Exploring the Role of Human Perception: A Comparative Analysis of Human Thermal Comfort and Urban Design Parameters

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ABSTRACT: Weather is arguably the most important factor of thermal comfort, both as an actual and perceived component, from a user's viewpoint. The received energy, real or presumed, by the user is highly decisive in how well an outdoor space is used. The present study illuminates the human perceptual mechanisms involved in an urban open environment and human thermal comfort assessment, with an emphasis on hot climates. The primary objective is to identify underlying conditions influencing people's behavior in and usage of outdoor spaces. An in-depth literature review lucidly demonstrated that a physiological approach alone is inadequate in characterizing human thermal comfort conditions. Therefore, embracing a holistic approach, a novel conceptual model is proposed, tentatively aligning direct and indirect factors of influence. The model is qualitatively focused, and will subsequently be tested by an empirical study, performed in the Walled City of Lahore, Pakistan. This study will decipher the influences of both weather parameters (e.g., air temperature, wind, and solar radiation) and personal factors (e.g., place perception, emotions, sensations, and behaviors) on participants' emotional estimations of urban open spaces. Age and gender are some of the demographics considered in the analysis. Users of urban open spaces being the fulcrum, the intended human versus machine conceptual framework is a robust side-by-side comparative analysis of the unique domains of science and social science. Fused with the physical design components, the model is distinguished by the simultaneous and equal assessment of the two basic characteristics of empirical measurements and subjective human feelings. The scope of the study is innovative, distinctive, and unprecedented in the context of hot climate cities. Therefore, it presents a significant and contributory step towards a greater understanding of the psychological dimension influencing weather assessment and consequently human behaviour in the urban environment, projecting implications on urban design.

KEYWORDS: Global Sustainability, Inclusive Urban Landscapes, Microclimate, Human Behaviour, Urban Design.

Introduction

Weather fundamentally affects the level and comfort of human activity in outdoor urban environments. As a result, the parallel investigation between received and perceived weather is a very important factor for both the use and perception of outdoor urban spaces (Bekele, Jones, & Rajamani, 2008; Kántor, Unger, & Gulyás, 2012; Lenzholzer & Brown, 2013). It is established that designing climate-sensitive outdoor urban places may have a positive social effect besides health, social, economical, and environmental benefits (Givoni, 1998; Graham, Vanos, Kenny, & Brown, 2017). In the last twenty years, researchers have focused on and fused the psychological variables involved in outdoor spaces alongside weather parameters (Hoppe, 2002; Hoppe & Seidl, 1991; Nikolopoulou, Baker, & Steemers, 2001; Nikolopoulou & Lykoudis, 2006a; Nikolopoulou & Steemers, 2003; Thorsson, Lindqvist, & Lindqvist, 2004). This shift in research approach aimed to achieve more holistic, inclusive, and balanced findings on human thermal comfort. In line with this, some findings have recently indicated that the processes of weather assessment may have been found to be intertwined with psychological and cultural processes (Knez & Thorsson, 2006, 2008) rather than being identifiable through the general thermal indices alone as suggested by the physiological heat balance models (Coccolo, Kämpf, Scartezzini, & Pearlmutter, 2016a; Hoppe, 2002). Therefore, expanding the concept of thermal comfort to embrace psychological/cultural aspects and spatial feeling is one of the key goals of the present research. The hypothesis of the present study is that: There is a direct relationship between thermal adaptation to reach thermal comfort and different levels of a sense of place in urban spaces.

To quantify human thermal perception (thermal comfort), more than 100 different indices (Igor Knez, Thorsson, Eliasson, & Lindberg, 2009) have been developed over the years, predominantly defining the amount of heat exchanged between a human body and its surrounding environment (Jendritzky, De Dear, & Havenith, 201). These models may be classified into three main streams: empirical indices, thermal indices, and linear equation indices. The first simplified model developed was based on the interactions of two simple meteorological variables. This was followed in the 1930s by Gagge's model, a first ever attempt to apply the principles of thermodynamics to the energy exchanged between the human body and its thermal environment (Coccolo, Kämpf, Scartezzini, & Pearlmutter, 2016b). Givoni, during the seventies, further refined the thermal comfort model by developing the Index of Thermal Stress. Later, during the 1970s, Fanger developed the Predicted Mean Vote, which is a well-recognized standard to quantify indoor human thermal comfort perceptions. Indoor human thermal comfort was already being examined and quantified consistently owing to the stable nature of the indoor environments. Conversely, quantifying the precise impact of an outdoor environment on human thermal comfort is still a challenge (Hoppe, 2002; Jendritzky et al., 2012). None of the over 100 indices nor the new Universal Thermal Climate Index-UTCI (www.utci.org) – which is presently in progress by an initiative of the International Society of Biometeorology – take into account the psychological variables involved in outdoor thermal perceptions.

Given the above, the aim of this paper is to clarify the psychological mechanisms involved in the human experience of outdoor spaces and weather assessments by proposing a conceptual model suggesting direct and indirect links of influence in an outdoor place–human relationship. This work is part of an on-going doctoral research at the School of Architecture, Planning, and Landscape (SAPL), University of Calgary. The objective and ambition is to integrate and enhance the knowledge of the complex relationship between climate and human behaviour and its implications for sustainable urban design in a hot, arid urban environment.

1.0 PSYCOLOGICAL AND ENVIRONMENTAL ASSESSMENT

The term 'adaptation' may be defined as the steady waning of an organism's response when exposure to a stimulus is gradually increasing. In connection with human thermal comfort, this draws in all the processes a user may go through to find a fit with the environment. A series of articles (Nikolopoulou et al., 2001; Nikolopoulou & Lykoudis, 2006a; Nikolopoulou & Steemers, 2003) have suggested that a) a purely physiological approach is inadequate and b) conditions influencing human behaviour and perceptions may account for some of the unexplained variances between objective and subjective thermal comfort assessments. In the transitional seasons, these parameters may influence both the experiences and expectations of the subjects' thermal behaviours from the preceding seasons. Other factors included in the studies were naturalness, time of exposure, perceived control, and environmental stimulation. Of the variables to be assessed, "experience", is of great significance for the understanding of the human factor. Place, experience and exposure (temporal dimensions) are central to human thermal comfort and the resulting behaviour in an outdoor open environment (Eliasson, Knez, Westerberg, Thorsson, & Lindberg, 2007; Knez, 2005a). Due to this, environmental assessment does not only involve thermal comfort estimations and psychological adaptations, but also the experience and time, which have a central role to the holistic understanding of a given outdoor setting (Igor Knez et al., 2009).

Humans tend to think, visualize and rationalize through a set of information gathering processes, which is typically through recognizing a physical stimulus (seeing, hearing, smelling, tasting, and touching) and conscious involvement of its experience (Eysenck & Keane, 2020; Kitchin, 1994). According to the length of exposure, the human sensory system (where received information is further processed) transforms this knowledge into pockets of cognitive and meaningful information. It is also established that any information stored in the human brain for 30 seconds or less, by definition, is explained as short-term memory. Thus, we know that short-term human memory has a very limited capacity where the sensory data is cognitively identified, named, and held for a maximum of no more than half a minute. If short-term memory is "here and now", long-term memory, on the other hand, may be explained as the psychological "past" that gives us the meaning of the places we engage with, because this is where all our experiences and knowledge (from facts to personal events) are stored. Long-term memory is organized into several different memory systems storing declarative (factual knowledge and experiences of which we are directly aware) and procedural (know-how skills such as how to walk and ride a bicycle) types of information. Hence any visual and experiential information that has been held longer, rehearsed, and elaborated through consistent exposure will be considered in this study.

Actually, it is important to acquire deeper and equitable knowledge about the long-term spatial perceptions or "schemata" as they are known to have significant influence on the human behavioral responses and acceptance or avoidance of places (Lenzholzer, 2010). Furthermore, long-term spatial perceptions, as pointed out by (Lenzholzer, 2012)(Igor Knez et al., 2009; Nikolopoulou et al., 2001), have a crucial impact on thermal sensation. A European study based on a survey of more than 10,000 people shows how neutral sensation could vary by 10 ˚C between Athens (23˚ C) and Freiburg (13˚ C). Only a few other studies concerning human thermal perception (thermal comfort) suggested that Swedes and Japanese might have evolved different culture-related subjective scales, accounting for the different assessments of thermal comfort between the members of the two cultures (Park et al., 2011). Also, (I Knez & Thorsson, 2006) outlined the differences in place-related identity versus environmental components. Due to this, the enunciatory part of long-term memory contains different organizing structures, implicitly influencing the processes of perceptions and comprehensions. Due to this, it is hypothesized that spatial perceptions are mental attitudes and a reasoning that has strong relational connections with the environmental assessments.

In summary, many outdoor open spaces, despite lacking in thermal comfort, are known to have attracted a large number of users for social activities. The relationship between the two concepts of actual thermal comfort and sense of place is vital for successfully functioning outdoor open spaces. Particularly in the context of hot, arid, and densely populated urban cities, the results of this study will be unique, novel, contributory and significantly useful to landscape architects, architects, and urban designers.

1.1. Objectives

In view of the significant knowledge gap comparing thermal comfort (science) and human factor (social science), the primary objective of this conceptual model is to decipher the influence of both weather parameters and personal human factors on participants' emotional estimations of the urban open spaces. Therefore, this model is aimed at side-by-side holistic comparisons of the direct and indirect factors impacting the users of outdoor open urban places. The model will be tested by an empirical study performed in the Walled City of Lahore, Pakistan.

2.0 METHODS

2.1. Conceptual Model

As can be seen in Fig. 1, a conceptual model comprises direct and indirect indicators of influence of place-related parameters on human responses. This conceptualization involves three main organizing entities, namely place (physical design) and science (weather parameters) vs. social science (human perceptions and responses) and by that this model will test some of the hypotheses as assumed.

This study is mainly based on interviews/surveys with the visitors to four different quarters, locally known as 'Mohallas', about their long-term thermal comfort experience and spatial perception, in the city of Lahore, Pakistan, 31.5204° N, 74.3587° E. These four Mohallas namely 'Shahi Mohalla', 'Jogi Mohalla', 'Noor Mohalla' and 'Daran Mohalla' are among the many comprising the Inner Walled City of Lahore, Pakistan. Besides interviews, a parallel weather parameter (microclimatic components) that influences human thermal comfort and sensation will also be measured. The field work will be performed for five days at each Mohalla, stretching to total of 20 days covering data collection on all four Mohallas.

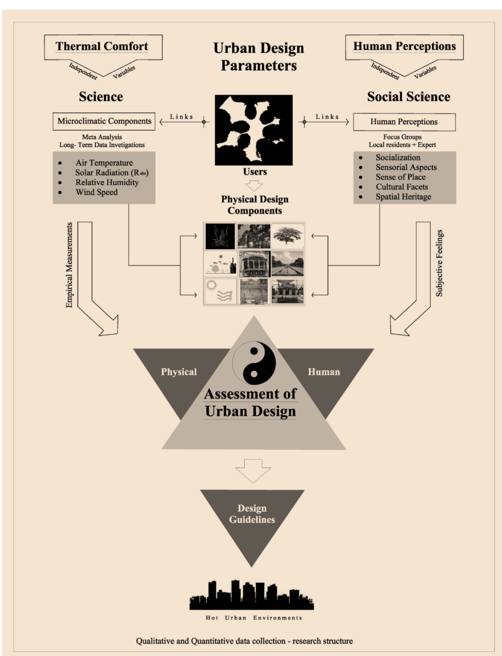

Figure 1: Proposed Conceptual Model: Holistic framework linking thermal comfort, human perceptions, and urban design parameters

The four Mohallas do not differ much concerning their fitness for the shorter and especially the evening sojourns. This fitness can be expressed by no supporting environment of ‘sitability’. In all four Mohallas, outdoor cafés where people can sit and enjoy leisure time are nonexistent. The local public, in the absence of any benches, generally use flights of stairs in front of their houses to settle and relax during the evenings. The Mohallas are similar in spatial structure and other parameters that might have a uniform influence on human thermal comfort experiences. For example, they are similar in terms of urban geometry, building typologies, and density. The proportions of typical streets inside the Mohallas are often expressed in terms of the height/width ratio (H/W). This ratio sets the height of the surrounding buildings in relation to the width of the street (the surrounding buildings measured from wall to wall). The lower the H/W value of a street, the wider its proportions(Lenzholzer & Van Der Wulp, 2010), hence the inherent H/W ratio of street network inside the selected four Mohallas of Shahi, Jogi, Noor and Daran may be classified as narrower.

2.2. Assessing Place Over Space

Space and place together define the nature of an outdoor open environment. However, this study will focus more on place instead of space (Blaison & Hess, 2016). Spatial analysis investigates physical dimensions which are of form (structure, openness), material (surface characteristics), naturalness (degree of artificiality), and location (space dimension). Weather parameters include meteorological components such as temperature (air and surface), radiation (direct and reflected long-wave and short-wave), wind speed, humidity, and overall day condition (cloudy-clear sky etc). The function of an outdoor open space may be further divided into physical activity (standing, sitting, lying, walking, running, etc.) and social activity (talking, playing, associating, etc.). In summary, space will entail and be limited to the only physical and spatial connotations (Igor Knez et al., 2009). Place, on the other hand, has noticeably been underplayed and subsumed under the geographer’s concept and analysis of space. Whereas phenomenologically addressing, space is equally, if not more important in the assessment of human thermal comfort and energy balance in connection with an outdoor open environment (Lemonsu et al., 2020; Unger & Matzarakis, 2006). Place is hugely grounded in the psychological and social aspects of space experience. As explained by (Koseoglu & Onder, 2011): “…generally based on transactions between space and personal emotional, cognitive experiences that a person attaches to any outdoor setting, alongside socially structured patterns that take place within the context of an outdoor setting as those actions are given significance by the culture within which they occur”. Therefore, an equitable and quantifiable understanding of the human thermal discomfort emanating from socio-spatial disarrangement can only be cohesively estimated through the proposed ‘relational approach’ of science in the backdrop of social science (man vs. machine) as envisioned in the conceptual model (See Fig. 2).

2.3. Users, Science and Social Science

This proposed model proffers equal and concurrent interaction of place parameters, microclimatic components, and their effect on human responses in a place–human relationship. Consequently, an outdoor physical environment (Mohalla) will be treated as an independent variable to test for an interactive effect between a place variable and a personal factor (dependent variable) on a human response. On the other hand, microclimatic components (independent variables) will be measured to assess the actual human thermal comfort and energy budgeting (dependent variable). Variables that intervene between independent and dependent variables may be divided into the categories of personal human factors involving the local residents of the respective Mohallas, the socio-cultural aspects of ‘Lahoris’, and the geographic dimensions of the Old Walled City, Lahore, Punjab.

As can be seen in Fig. 1, this study will be informed by, a) the scientific dimensions of air temperature, solar radiation, relative humidity and wind speed, b) social science, which will include socialization, sensory effects, sense of place, cultural facts and spatial heritage and c) users’ psychological parameters of knowledge/experience, attitude/expectation, belief/preference, and perceived control. Additionally, the demographic variables of age, gender, and education along with the biological base (e.g., metabolic rate—energy output needed for bodily functioning—that may be important for thermal sensation and perception/comfort), physical and social activity parameters that define the function of the place, as well as the person-related activities, and situation, which entails the length of exposure and momentary clothing are all germane to this study.

2.4. Human Response

The main assertion of the study is to balance the over-reliance on the measured microclimatic components and its projected impact on human thermal comfort. Thus, the conceptual model will aim to comparatively examine the role of physical and psychological parameters in the formulation of human perceptions and in influencing the perceived human thermal comfort in the context four different Mohallas of the Walled City of Lahore. Human responses to the environmental conditions will depend on sensation (sensory unconscious detection of environmental stimulation/information), perception (conscious interpretation and elaboration of sensory data), cognition (how we learn, remember, and think about information), emotion (states, processes, and expressions that convey qualities of affect, feeling, and mood), behaviour (activities, doings, reactions, and movements).

2.5. Spatial Perception and Variables of Legibility

Human perceptions are described as a process in which sensory input is transformed into meaningful experiences and interpretations (Barnston, 1988). Although interpretation is very important in receiving sensory input, processing it is somehow a static function. The process that constructs human perception is subjected to inner and outer influences, and, as a result, psychological perceptions are open to unique and varied human interpretations. To assess this dimension, some of the spatial variables considered are paths, edges, districts and landmarks, for example Lynch (1960) establishes, (see Fig. 2).

Factors affecting human/users perceptions

	Mosques, Gates, Havelis Mandis/Markets, Baghs	Bazaar, Galiyaan, Path network, Royal tails, Canals to Chaukandis	Mohalla Centre/Chowk, outoor open squares.	Walls in and around The Walled City Lahore, Edges of water canals.	District
Visual effect	Node and Sign	Path	Node and Sign	Edge	District
Example	Hazoori Bagh of Badshahi mosque, Dehli gate, Azam cloth market, Ainak Bazaar, Waan Market, Akbari Mandi etc.	Bazaars and Galis, such as in the Mohallas of the Walled City of Lahore.	Kamran key Baradari, Baradari at Jehangir's tomb Hiran Minar, Sheikhupura. Garden of Lahore Fort	Lahore Canal, Ring road Lahore River embankment e.g. Band Road Lahore	Gulberg, Lahore Anarkali, Lahore Lower Mall, Lahore Shadbagh, Lahore
Image					
	Front Courtyard, Masjid Wazir Khan, Lahore.	Tourist Trails, TWCL	Pavilion at Hazoori Bagh Lahore Fort, Lahore.	Masti Darwaza Lahore Fort, Lahore.	Typical Mohalla The Wall City, Lahore

Figure 2: Element of Image: Paths, Edges, Districts, Nodes and Landmarks.

2.6. Study Area, Climate, and Participants

Lahore is the capital of the Pakistani province of Punjab and is the second largest city with a population of 13 million people (Pakistan Bureau of Statistics, 2021). According to Köppen climate classification, Lahore has a semi-arid climate of Bsh. The hottest month is June when average highs routinely exceed 40 ˚C. The city's highest recorded temperature 55 ˚C under direct sun light in June 2007.

A total of 400 people (100 from each Mohalla), and users of the outdoor urban places (a chowk, a square, a courtyard, and bazaars) located within the Mohallas will participate in this study. The respondents will all be above the age of 21, and the study will engage with residents of the Mohallas only.

2.7. Micrometeorological Measurements

There are several energy budgeting models available to assess human thermal comfort (Epstein & Moran, 2006). This study will be informed by the relative magnitude of the streams of energy to and from the human body in interaction with their surrounding outdoor environments. Outputs from the model will result in designing guidelines in consideration to main energy flows and their impact on human movements in outdoor environment.

To answer the research questions, this study will utilize the human thermal comfort model COMFA to measure high-density site-specific microclimatic parameters as recorded at the local weather station. Furthermore, a wide range of data input and comparative analysis required in this study will mainly benefit from the following equation used in COMFA (Mazhar, Brown, Kenny, & Lenzholzer, 2015):

Energy Budget (EB-W^{m-2}) = $M + R_{abs} - Conv - Evap - TR_{emitted}$

M= Metabolic energy

R_{abs} = Absorbed solar and terrestrial radiation

C_{onv} = Sensible heat lost or gained through convection

E_{vap} = Evaporative heat loss

$TR_{emitted}$ = Emitted terrestrial radiation.

The data from the microclimate measurements will be evaluated for all the Mohallas. The data that is to be used will be recorded by the local weather stations once every five minutes and averaged over each hour. All microclimatic measurements will be used to plot the human energy budgeting diagrams. The only challenge in this regard is that Lahore city does not record solar radiation data and thus would not be verifiable. However, given the generally cloudfree skies during the spring and hot summer seasons, the data readings are estimated to be highly accurate.

2.8. Investigating Psychological Components

Structured survey questions will be carried out on each Mohalla. This instrument will be comprised of questions about demographic variables, general and specific questions about current weather and place, and behaviors and attitudes related to the place and person (I Knez & Thorsson, 2006, 2008). All questions from the questionnaire will be analyzed in the present study (see below). They are estimations of perceptual and emotional dimensions of weather and place, and of the urban versus open-air attitude in participants:

1. How do you perceive the current thermal condition today? (perception: perceived weather). Participants will be asked to answer this question by responding to three 5-point scales: (1) Hot–Warm; (2) Slightly warm; (3) Neutral (4) Slightly cool and (5) Cold (Lenzholzer, Klemm, & Vasilikou, 2013).
2. How do you perceive the place right now? (perception: perceived place). Participants will be asked to answer this question by responding to four 5-point scales: (1) ugly– beautiful; (2) unpleasant–pleasant; (3) windy–calm; and (4) cold–warm (Thorsson et al., 2004).
3. How do you visualize this outdoor space right now? (emotional and thermal perception). Participants will be asked to answer this question by responding to four 5-point scales: (1) elated–bored; (2) glad–gloomy; (3) calm–nervous; and (4) active–passive. These scales were derived from (Igor Knez & Hygge, 2001). Participants were also asked to estimate their thermal comfort by responding to a 9-point scale; from very cold to very hot with the score 5 as comfortable (Fazia Ali-Toudert1, Moussadek Djenane, Rafik Bensalem3, n.d.).

2.9. Users' Perceptions: Aesthetics, Evening Get-Together, and Features of Design:

Participants' responses based on a 6-point scale will be recorded: (1) Very satisfied; (2) Satisfied; (3) Rather satisfied; (4) Less satisfied; (5) Non satisfied; (6) Not in the least satisfied. "How much of a Mohall user (find pleasure in the street-life around corner cafes, bazaars, the amusement derived from the local culture of the walled city) (Igor Knez, 2005b).

3.0 ANTICIPATED RESULTS

The residents' responses will be used to carry out the comparative investigation of the estimated perception of the current weather conditions. Their estimation will be independent of the measured microclimatic parameters. For a robust framework of findings, any effects of age and gender on outdoor attitude and expectation will also be recorded. In summary, results will show the relational connection between how the current weather was estimated/perceived against the level of outdoor activity taking place. The findings will be used as a measure of high medium and low-level connection between actual and perceived perceptions on human behaviour and movement patterns. Participant's perceptions will be plotted according to the respondents' gender and age, as the weather and physical design features' assessment is generally influenced by their ability to withstand outdoor conditions, hence will present a broader range of responses. The age of and the environmental attitude in participants is also expected to have influence on the current weather assessments. Finally, residents from each Mohalla, will be asked to share how sensitive they felt to wind speed variations and sun during different seasons. Thus, according to the results obtained, the participants' perception of the outdoor urban places as pleasant to not-in-the-least-pleasant will be analyzed against the measured weather parameters.

4.0 DISCUSSION

The aim of this article is to highlight the psychological (individual) mechanisms involved in outdoor places and weather assessments to broaden the previous work on thermal comfort indices as well as to the body of research addressing the significance of weather parameters for the use and design of urban places. This will be done by clarifying the human information processing and how mental representation such as long-term cultural connections, stored in long-term memory, might influence place-related responses. This concept is rationalized in a conceptual model, tentatively proposing "Science" and "Social Science" links having an influence in a place–human relationship, which will be subsequently tested by an empirical study inside the four Mohallas of the Walled City of Lahore, Pakistan. The aim is to inform the impact of weather (space) and personal factors (place) on perceptual and emotional estimations (human response) of outdoor urban places.

Concerning the "independent variable" of microclimatic components (see Fig. 1), the participants are expected to perceive the weather as best they feel, largely based on the sensory feelings when the air temperature was high/low, sun/shade, and the overall day conditions of whether depending on if it was a clear or cloudy sky. It is known that air temperature and cloudlessness influence environmental assessment and activity as demonstrated by (Igor Knez et al., 2009; Nikolopoulou & Lykoudis, 2006b; Nikolopoulou & Steemers, 2003). Furthermore, concerning the place-related emotions and spatial psychology, participants of the Mohallas are apparently most glad and have historically been more active during the afternoon hours when the sun has set. Most outdoor spaces see more engagement in outdoor activities when it is cloudy. On the other hand, they are empirically least glad during the noon hours when the sun is high, and sky is clearer. This hypothetically indicates a relation between emotions and high temperature and cloudy/clear sky conditions. which is, generally, in line with (Cunningham, 1979)showing that sunlight might lead to a positive mood.

Concerning “dependent variables” of human perception (see Fig. 1), and in line with Knez and Thorsson (2006, 2008), where no effects of gender were shown to have any significant influence on participants’ attitude expectation, age variable will be examined more closely than the gender. Independently of the weather conditions, the residents of the Mohallas are empirically known to have estimated the current weather less warm than it actually is. They are known to be more sensitive to the wind speed variations due to narrower and taller streets. Furthermore, regarding the participants’ age, it was shown that the younger participants compared to the middle-aged and older participants generally perceive the current weather as comfortable. This is in line with Lawton et al. (1982); it is suggested that age might also be an important/personal factor in environmental assessment.

5.0 CONCLUSIONS

Outdoor spaces consist of a complex mosaic of different elements of design that may broadly be categorized into natural and built. Taken together and in line with the hypothesis, the aim of this research is to find significant influences of weather parameters comprising air temperature, solar radiation, humidity, wind speed, spatial psychology, and age on the participants’ perceptual and emotional estimations of the outdoor urban places. This study is the first of its kind in the context of Lahore and is a highly significant step towards the understanding of the psychology of outdoor open urban places and weather assessments. This will add to the future studies and understanding on the human thermal comfort and energy budgeting meant for the successful functioning, use and design of urban places that is ought to be considered. Finally, it is pertinent to underline that the suggested model is a conceptual one, meaning that the model, in its present form, is contingent upon its performance.

In conclusion, the scope of this study is innovative, distinctive, and unprecedented in the context of hot climate cities. As a result, it presents a significant and contributory step towards a greater understanding of the psychological dimension influencing weather assessment and, consequently, human behaviour in the urban environment, projecting implications on urban design.

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