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Thermal Comfort Perception In Naturally Ventilated Affordable Housing Of Mumbai, India

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ABSTRACT

This paper presents a systematic review on different thermal comfort models in Indian residential buildings, to identify which model and building techniques are best suitable for designing affordable housing in warm and humid climate in India. Many case studies and models were reviewed and it was found that comfort studies in Indian residential buildings are scarce, scattered and unorganized. Further, due to differences in socio-cultural set-up and local adaptations, the prodigious variations in occupant's comfort requirements are reported. A literature case study is been done in which a longitudinal field research and in-situ field measurements are used to examine thermal adaptation in Mumbai, India's low-income homes. The comfort-related behaviours in low-income dwellings were influenced by temporal considerations, spatial arrangement, and underlying societal norms. Rather than thermal needs, the gendered socio-cultural practice of the purdah regime and western influences dominated clothing adaption. The study is useful in assessing how occupant behaviour affects building performance, which helps to guide building operation and design. The creation of design criteria for housing plans to produce low-income, thermally comfortable homes could have policy implications.

(Keywords- Human thermal comfort, literature search, affordable housing, thermal comfort, India, comfort standards and perceptions.)

INTRODUCTION

Thermal comfort is defined as ‘that condition of mind which expresses satisfaction with the thermal environment and is assessed by subjective evaluation’ (American Society of Heating Refrigerating and Air Conditioning Engineers, 2017). There are two widely adopted approaches to thermal comfort – heat balance approach and adaptive approach. The heat balance approach, based on laboratory studies, considers occupants as passive recipients of thermal stimuli, thus miscalculating comfort conditions for naturally ventilated buildings. On the other hand, the field study-based adaptive approach considers the influence of thermal adaptation and is deemed effective in predicting the often wider comfort range observed in naturally ventilated buildings. However, the adaptive practice is context dependent (Nicol & Humphreys, 2002) and is influenced by psychological, physiological and behavioural factors (de Dear et al., 1997). This complexity of thermal comfort perception further increases within low-income population where another degree of freedom exists in the form of socio-economic level (Pérez-Fargallo et al., 2018). However, till date, the issue of adaptive comfort in these vulnerable and resource-constrained communities has not been adequately addressed in scientific literature.

There exists limited literature on thermal behaviour within naturally ventilated housing, particularly occupied by low-income groups (LIG), where the issue of thermal comfort is reduced to be an issue of unavoidable acceptance because of the lack of affordability of space heating or cooling equipment. Sanchez et al. and Moore et al. found that occupants of low-income households prefer a combination of passive thermal strategies such as turning on ceiling fans, opening or closing windows and doors, opening or closing curtain, along with clothing and activity adjustments. Additionally, Pérez-Fargallo et al. pointed out that LIG occupants lower their thermal expectations due to fuel poverty and thus reflect an unfamiliar comfort behaviour. The scant literature within LIG households focuses merely on economic affordability with no regard to other non-thermal factors (socio-cultural or contextual). A comprehensive understanding of occupant behaviour within low-income housing, which remains decoupled from the socio-economics in the existing literature, is thus required. This knowledge gap is addressed here by investigating the patterns of adaptive comfort behaviour within LIG housing and analysing the related non-thermal triggers and drivers.

OBJECTIVES

1. To determine the ideal temperature, thermal neutrality, and thermal tolerance of affordable housing in warm and humid climate of India.
2. To investigate how psychological factors affect the low-income population's experience of comfort.
3. To determine whether the current comfort requirements are applicable in the context of affordable housing in India.

Thermal comfort standards

This section covers the brief introduction of widely used thermal comfort standards. At present, the ASHRAE 55 and ISO7730 are globally used thermal comfort standards. Other building standards and codes (i.e. NBC India, ISHRAE IEQ and CIBSE) apprehending the local comfort parameters, have also been adopted in different parts of the world. However, the systematic discrepancies regarding implementation of these standards have been observed due to inadequate consideration of adaptive behaviour which substantially depends on socio-cultural set-up and local adaptation (Parsons, 2001). The brief introduction of widely adopted standards particularly the ASHRAE 55, ISO7730 and CEN EN16798 are presented here:

A. ANSI/ASHRAE Standard 55

Originally published in 1966 and mostly utilised in the United States, it has now gained recognition as a globally accepted standard for the planning, commissioning, and testing of interior spaces. "The state of mind that expresses satisfaction within the thermal environment" is the definition given for thermal comfort. In order to provide an appropriate indoor thermal environment that is suitable for the majority of occupants (> 80%) exposed to identical environmental conditions within a space, ASHRAE 55 specifies the combination of personal and environmental elements (ASHRAE, 2017). The guideline also specifies the dissatisfaction limit based on individual variances in thermal preference. The impact of non-thermal environments on human health, however, has not been addressed (Olesen and Brager, 2004). Every three to seven years, the ASHRAE 55 is updated based on new developments in research and real-world application. Notable versions of the standard have been released since 2004 and 2010. The criteria gaps between the ISO standard and ASHRAE 55 were corrected in ASHRAE 55-2004, which led to the introduction of the computer-based adaptive model that links indoor temperature to external data. The impact of faster airspeed on occupant thermal comfort, especially in NV areas, was also acknowledged by this model (ASHRAE, 2004). By reinstating the term "SET," ASHRAE 55-2010 modified the process for calculating the cooling effect of increased airspeed and air movement in interior spaces.

However, because of numerous sociocultural factors, the findings of field case studies, particularly those pertaining to inexpensive housing in India, differ from those of ASHRAE.

B. Adaptive model

This approach is founded on the adaptation principle, which says that people will respond in ways to get back to their previous level of comfort if something changes that makes them uncomfortable. The results of field surveys carried out in a variety of situations are connected to the adaptive notion. The physical measurement of the temperature environment and the subjective reactions of the occupants are the subjects of these surveys. In order to estimate the comfort range of thermal variables like RAT, RH, and air velocity, the data so gathered is statistically evaluated (Sharma and Ali, 1986). By tying the occupant's response to the comfort vote, the adaptive technique establishes the range of the comfortable temperature. The way that people interact with various aspects of the building (such as windows, doors, fans, etc.) and external surroundings determines the ideal temperature.

There are numerous factors which can influence the occupant responses to the prevailing environment and hence, the comfort temperature can be changed (Nicol and Humphreys, 2002). The primary contextual variable in thermal comfort studies is the climate which impacts on thermal attitude of occupant and design of building. However, the climate may not change the basic mechanisms of interaction between occupant and thermal environment. There are several ways in which the living climate can influence the occupant responses towards the indoor climate. The building forms, building types and building services plays critical role in defining the survey results. Another influencing factor is time as the occupant responses and activities occur in a set time frame (Nicol and Humphreys, 2002).

Further, the meta-analyses of comfort surveys also help to draw different interferences from large volume of restricted surveys on thermal comfort. However, field study has some bottlenecks related to inaccurate measurement of environmental conditions and generalisation of survey results as two different surveys can never give similar outcomes even for the identical environmental conditions. The comfort temperature can be altered since a variety of factors can affect how a person reacts to their surroundings (Nicol and Humphreys, 2002). The climate, which affects human thermal attitude and building design, is the main contextual variable in studies on thermal comfort. But the fundamental mechanics of the interaction between the thermal environment and occupants might remain unchanged by changes in climate. The living climate can affect how an occupier reacts to the interior climate in a number of ways. Building types, building forms, and building services are important factors in determining the survey's findings. Time is another component that influences things because occupant responses and activities happen within specific time frames (Nicol and Humphreys, 2002). Additionally, the comfort survey meta-analyses aid in identifying various interferences from a substantial number of limited comfort survey responses. Field research does, however, have certain limitations because it is difficult to quantify environmental circumstances accurately and generalise survey results from two surveys because no two surveys will ever produce results that are similar, even under the same environmental conditions. Errors in determining the link between thermal variables are also caused by inaccurate data measurement (Humphreys and Nicol, 2000). Indian buildings are inhabited by a diverse range of cultural backgrounds and behavioural patterns. These structures come in a variety of shapes and sizes and are situated in various climate zones. These structures have a broad comfort temperature range that not only satisfies occupant comfort standards but also significantly lowers building energy usage. The majority of buildings in India, both new and ancient, are of the NV type; nonetheless, the country has not yet had an appropriate contextual model for adaptive thermal comfort. Even though the adaptive properties have been measured using the IMAC model, its application is restricted to office buildings. Therefore, additional work is needed to improve these models, especially for India's affordable residential constructions.

Thermal comfort models

A. Heat balance models

The thermoregulatory system of the human body is thought to be responsible for maintaining an almost constant internal body temperature, according to heat balance models. Therefore, the physics of heat and mass transport between the body and the surrounding environment mediate the effects of the immediate thermal environment. People will react physiologically to any temperature mismatch with their thermal surroundings in order to maintain a consistent internal body temperature. People's thermal perceptions, such as how hot or chilly they feel, are thought to be roughly correlated with the strength of these reactions as expressed in terms of mean skin temperature, latent heat loss, and wittedness from sweating. These serve as the foundation for the creation of thermal comfort models for heat balance.

Fanger’s heat balance model

Predicted mean vote (PMV) and predicted percentage of dissatisfied (PPD)

Fanger sought to create an index in the 1960s so that HVAC engineers could forecast whether a given temperature condition would be deemed tolerable by a sizable population. Linear correlations between (i) mean skin temperature and activity level and (ii) sweat secretion and activity level were found through experimental work with college-age individuals in a climate chamber. The comfort equation, which could forecast the circumstances under which humans would feel thermally neutral, was subsequently created by

substituting these values into the heat balance equations.. In order to have practical applications, the seven-point ASHRAE thermal sensation scale (-3 cold, - 2 cool, - 1 slightly cool, 0 neutral, +1 slightly warm, +2 warm, and +3 hot) and experimental studies involving 1396 subjects were incorporated into the comfort equation to create an index known as the predicted mean vote (PMV). Similar to the comfort equation, the PMV equation is rather intricate; Fanger has more information on this. In a nutshell, PMV depends on four external factors: garment insulation, activity level (measured in metabolic rate, M in W/m2), air temperature, mean radiant temperature, relative air velocity, and air humidity (i.e., vapour pressure).
Thus:

$$PMV=f\ [ta;\ tmrt;\ v;\ pa\ ;\ M;\ Icl] \qquad \textbf{(1)}$$

A group of building occupants' mean thermal sensation vote (PMV) for any combination of the four environmental factors, predominate activity level, and apparel is represented on a standard scale. Since no two people are the same, there will always be some variance in how any big group of people feels the heat. Since these folks are the ones who would probably complain, it is crucial to establish what proportion of people would be unhappy with the surroundings. An empirical association between PMV and the anticipated proportion of dissatisfied (PPD) was established as follows, based on experimental investigations in which participants voted on their thermal sensations:

$$PPD = 100 - 95 \times \exp\ [-0.03353 \times PMV^4 - 0.219 \times PMV^2\ ] \quad \textbf{(2)}$$

PMV–PPD versus adaptive models

Many researchers all over the world have started using the PMV model to evaluate the interior thermal environment. The PMV model generally functions effectively in constructed environments with HVAC systems. However, for naturally ventilated (or free-running) buildings, the most acceptable indoor temperature considerably rises in warmer climes and falls in colder climates. This is hardly shocking considering that "Fanger made it very evident that the HVAC (heating, ventilation, and air conditioning) industry was to use his PMV model to create artificial climates in controlled spaces." People may perceive warmth in warm areas that is less intense than what the PMV model predicts when they are in non-air-conditioned rooms, primarily because they have low expectations.
The heat balancing model has been put to the test through extensive and rigorous laboratory trials, producing results that are quite consistent and repeatable. Its foundation is a very linear, deterministic logic. However, the two-equation PMV–PPD heat balancing model's direct cause-and-effect methodology is more difficult to apply to the more complicated ecosystems found in actual buildings that are inhabited by actual people rather than subjects. Some have proposed that the adaptive perspective is in agreement with the static heat balance, rather than in opposition to it. Since the heat balancing model takes into account the behavioural modifications that occupants make to clothing, metabolic rate, and thermal characteristics, it is more accurate to refer to it as a partially adaptive model. For a wide range of clothing thermal insulation, it has been shown that PMV can be represented as a function of temperature and relative humidity using the linear regression technique.

However, some claim that the simple regression-based adaptive technique sometimes yields inconsistent results from various field experiments (with respect to regression coefficients and anticipated comfort temperature ranges). It is recommended that the PMV-PPD model's effectiveness and applicability be enhanced by utilising the results of many field experiments. According to a recent assessment of thermal comfort field tests conducted across several global temperature zones, people tend to interpret the same environment differently, and situations with limited adaptive means are generally rated as less comfortable. To reconcile and harmonise the many adaptive models, more work is needed.

Furthermore, how can a set of environmental and thermal characteristics be deemed acceptable in a naturally ventilated or mixed-mode setting yet inappropriate in an HVAC context? It has been discussed how to model thermal comfort using a new alliesthesia-based method. It will be difficult, but not impossible, to overcome the paradigm shift from the comparatively straightforward, instrumentally measurable criteria to a far more intricate parameterization of the spatial and temporal dimensions of alliesthesia. Further work is needed to address the necessary alliesthesia, particularly on the multi-node physiological models.

Materials and methods

Study area

The coastal city of Mumbai spread across 603 square kilometres is located in the south western part of India. The city falls within tropical savanna climate as per Koppen classification and warm–humid climate according to National Building Code of India. Mumbai has three distinct seasons: monsoon, winter and summer and experiences an average annual temperature of 27.2°C and average annual precipitation of 245.7 cm (M.C.G.M., 2011). Two government-provided affordable housing– a slum rehabilitation housing and an institutional staff housing, situated in administrative ward M and ward S, respectively, were selected as the field study locations. More than half of the population of selected wards M and S consist of low-income people and thus these wards are representative of the city’s low-income population (Mehrotra et al., 2018). The housing units comprise conventional concrete frame structure with brick in-fill walls and the floor area ranges from 22 to 26 square metres. The selected buildings were operated in free-running (fan-assisted natural ventilation) mode during the investigation. In the free-running mode, no energy is supplied for heating or cooling and the thermal environment can be controlled to an extent by opening windows or doors, using ceiling fans or curtains (Humphreys et al., 2007).

Parameter	Location 1 (Ward M) 	Location 2 (Ward S) 
No. of floors	G+7	G+2
Unit area	22 sq m	26 sq m
External walls	Brick-kiln fired (*U*-value = 1.8 (W/m^2 K))	Brick-kiln fired (*U*-value = 1.6 (W/m^2 K))
Roof	Uninsulated reinforced concrete	Uninsulated reinforced concrete
Floor	Uninsulated reinforced concrete	Uninsulated reinforced concrete
Windows	UPVC frame with single glazed clear glass panel	Wooden frame with clear glass panel and mild steel grill

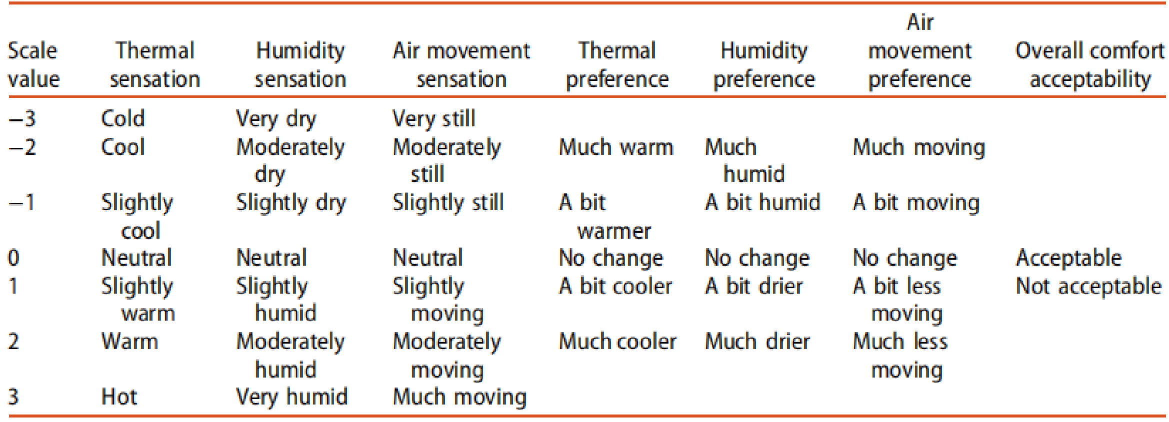
Field study

In order to understand the thermal comfort conditions and preferences of the occupants, a longitudinal field study that followed the guidelines of ASHRAE Class II was carried out in Mumbai over the course of three distinct seasons. Because longitudinal sampling provides responses over a longer time span, such as months or seasons, and ensures a variety of thermal environments, it has been preferred over the cross-sectional method in several classical studies on thermal comfort (de Dear et al., 1997; Humphreys et al., 2007; Sharma & Ali, 1986). A survey on thermal comfort was used as part of the data gathering process, and environmental variables like air temperature, relative humidity, and air velocity were also measured and tracked in real time. The Institute ethics committee was consulted and granted ethical approval (Proposal no: IITB-IEC/2020/016).

At the onset of the study, all participants gave verbal consent, ensuring that their answers would be kept private and that they could withdraw from the research at any time. Because longitudinal surveys are completed several times a day and across different seasons, they need commitment from their subjects. It frequently happens that some participants become disinterested, which results in an uneven distribution of surveys throughout the day and seasons. Before the surveys began, participants were made aware of the amount of time and effort needed in order to reduce sample loss. After being created in English, the questionnaire was translated into Hindi.

In every season, questions were asked of each responder three times a day: in the morning (9:00 am–12:00 noon), in the afternoon (12:00 noon–5:00 pm), and in the evening (5:00 pm–9:00 pm). Based on the city's average temperature peaks, these times were selected.

Table 2. Sensation scales used (Humphreys et al., 2016).



Scale value	Thermal sensation	Humidity sensation	Air movement sensation	Thermal preference	Humidity preference	Air movement preference	Overall comfort acceptability
−3	Cold	Very dry	Very still				
−2	Cool	Moderately dry	Moderately still	Much warm	Much humid	Much moving	
−1	Slightly cool	Slightly dry	Slightly still	A bit warmer	A bit humid	A bit moving	
0	Neutral	Neutral	Neutral	No change	No change	No change	Acceptable
1	Slightly warm	Slightly humid	Slightly moving	A bit cooler	A bit drier	A bit less moving	Not acceptable
2	Warm	Moderately humid	Moderately moving	Much cooler	Much drier	Much less moving	
3	Hot	Very humid	Much moving				

Subjective measurements

The questionnaire was divided into four sections: adaption controls, personal variables, subjective thermal comfort ratings, and sociodemographic profiles. The following sociodemographic details about the respondents were gathered: years of residency, housing unit location, height, weight, gender, and ownership of appliances. Voting on preferences and questions regarding temperature, humidity, and air movement sensation were included in the subjective thermal comfort category. There was also a closed-ended inquiry on the overall CA. The five-point Nicol preference scale and the seven-point ASHRAE thermal feeling scale were employed.

Variables related to individual thermal comfort, such as clothing insulation and metabolic rates, were investigated. The ASHRAE Standard 55-2010 clothing insulation checklist was used, and additional clothing items from pertinent literature were incorporated, including the dhoti and typical Indian ensembles and garments including sarees, salwar kameez, and dupattas.

In addition, appropriate chair insulation was noted and applied to the insulation values. We asked respondents about their recent 15-minute metabolic activity, and we used ISO 8996, "Ergonomics of the thermal environment – Determination of metabolic rate," to determine the relevant metabolic rates (International Organisation for Standardisation, 2004). Adaptation controls have been covered in a follow-up study (Malik et al., 2020b) and are outside the purview of this one.

Results

Sample size description

Through three Mumbai seasons of the field study, a total of 705 sets of responses were gathered. Depending on the participants' availability and desire to participate, the sample size changed with the season. Based on the gender distribution of thermal comfort responses, it may be inferred that approximately 75% of the replies were provided by female participants. Because they spend more time indoors than their male counterparts, female members of low-income homes tend to be more numerous. Responses to surveys are distributed seasonally, with 40% occurring during the monsoon season, followed by 35% in the winter and 25% in the summer. Responses are distributed as follows: 17% in the morning, 41% in the afternoon, and the remaining 42% in the evening. The night time hours of 9:00 pm to 9:00 am were not used for measurements due to restricted access to the residential apartments.

Personal variables: clothing insulation and metabolic rates

When the field research was conducted, the apparel worn by the occupants included both Indian outfits like sarees, salwar kameez and lungis, as well as western outfits like jeans, shirts and trousers. With a minimum value of 0.15clo and a high value of 1.52clo, the mean clothing insulation was found to be 0.53. Male participants were able to readily change from lungi (0.15 clo) to trousers, shirt and cardigan (0.93 clo), resulting in a larger range of clothing insulation. Contrarily, due to sociocultural norms, female members had fewer possibilities to modify their attire.

Moreover, because of the widespread Islamic purdah rule, there have been cases of females wearing garments with abnormally high insulation levels during the heat (1.52 clo). In a follow-up study published as Malik et al. (2020b), a thorough examination of behavioural adaptation in the form of seasonal and gender-specific clothing adjustments has been provided. At the time of the inquiry, the respondents' activity levels for the previous 15 minutes or less were recorded. The metabolic rates varied from 2.0 Met (standing and working) to 0.7 Met (sleeping). The value that was observed to occur most frequently was 0.9 Met, which is associated with "passive seated" behaviour. Given that over 40% of the observations had metabolic rates greater than 1.2 met, it was important to evaluate the insulation provided by clothes in addition to activity levels. The adjusted clothing insulation for inhabitants with dynamic activity levels (met>1.2) is referred to as dynamic clothing insulation, and it was taken into consideration.

Environmental conditions

The outside temperature and relative humidity ranged widely, with the lowest recorded daily mean temperature of 23.1°C in January—the coldest month—and the highest temperature of 31.4°C in May, the hottest month of the summer. Winter saw the lowest daily mean outdoor humidity level, recorded at 39.0%, while monsoon season saw the highest humidity levels, recorded at 86.3%.

The daily mean air temperature and daily mean outdoor temperature throughout the survey period are described in Table 6. While conducting the questionnaire survey, the following interior environmental variables were simultaneously recorded: indoor air temperature (Ta), globe temperature (Tg), relative humidity, air velocity (Va), carbon dioxide concentration (CO2), and illuminance levels. Furthermore, standard calculations were used to establish the operative temperature and mean radiant temperature (Humphreys et al., 2016). The examination of illumination levels is not included in this paper. Table 6 provides descriptive statistics of the interior and outdoor environmental conditions.

The strength of the correlation between the indoor environmental factors recorded during the field surveys is summarised in Table 7. The inhabitants may have embraced the usage of environmental controls to increase interior air velocity during high temperature and humidity settings, as suggested by the robust positive correlations between air velocity, Va and Tair ($r = 0.25$, $p < .001$), and Rhin ($r = .36$, $p < .001$). This is in line with ASHRAE Standard 55 (American Society of Heating, Refrigerating, and Air Conditioning Engineers, 2017), which states that, provided there are higher air speeds between 0.2 and 0.8 m/s, indoor operating temperatures can be raised above still air limits by up to 3°C. According to earlier research, people use faster air speeds to feel comfortable in rooms with higher humidity and temperatures (Indraganti, 2011; Indraganti et al., 2015; Manu et al., 2014; Mustapa et al., 2016).

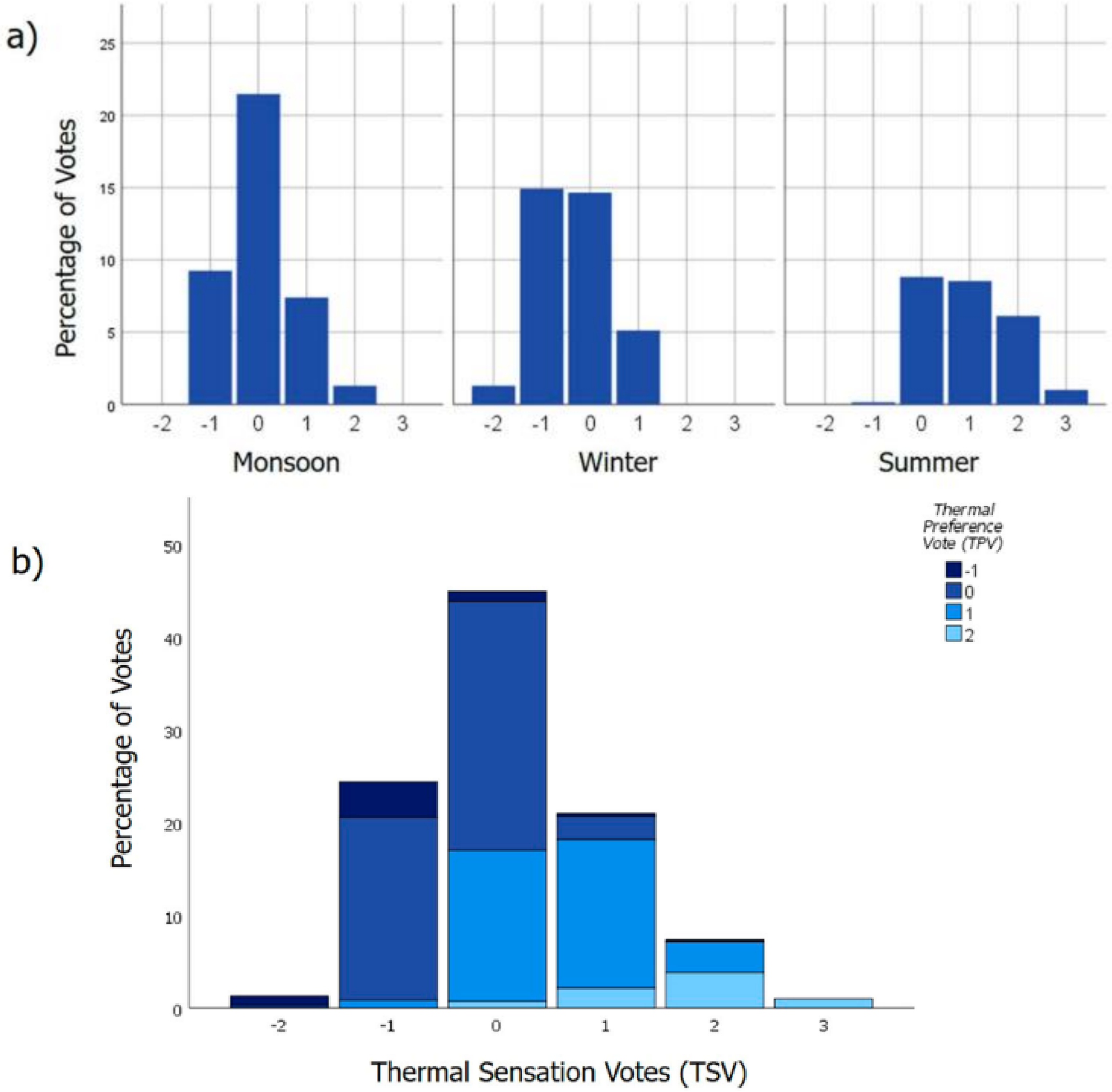
Table 6. Seasonal averages of outdoor and indoor environmental data.

		Season 1: Monsoon			Season 2: Winter			Season 3: Summer		
Environmental variable	Unit	Mean	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.
Daily mean outdoor temperature, T_{out}	°C	26.1	24.3	28.3	24.9	23.1	27.5	29.7	29.1	31.4
Daily mean outdoor air relative humidity, Rh_{out}	%	82.2	76.6	86.3	51.4	39.0	66.7	69.0	66.7	75.4
Air temperature, T_{air}	°C	28.4	27.0	30.5	27.0	24.2	30.6	31.2	28.1	34.2
Globe temperature, T_g	°C	28.5	26.9	30.5	27.4	24.8	30.8	31.8	29.4	33.8
Indoor air relative humidity, Rh_{in}	%	78.0	61.3	87.4	50.8	26.6	70.3	62.9	54.2	79.0
Indoor air velocity, V_a	m/s	0.5	0.0	2.9	0.1	0.0	1.0	0.4	0.0	1.3
Ambient carbon dioxide, CO_2	ppm	594	431	1522	664	457	1494	575	447	1005

Table 7. Correlation among environmental variables.

Variables	T_{air}	T_g	T_{mr}	CO_2	Rh_{in}	V_a
T_{air}	1	0.95**	0.79**	−0.03	0.21**	0.25**
T_g		1	0.94**	−0.10**	0.12**	0.24**
T_{mr}			1	−0.16**	0.02	0.29**
CO_2				1	0.04	0.14
Rh_{in}					1	0.36**
V_a						1

**Correlation significant at the 0.01 level (two-tailed).
*Correlation significant at the 0.05 level (two-tailed).



Discussion

1. In terms of temperature, humidity, and air movement sensation, the majority of the occupants reported feeling comfortable.

2. Eighty percent of the participants said that the environment was acceptable, with the winter season having the highest approval (95%), followed by the summer and monsoon seasons.

3. Of those voting, 80% found that operating temperatures between 24.6 and 32.2°C were pleasant.

4. The relationship between income levels and CA votes showed that pleasure with the thermal environment declines with income. This suggests that comfort levels change as income levels rise. The degree of adaptive control was found not to be associated with psychological adaptation since there were differences in the adaptive controls that could be exercised and available.

5. ASHRAE and NBC, two established comfort standards, were unable to accurately forecast the level of comfort in Mumbai's cheap homes. The observed neutralities are distributed over a wider range of operating temperatures, whereas the standards prescribe a more constrained comfort zone. Occupants in affordable homes were found to have excellent thermal adaption, making them less sensitive to indoor temperatures.

Conclusion

Indoor thermal comfort is often overlooked in energy saving programmes and regulations, despite its importance in assessing building energy. This study adds to the understanding of the thermal comfort needs of inexpensive housing tenants through design principles and recommendations, which may aid in the sustainability and liveability of the stock of future cheap housing. It might also help close the difference in building performance, which would improve energy efficiency. The results could lead to the development of a novel adaptive comfort model that considers the economic and social dimensions of comfort for low-income individuals.

In a hot, humid climate, the major objectives of building design are to prevent the inside surfaces from getting hotter than the shadow and to permit unimpeded airflow throughout the structure. A thorough analysis of natural air flow, including its basic characteristics and expected behaviour in proposed projects, provides solutions to specific problems and ultimately leads to the formulation of recommendations for the most effective way to use it for adequate ventilation. These are by no means conclusive findings. Clearly, a great deal of study remains to be done. Nonetheless, there are currently several that appear to offer thoughtful planning and design when taking into account the natural ventilation of buildings.

On days with light breezes, orienting in the direction of the breeze is the best way to optimise its benefits. However, this must be weighed against the best shade that a north-south orientation offers. To maintain proper ventilation, the building should be as open as feasible and only one room thick, even though this complicates the planning of large-scale buildings. Avoid having dead air pockets in the section and in the plan. It is ideal to have ceiling-level ventilation, and the sills of openings should be low to permit air to pass through the bottom portion of a room where people may be seated or sleeping.

The goal should also be to minimise heat intake from glares and direct solar radiation. This can be achieved by opening windows and doors, drawing curtains and blinds to offer shade indoors, and avoiding the use of artificial lighting, which raises the temperature of the space.
To accomplish maximum air changes, the openings on the inlets and outlets should be as large as practical; that is, the wider the openings, the greater the air changes. To operate at maximum speed in a hot and humid environment, a building's outlet openings must be larger than its inlets.
Using environmentally friendly and energy-efficient materials can also be quite advantageous.

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