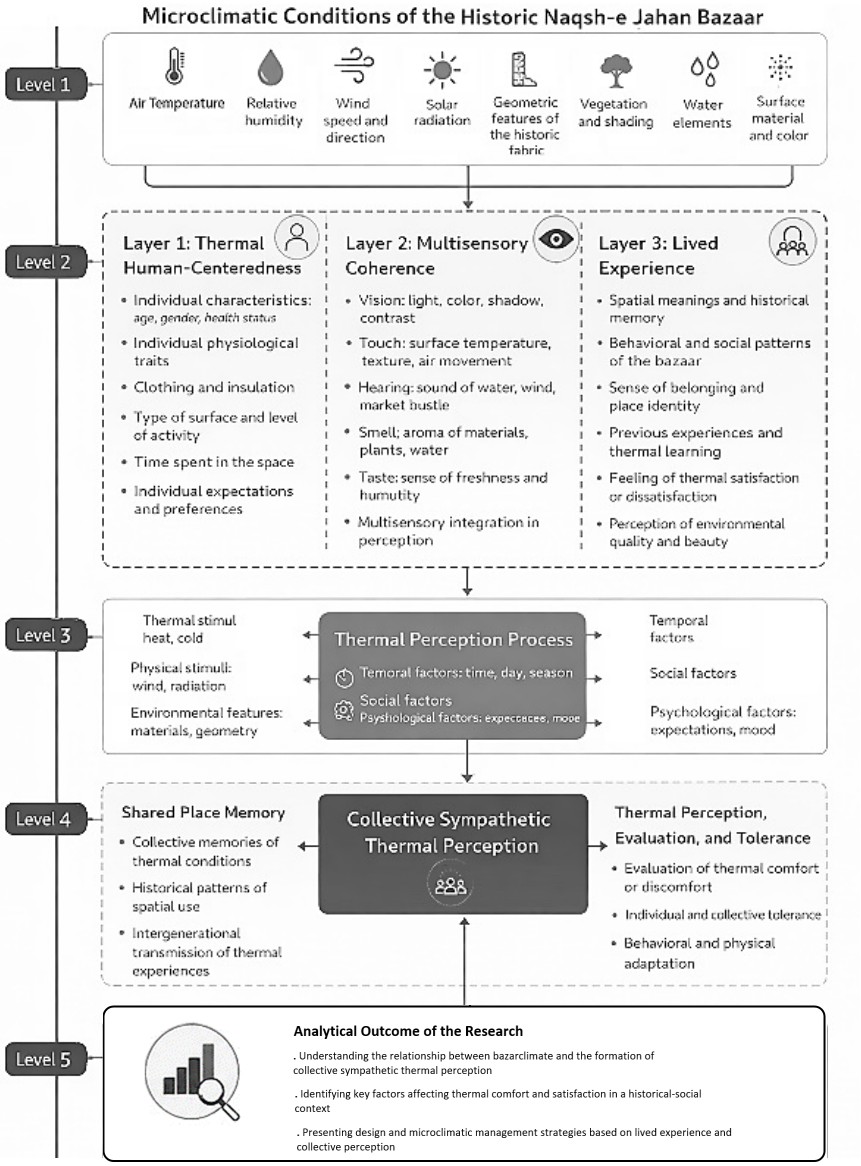


Fig. 3. The conceptual framework of collective sympathetic thermal perception (CSTP). Source: Authors.

Methodology

This study was conducted using a mixed-methods approach, with a qualitative emphasis. The primary research strategy was descriptive phenomenology, aiming to uncover the essential structure of occupants' thermal experience and to explain how thermal perception is formed within the socio-climatic context of the historical Isfahan Bazaar. Within this framework, qualitative data were employed to extract the concepts and themes of lived experience, whereas quantitative data served a supplementary role in explicating the relationship between environmental conditions, thermal perception, and functional outcomes.

The study area was confined to the western and eastern corridors of the historical Naqsh-e-Jahan Bazaar in Isfahan. Owing to its spatial and microclimatic diversity, the continuous presence of occupants, the variety of land uses, and its connection to collective memory, this area provides a suitable context for a phenomenological examination of thermal experience. Given the semi-open nature of the bazaar, this study employed the indices appropriate for outdoor spaces -namely UTCI and PET- to interpret environmental conditions. Sampling was conducted purposively, criterion-based, and with maximum variation. Participants comprised vendors, shoppers, and passers-by. In total, 100 individuals participated in the study- 50 during the second half of Dey 1403 and 50 during the second half of Tir 1404. Data collection was carried out across three time windows (10:00–13:00, 14:00–17:00, and 18:00–

21:00) and on Saturdays, Thursdays, and Fridays, so as to cover temporal, behavioral, and climatic diversity.

Data collection was conducted as a cross-sectional study at level three of thermal comfort research (Heidari & Sharples, 2002), and thermal perception questionnaires were completed simultaneously with the measurement of environmental conditions at the occupants' place of presence. As presented in Table 2, a DHT[22] sensor connected to an Arduino Uno board and a Benetech GM1365 data logger were employed to record environmental data, including air temperature, relative humidity, and Mean Radiant Temperature (MRT). Furthermore, to gain a deeper understanding of lived thermal experience, episodic interviews were conducted with 30 participants in order to document the detailed narratives and situational memories of thermal experience. In addition to assessing thermal sensation, comfort, and preference, both the questionnaire and the interviews covered human variables such as clothing insulation, health status, mood, activity type, expectation, acclimatization, and thermal acceptability. To this end, the Ashrae scale was used to measure thermal sensation, the Bedford scale to evaluate thermal comfort, and the McIntyre scale to measure thermal preference.

To ensure data quality in this mixed-methods study, the researchers evaluated validity and reliability in both the qualitative and quantitative strands in parallel and in accordance with the disciplinary standards of each domain. In the qualitative strand, the credibility of the findings was first secured through trustworthiness mechanisms. These mechanisms included member checking-in which the interpretations and extracted codes were returned to 22 of the interviewees for confirmation of their full correspondence with the participants' actual lived experience-alongside thick description of behavior and peer debriefing. These methods monitored the coding and thematization process. In the quantitative strand, the measurement of thermal perception was not grounded in self-constructed items but was built directly upon the aforementioned standard scales having international validity. Since the measurement instrument was composed of these previously validated scales, their structural reliability had been established in earlier classic studies, and their content validity is fully acknowledged across the global thermal comfort literature.

To ensure the questionnaire's precise adaptation to the local characteristics of the research context and to the measurement of contextual and behavioral variables, five experts and professors of architecture and climatology evaluated and confirmed the content validity of the final questionnaire. Prior to the main data collection, the reliability of the measurement instrument was examined through a pilot study conducted on 15 bazaar occupants. The calculated Cronbach's Alpha Coefficient was 0.84, indicating very high internal consistency and the satisfactory reliability of the quantitative instrument. Qualitative data

Table 2. Research instruments and measured variables. Source: Authors.

Instrument	Measured Variable	Measurement Range / Accuracy	Location and Procedure	Research Role
DHT22 Sensor	Air Temperature & Relative Humidity	Temperature: ~±0.5°C; Humidity: ±2% to ±5%	Installed at 1.1–1.5m above floor level; shielded from direct solar radiation and hot/ cold surfaces.	Capturing microclimatic conditions concurrent with participant surveys.
Benetech GM1365 Data Logger	Temperature & Relative Humidity	-30°C to +80°C; Temperature: ±0.2°C; Humidity: ±2%	Fixed positioning within the study area; automated, computer-linked data logging.	Continuous environmental monitoring for correlation analysis between environmental parameters and dependent variables.
Field Observation Form	User behavior, pausing patterns, movement, shade-seeking	Qualitative	Completed by the researcher during field measurements.	Interpreting adaptive behaviors.
Questionnaire	Thermal Sensation, Preference, and Satisfaction	Ordinal and multiple-choice scales	Administered in-person within the bazaar.	Collecting quantitative data on thermal perception.
Episodic Interview	Lived Experience Narratives	Qualitative	Semi-structured dialogue with selected participants.	Extracting phenomenological themes.

were analyzed according to the seven-step Colaizzi method (Colaizzi, 1978). In this process, 487 meaningful statements were extracted and organized into 91 initial codes and 18 sub-themes. Ultimately, this analysis led to the formation of three main conceptual layers of the study. To enhance the credibility of the findings, a return to participants was conducted with 22 of the interviewees. The supplementary quantitative data were also analyzed using SPSS 26.

Results

Thermal perception was assessed among 100 participants in the historic bazaar corridors of Isfahan, including 62 men and 38 women, with a mean age of 42 years. Based on urban activity typologies, respondents were classified into three main groups: permanent vendors with obligatory activity (45%), local shoppers and pedestrians with elective activity (35%), and tourists and socially engaged individuals (20%). Clothing insulation (Clo), calculated according to ISO 7730, ranged from 1.2 to 1.6 in winter and from 0.35 to 0. 55 in summer. Metabolic rate (Met), depending on activity type, varied from 1.2 Met (sitting and conversing) to 2.0 Met (walking with moderate load).

• Quantitative analysis

The quantitative analysis was organized into three interrelated layers: first, the distribution of reported thermal sensation votes (TSV) and their comparison with an independent a priori reference value; second, the pattern of thermal preference; and third, modeling the relationship between measured physiological stress (PET/ UTCI) and perceived sensation. Prior to data collection, seasonal reference values were determined on the basis of the adaptive thermal comfort literature in hot-arid climates rather than derived post hoc from the sample mean. Accordingly, the winter TSV reference was set at TSV_ref = -0.5 (slightly cool, yet within the acceptable range), and the summer reference at TSV_ref = +0.3 (slightly warm, yet attenuated). These reference values defined the null hypothesis: the observed mean thermal sensation does not differ significantly from the independent climatic adaptation expectation. Failure to reject this hypothesis would indicate alignment between collective perception and the adaptive pattern.

The data were analyzed using one-sample t-tests (df = 49 for each season). In winter, the mean thermal sensation was M = -0.52, with SD = 0.89 and SE = 0.13. Comparison with the reference value of -0.5 yielded t(49) = -0.16, p = 0.874, and a 95% confidence interval of (-0.77, -0.27). In summer, the mean was M = +0.34, with SD = 0.92 and SE = 0.130. Comparison with the reference value of +0.3 yielded t(49) = 0.31, p = 0.759, and a 95% confidence interval of (0.08, 0.60). In both seasons, the difference between the observed mean and the independent reference value was not statistically significant ($p > 0.05$). This indicates that collective thermal perception remained within the expected adaptive range, and that the bazaar environment, despite high external physical stress, shifted thermal sensation toward a near-neutral zone. Both confidence intervals also remained entirely within the thermal acceptance band of -1 to +1.

The thermal preference pattern, based on the McIntyre scale, reinforced this finding: 58% of participants in winter and 64% in summer selected the option "remain as it is." When weak preference responses were included, relative acceptance exceeded 76% in both seasons. By contrast, only 22% in winter and 28% in summer expressed a preference for cooler conditions. The convergence between the "majority without desire for change" and the "non-significant deviation from the reference" provides two independent indicators of a single phenomenon: perception stabilized within the acceptance zone.

Simultaneous measurements showed that the bazaar's built form functioned as a highly effective thermal moderator. In summer (July 2025), the urban reference station in Isfahan recorded an air temperature of 41.2°C, whereas the calibrated DHT[22] sensor measured an average indoor air temperature of 33.4°C in the bazaar corridors, indicating a substantial reduction of 7.8°C. Calculation of the outdoor thermal stress index showed that PET decreased from 46.5°C in open space to 34.1°C inside the bazaar, owing to full shading by the façades and the vaulted roof. This shift reflects a transition from "severe thermal stress" to "moderate thermal stress".

In winter (January 2025), the high thermal mass of the bazaar fabric prevented rapid heat loss, and the average indoor air temperature in the corridors was 4.5°C higher than outside conditions. The average UTCI inside the bazaar was 11.2°C, corresponding to "slight cold stress,"

whereas in the surrounding urban open space it fell below 5.0°C, indicating "moderate cold stress."

Regression Modeling of Actual Thermal Sensation (TSV) and Physiological Equivalent Temperature (PET)

To estimate the thermal comfort zone of occupants more precisely, actual thermal sensation votes (TSV), collected on the 7-point ASHRAE scale (+3 to -3), were regressed against PET.

Summer regression equation:

$$TSV_{summer} = 0{,}114 \times PET - 3{,}056 (R^2 = 0{,}68 < p < 0{,}001)$$

Setting TSV = 0 (neutral or desirable thermal sensation) yields the neutral PET for summer:

$$0 = 0{,}114 \times PET_{neutral} - 3{,}056 \implies PET_{neutral\,summer} = 26{,}8^{\circ}C$$

Winter regression equation:

$$TSV_{winter} = 0{,}138 \times PET - 2{,}392 (R^2 = 0{,}72 < p < 0{,}001)$$

Setting TSV = 0 yields the neutral PET for winter:

$$0 = 0{,}138 \times PET_{neutral} - 2{,}392 \implies PET_{neutral\,winter} = 17{,}3^{\circ}C$$

The high coefficient of determination (R^2 > 0.65) indicates that the physical PET index explains a substantial share of the variance in perceived thermal sensation. The remaining variance may be attributed to individual adaptive factors (clothing, beverage intake, weather history) and cultural factors (contextual expectations, sense of belonging to the bazaar), which are further elaborated in the qualitative analysis section. The two neutral temperatures differ by 9.5°C, suggesting seasonal adaptation consistent with ASHRAE 55 and the findings of de Dear and Brager regarding increased thermal expectations in warm seasons. These results show that the acceptable thermal comfort range for bazaar occupants (-1 to +1) is considerably wider than that of standard indoor environments (ASHRAE 55). In summer, this acceptance zone extends to PET = 35.6°C, while in winter it extends down to PET = 10.1°C. The wider summer span reflects the difference in slope between the two regression equations: the steeper winter slope (0.138) compared with summer (0.114) indicates greater sensitivity of perception to changes in physical stress and, consequently, a narrower acceptance band.

These two analyses measure the same phenomenon from complementary perspectives. The t-test shows that the collective level of perception does not significantly deviate from the adaptive expectation, thereby confirming overall acceptance. The regression model demonstrates how that perception varies continuously as a function of physical stress and quantifies the neutral temperature and acceptance range. The internal consistency between the two narratives is clear: substituting the mean summer PET inside the bazaar (≈34.1°C) into the summer equation yields TSV = 0.114 × 34.1 - 3.056 ≈ +0.83, which is consistent with the dominant sensation of "slightly warm." This layered consistency quantitatively supports the notion of a single-step attenuation process: the bazaar reduces external physical stress before it reaches perception, and this reduction keeps collective perception within the acceptance range, thereby supporting thermal comfort.

- Analysis of the influence of presence duration and gender on thermal perception (Independent samples t-tests)

Before conducting the tests, the assumptions of normality and homogeneity of variance were examined and confirmed (|Z_skewness| < 3.29, |Z_kurtosis| < 3.29, and Levene's test p > 0.05).

Effect of Duration of Presence: Users were categorized into two groups based on their duration of stay in the bazaar (less than one hour and more than one hour). An independent t-test revealed that the duration of presence had no significant effect on thermal sensation. This finding suggests that as the duration of stay increases, the adaptive mechanism is activated; occupants dynamically stabilize their thermal comfort through behavioral adjustments, such as modifying clothing insulation, reducing walking speed, or altering their spatial position.

Effect of Gender: An independent t-test indicated no statistically significant difference between men and women regarding Thermal Sensation Vote (TSV) and thermal preference (p_"winter" =0.980 and p_"summer" >0.05). Despite inherent biological differences, this convergence suggests that psychological factors-grounded in climatic-cultural identity, coordinated behavioral adjustments, and the phenomenon of "Thermal Silence"-mediate the relationship between physiology and subjective assessment.

- **Qualitative analysis**

In the qualitative phase, 30 in-depth phenomenological interviews were conducted. Theoretical saturation was reached by the 25th interview, and five additional interviews were undertaken to ensure data adequacy. Twenty-six

interviews were audio-recorded with written consent, while four were documented through detailed contemporaneous note-taking due to participants' unwillingness to be recorded. All ethical principles of the Declaration of Helsinki, including confidentiality, written informed consent, and the right to withdraw, were fully observed.

Qualitative data were analyzed using Colaizzi's seven-step method. Following verbatim transcription, 487 significant statements were extracted and, through a process of constant comparison, organized into 18 sub-themes and three principal themes corresponding to the study's conceptual layers. To assess dependability, 30% of the transcripts were independently coded by a second researcher, and the inter-coder agreement was found to be excellent (Cohen's kappa = 0.87).

- Layer one (18% of codes): Individual and physiological experience

At this level, occupants reported thermal sensation primarily through bodily responses such as sweating and shivering. In the Naqsh-e Jahan Bazaar, however, this individual sensation was often in tension with the normative pressure of collective presence. Participants acknowledged that even under thermally uncomfortable conditions, they frequently preferred remaining in the space to leaving it, due to the social structure of the setting, including being among others, pursuing a purpose, and responding to the gaze of others. This finding demonstrates the social nature of thermal comfort in public space: a partial transcendence of individual comfort in favor of sustained collective presence. The finding is consistent with the notion of collective sympathetic thermal perception, whereby observing the adaptive behavior of others, such as sitting in the shade or consuming seasonally appropriate drinks, reassures the individual that environmental conditions are shared and tolerable.

- Layer Two (68% of codes): Cognitive-Sensory Processes

The greatest density of extracted codes belonged to this layer, which explains the perceptual and sensory moderators shaping thermal experience.

Perception of Contrast and Thermal Pleasure (75% of interviews): In line with Cabanac's theory of alliesthesia (1971) and subsequent discussions by Parkinson et al. (2012), thermal pleasantness appears to be rooted not in physical stability but in dynamic thermal contrasts. Many participants explained that their thermal experience was strongly influenced by sudden temperature transitions. For example, moving from a very hot outdoor setting into a cooler environment, such as a shop or chamber in the bazaar with relatively controlled thermal conditions, could generate an intense feeling of pleasure, whereas the reverse transition was often associated with discomfort. The movement of shoppers and passersby through corridors, passageways, and intermediate spatial zones of the bazaar offers a clear example of dynamic thermal alliesthesia in practice.

Consistent with the findings of Li et al. (2026), who demonstrated that route-based microclimatic variation affects thermal comfort votes, occupants in the Isfahan bazaar likewise experience different potentials for dynamic thermal pleasure as they pass through thermally diverse spaces. These findings indicate that occupants do not experience temperature in absolute terms, but rather in relation to their immediately preceding condition. Moreover, the thermal pleasure component reveals that some conditions lying outside the conventional standard comfort zone may still generate desirable and pleasurable experiences. For instance, a strong sensation of warmth after exposure to winter cold was described by some participants as distinctly pleasant. Accordingly, the desirability of a thermal condition depends not only on absolute temperature, but also on change, contrast, and the body's prior state. Outdoor temperature may vary over short or long durations, and this dynamic quality, together with other environmental features or stimuli, may shift the occupant's thermal comfort range upward or downward while still producing no strong preference for thermal change (Lai et al., 2020).

Multisensory Coherence and Embodied Awareness: Non-thermal stimuli can also shape thermal perception. For instance, in summer, the reverberation of water sounds may evoke a perceptual sense of coolness even when air temperature remains unchanged. This phenomenon may be interpreted through the concept of embodied awareness (Varela et al., 2017), a process in which mind and body interact integrally with the environment, and multiple

stimuli provide the perceptual ground through which thermal conditions are interpreted. This finding confirms the importance of multisensory design in outdoor and semi-open spaces.

Seasonal Memory and Expectation: Occupants compare their present experience with prior memories, and this comparison contributes to the formation of thermal expectations. For example, coldness in winter is often perceived not as a problem, but as an integral part of the seasonal experience. This finding aligns with the theory of psychological adaptation proposed by Nikolopoulou & Steemers (2003), which emphasizes the role of pre-structured expectations in shaping thermal evaluation. Independent samples t-tests further showed that occupants whose expectations were seasonally congruent reported more neutral thermal sensationsxxBy evaluating environmental conditions against pre-formed expectations, the brain appears to reduce prediction error and, consequently, generate a lower allostatic load. Within this process, semantic memory (cultural schemas) seems to play a dominant role in winter, whereas episodic memory (recent lived experience) becomes more influential in summer. Participants frequently noted that thermal experiences from previous phases of the season affected their evaluation of present temperature. Many explained, for example, that the heat of early summer is typically felt as more intense than the heat of late summer, because the body has not yet adapted to the new thermal regime. As the season progresses and exposure continues, the body gradually adjusts to the prevailing climatic conditions, and the same temperature becomes more tolerable. These accounts are consistent with the notion of gradual adaptation, indicating that human thermal experience does not depend solely on the immediate temperature of the environment, but is also shaped by prior exposure and the body's adaptive trajectory. As repeated exposure accumulates, initial thermal sensitivity declines and the individual's evaluation of the thermal environment changes accordingly. Temperature, therefore, operates not merely as a physical variable, but as a perceptual mechanism capable of activating climatic memories. This phenomenon may be understood as a form of temporal bridging, through which present thermal experience summons seasonal memories of the past and creates a link between lived time and the present moment.

- Layer three (14% of codes): The cultural-existential dimension

At this level, thermal conditions become part of place memory and place meaning. Many participants connected the heat and cold of the bazaar with memories from earlier periods of their lives. Winter cold was associated with conviviality and gathering, while summer warmth evoked childhood play, seasonal foods, and the climatic identity of Isfahan. This affective-cultural memory transforms thermal conditions into part of the place's identity, such that even under circumstances of thermal stress or discomfort, attachment to place remains intact because the prevailing conditions are perceived as authentic. Contextual expectation is also significant: occupants expect historic spaces to retain natural thermal conditions, and therefore modern technological interventions may be perceived as conflicting with the authenticity of place. This finding underscores the importance of culturally consonant design and the use of traditional environmental strategies such as wooden shading devices, water basins, and planted courtyards.

Thermal Comfort as Social Practice: Thermal comfort in the bazaar emerges not as an isolated biological response, but as a social and systemic practice. Three principal dimensions are particularly salient.

Social Interaction (72% of interviews): Participants often tolerated thermal discomfort in order to sustain the pleasures of social presence. This finding is consistent with the arguments advanced by Hitchings (2011) and Shove (2003), both of whom suggest that the perception and expression of thermal discomfort are not merely physiological processes, but are formed within social and normative contexts.

The Phenomenon of Thermal Silence: A total of 38% of participants refrained from expressing dissatisfaction because of gender norms, age-related expectations, or an insistence on adapting to the historic setting. This form of normative conflict reveals the cultural modulation of thermal comfort perception, which is, in turn, mediated by the bazaar atmosphere. These findings are consistent with the work of Harlan et al. (2006) and Klinenberg (2015),

both of whom demonstrated that climatic and thermal consequences are distributed unevenly across social groups. From this perspective, the design and management of public spaces should move beyond mean-centered approaches and attend more explicitly to the needs and experiences of vulnerable groups.

Local Physiology and Climatic Identity: Local inhabitants of Isfahan appeared to express greater tolerance to heat than visitors from other regions, largely because they interpreted heat endurance as part of their climatic identity. This finding is consistent with the perspectives of Orlove & Strauss (2003) and Ingold (2010), who argue that climate should be understood not merely as a natural phenomenon, but as part of the symbolic and identity-making system of communities. From this perspective, climate change cannot be reduced to shifts in environmental indicators alone; it may also weaken climatic identity and erode the cultural meaning of seasons. In a related vein, Chappell & Shove (2007) demonstrated that global thermal comfort standards are often formulated on the basis of specific cultural models and therefore overlook the diversity of ways of living across different climates. Under such conditions, thermal experience may gradually shift from a locally rooted cultural phenomenon to a homogenized and standardized one.

Dynamic Mechanism of the Collective Sympathetic Thermal Perception Model

Based on the qualitative and quantitative findings of this study, the model of Collective Sympathetic Thermal Perception operates through three sequential and dynamic stages:

- **(a) Stage of social observation and appraisal**

Upon entering the bazaar, the occupant observes the adaptive behaviors of others, such as sitting in the shade or adjusting clothing. This process begins with the activation of mirror-neuron mechanisms (Rizzolatti & Craighero, 2004), through which the brain simulates the thermal condition of the environment and, even before direct physiological exposure, elevates the individual's threshold of tolerance.

- **(b) Stage of imitation and behavioral synchronization**

The occupant then imitates the successful adaptive behaviors of the collective, such as reducing clothing insulation, adjusting walking speed, or using vernacular cooling devices. This imitation constitutes a form of behavioral synchrony enabled through social learning (Bandura, 1977). Beyond its thermodynamic function, such synchrony reinforces the sense of belonging, reduces psychological allostatic load, and minimizes the fatigue associated with confronting the environment.

- **(c) Stage of social confirmation and experiential stabilization**

Through social comparison (Festinger, 1954), occupants assess their own condition in relation to others and become reassured that the prevailing thermal state is part of a natural and shared collective experience rather than an individual problem. At this stage, the occupant shifts from merely reacting to the environment toward actively interacting with it. This transition contributes to the emergence of positive thermal silence, in which discomfort is not simply suppressed, but reinterpreted as socially normalized and experientially manageable.

A Multilayered Explication of Thermal Experience in Collective Sympathetic Thermal Perception

Based on Fig. 4 and the interplay among the three extracted conceptual layers, the final conceptual model of the study demonstrates that thermal experience emerges from a complex interplay of social, temporal, cultural, and existential factors, and cannot be reduced to a mere physiological response of the body to temperature.

Within this model, the layer of thermal human-centeredness provides the social and normative ground of experience, demonstrating that thermal responses are shaped within a field of collective interaction. The layer of multisensory coherence explains the temporal and adaptive dimensions of thermal experience and emphasizes the roles of memory, adaptation, prior experience, and embodied awareness. Finally, the layer of lived experience reveals the cultural, identity-related, and meaning-laden dimensions of thermal perception.

The findings show that these three layers are dynamically and reciprocally interconnected. Social norms may shape seasonal expectations; thermal memories may strengthen

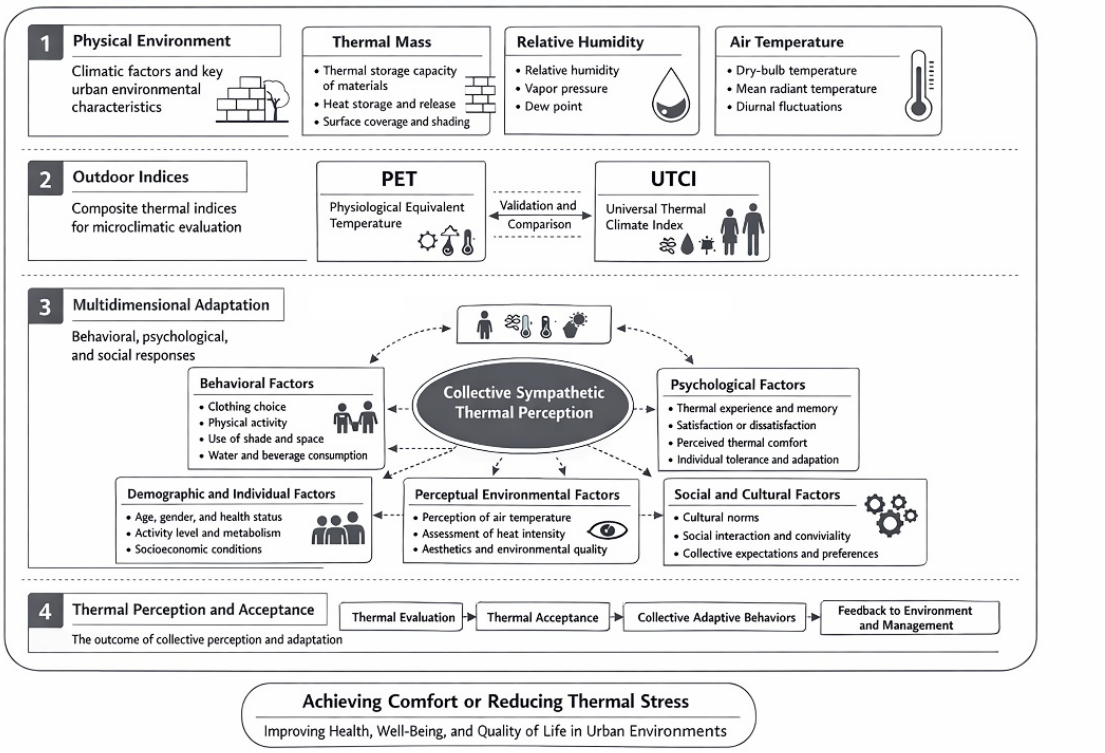


Fig. 4. Explication of collective sympathetic thermal perception (CSTP) in the Historic Bazaar of Isfahan. Source: Authors.

place attachment; and the cultural meanings of temperature may influence tolerance of climatic conditions. Thermal experience, therefore, is a multidimensional, situated, and collective phenomenon formed through the interaction of body, memory, culture, and society. This conceptual model offers an interpretive framework for understanding human thermal behavior in urban spaces and provides a basis for developing human-centered approaches in architectural design and climate-responsive planning.

The following section explains how the three layers of Collective Sympathetic Thermal Perception affect and reinforce one another.

• Layer 1 -> Layer 2: Linking social norms and seasonal memory, from collective expectation to individual adaptation

Quantitative findings show that the mean thermal sensation votes (TSV) in both seasons differ significantly from the level of physical stress indicated by the outdoor environment and remain within the acceptable range (-1 to +1). This reduction in stress occurs through a mechanism of one-level attenuation, whereby moderate or severe thermal stress is reduced to mild stress. According to outdoor thermal stress indices such as PET and UTCI, the environment outside the bazaar in summer falls within the range of severe heat stress (PET > 41°C), while in winter it falls within the range of moderate cold stress (PET < 8°C). Yet occupants' perceptions in both seasons were recorded at the level of mild stress.

This gap between environmental stress and perceptual evaluation indicates a form of tension in the first layer, namely individual physiological sensation: occupants feel heat or cold, yet continue to remain in the space. This tension is moderated through the mechanisms of the second layer.

First, alliesthesia, or sensory adaptation, occurs. Movement across environments with different thermal conditions-for example, from sun to shade, from open space to covered bazaar corridors, or from retail stalls to the bazaar passageways-reduces sensitivity to baseline temperature and makes environmental conditions more tolerable in perception. Second, thermal memory and embodiment play an important role: the body gradually adapts to seasonal temperatures. In winter, occupants who had remained in the space for longer periods reported thermal sensations similar to those who had stayed for shorter periods ($p = 0.389$), indicating a form of physiological-cognitive adaptation. Third, multisensory coherence becomes operative: the combined experience of light, sound, smell, and humidity

alongside temperature modulates thermal perception and reduces the intensity of stress.

Social norms reinforce these mechanisms through two pathways. In the cognitive pathway, norms shape occupants' expectations and interpretations. When a community considers tolerance of heat or cold to be acceptable, or even valuable, individuals undergo the adaptation process more readily. In the behavioral pathway, norms guide adaptive practices-such as standing in the shade, eating ice cream, or adjusting clothing-and thereby contribute to reducing thermal stress by one level.

The distribution of thermal preference showed that more than half of the occupants did not wish to change the thermal conditions. This can be explained through the mechanism of collective sympathetic perception: the presence of others and the observation of their adaptive behavior create a form of cognitive reassurance that environmental conditions are shared and tolerable. In this way, the mechanism functions as a bridge between the first layer, individual experience, and the second layer, collective-sensory experience.

• Layer 2 -> Layer 3: The role of seasonal memory and Alliesthesia in reinforcing the cultural meaning of space

Seasonal memory operates through two pathways. The first is physiological adaptation, through which the body gradually adjusts to seasonal temperatures. The second is psychological adaptation, through which expectations and interpretations change as a result of repeated experience.

In winter, expectations derive largely from semantic memory-that is, memories of previous winters and cultural schemas such as "winter = cold." Individuals who have experienced Naqsh-e Jahan Square in previous winters already anticipate cold conditions. This expectation creates a cognitive buffer that reduces the intensity of perceived stress.

In summer, expectations depend more strongly on episodic memory, namely recent experience and environmental cues such as sunlight, shade, or wind. Occupants who had been exposed to direct sunlight before entering the square expected greater heat. By contrast, those who entered through shaded paths anticipated cooler conditions. This thermal contrast, interpreted through the framework of alliesthesia, contributes to stress attenuation, such that severe heat is perceived by users as only mild stress.

When occupants derive a pleasant experience from these thermal transitions, that experience does not remain a momentary reaction. Rather, it becomes part of place memory. The linkage between bodily experiences, symbols, and cultural meanings enables public spaces to acquire a distinct and multilayered identity. Under these conditions, thermal experience extends beyond a purely physiological phenomenon and becomes part of cultural capital and urban identity.

• Layer 3 -> Layer 1: Reinforcing social norms through cultural meaning and place identity

With regard to the role of place attachment and spatial identity in sustaining the activities of shopkeepers in Qeysarieh Bazaar, the phenomenological analyses of this study show that the deep mental and occupational bond between occupants and the historic bazaar of Naqsh-e Jahan plays a moderating role. This bond raises the threshold of thermal tolerance and strengthens acceptance of prevailing thermal conditions across seasons.

The findings of the third layer show that temperature is not merely a physical stimulus, but also a carrier of social and cultural meanings. A particular temperature may evoke memories of the past. Enduring heat or cold may be understood as part of a community's climatic identity. Likewise, thermal experience may render a space distinctive and memorable.

At this level, cultural meanings and place identity become a reproductive force for social norms. When an urban space possesses a clear and meaningful climatic identity, that identity becomes a foundation for the continuity of social norms, particularly norms concerning the expectation of enduring climatic conditions. Thermal experience is therefore not only the outcome of environmental conditions, but also a reflection of the socio-cultural values and beliefs of the community. These values become stabilized in collective memory through narratives, symbols, and shared experiences.

As a result, an interactive cycle emerges among the three analytical layers, a cycle in which each layer reinforces and reproduces the others. This interaction ultimately stabilizes the mechanism through which thermal comfort is achieved, or thermal stress is reduced, within a durable socio-cultural context.

Conclusion

The findings of this study show that occupants' thermal perception in the historic bazaar of Naqsh-e Jahan can be explained through a mechanism of thermal stress attenuation directed toward the approximation or achievement of thermal comfort. Environmental conditions outside the bazaar, in Naqsh-e Jahan Square, fall within the range of severe heat stress in summer (PET > 41°C) and moderate cold stress in winter (PET < 8°C). Nevertheless, the spatial and architectural characteristics of the bazaar-including continuous shading, semi-enclosed corridors with natural ventilation potential, and the adaptive behaviors of occupants-reduce the intensity of thermal stress. The quantitative data confirm this pattern: the mean thermal sensation vote (TSV) was -0.52 in winter and +0.34 in summer. Both values fall within the acceptable range (-1 to +1, based on ISO 7730) and do not differ significantly from the predicted thresholds ($p_{winter} = 0.874$, $p_{summer} = 0.759$). These results indicate that the historic bazaar does not necessarily create conditions of full laboratory-defined comfort, but it does provide an environment that is distinctly tolerable and desirable for prolonged occupancy.

To explain this phenomenon, the present study proposes the conceptual model of Collective Sympathetic Thermal Perception, which interprets thermal perception through three complementary layers.

In the first layer, physiological human-centeredness and social practice, the occupant's physiological stress interacts with social norms. These norms shape thermal expectations and adaptive behaviors. At this level, the phenomenon of thermal silence becomes evident, as a considerable proportion of occupants (approximately 38%) refrain from expressing dissatisfaction despite experiencing actual thermal stress, owing to occupational commitments, collective norms, or emotional attachment to the space, and thus remain in place. Under these conditions, observing the adaptive behavior of others-such as moving slowly in the shade-creates a form of social confirmation that the shared environmental condition is tolerable.

In the second layer, alliesthesia and embodiment, thermal perception is formed in relation to multisensory perception. Transitions between thermally contrasting environments-such as moving from the sunlit open square into the shaded, covered, and semi-open bazaar corridors-activate the mechanism of alliesthesia (sensory pleasure arising from thermal contrast), thereby reducing sensitivity to baseline temperature. Embodied awareness and seasonal memory further reinforce this process, such that prior experiences of winter (semantic memory) or summer (episodic memory) modulate occupants' thermal expectations.

In the third layer, lived experience and place identity, temperature becomes part of the cultural experience of space. The repetition of thermal experiences within a specific spatial setting generates a shared climatic identity that increases occupants' threshold of thermal tolerance. At this level, thermal perception is not merely a reflection of physical conditions, but rather the outcome of interaction among body, memory, and the cultural meaning of space. The interaction among these three layers produces a feedback cycle: the climatic identity of place reinforces social norms, social norms guide adaptive behaviors, and these behaviors reduce the intensity of thermal stress. The estimated functional neutral temperatures (26.8°C in summer and 17.3°C in winter) are also consistent with users' mean thermal sensation votes, indicating that perceptual and cultural mechanisms play a key role in shaping thermal acceptance in the bazaar.

From the perspective of urban design and policy, the findings suggest that public spaces in hot-arid climates should not focus solely on thermal homogenization and uniformity, but should instead emphasize three practical principles:

- **Enhancing microclimatic diversity:** creating deliberate thermal transitions and contrasts among sunny, shaded, and semi-open spaces in order to activate alliesthesia, support embodied awareness, and foster multisensory coherence.
- **Reviving and reinterpreting vernacular architectural elements:** preserving the appropriate spatial geometry of bazaar corridors to maintain continuous shading, while employing vernacular features such as iwans, vaults, and water elements (e.g., pools), which serve both physical functions-such as evaporative cooling and airflow guidance-and symbolic functions, including the stimulation of sensory memory and identity.
- **Adopting broader comfort ranges:** applying more flexible acceptance ranges (3.5 to 4.2°C beyond fixed standards) in the design of urban open spaces, in accordance with local perceptual and cultural mechanisms.

Despite these contributions, the study has several limitations. Data were collected only during the two extreme seasons, summer and winter, while other seasons were not examined. The sample size in each season (50 participants, 100 in total) remains limited for deeper analysis. Some physiological variables, such as clothing insulation and metabolic rate, were estimated on the basis of standard tables and field observations rather than direct laboratory measurement, due to the practical constraints of data collection in public space. In addition, the findings are closely tied to the hot-arid climate of Isfahan and the unique spatial structure of the historic bazaar; therefore, their direct generalization to other climates and contemporary urban settings requires further research.

Overall, thermal perception in historic public spaces is a multilayered phenomenon that extends beyond purely physiological responses and is formed through the dynamic interaction of body, space, and culture. The model of Collective Sympathetic Thermal Perception provides both a conceptual and an applied framework for analyzing this interaction and demonstrates that understanding thermal comfort in built environments requires simultaneous attention to the physiological, perceptual, and social dimensions of human experience.

Declaration of Conflicting Interests

The authors declare no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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