Engineering and Technology Journal e-ISSN: 2456-3358

Volume 10 Issue 01 January-2025, Page No.- 3704-3711

DOI: 10.47191/etj/v10i01.27, I.F. – 8.227

The Role of Air Movement Perception in Enhancing Thermal Comfort in Naturally Ventilated Living Rooms: A Case Study of Eshdc High- Density Estates in Enugu, Nigeria

Aloysius O. Onochie[1], Oluchi C. Ifebi[2], Charles C. Munonye[3], Kelechi E, Ezeij[4]

[1] Department of Architecture, Nnamdi Azikiwe University, Awka, Anambra State Nigeria

[2,3,4] Department of Architecture, Chukwuemeka Odumegwu Ojukwu University, Anambra State

ABSTRACT: Residents in the study area were observed spending more time on balconies or terraces than in their living rooms in the evenings. While the exact reasons for this behavior were unclear, inadequate air movement in the living rooms was suggested as a potential cause. This study investigated air movement in naturally ventilated living rooms of Enugu State Housing Development Corporation (ESHDC) high- density estates in Enugu Capital Territory, Nigeria, during the peak of the rainy season. A total of 130 housing units were randomly selected from 433 housing units and surveyed using questionnaires. The data were statistically analyzed to assess occupants' perceptions of air movement. Results revealed that more than half of the respondents (55.3%) rated level of air movement sensation (LAMS) as 'just okay,' while 41.5% reported experiencing 'Low' air movement sensation (LAMS). Regarding level of air movement preference (LAMP), half of the respondents (50.4%) desired 'more air movement,' while 49.5% were satisfied with "no change" in their indoor environment. Spearman's Rho correlation analysis indicated that there is a positive and significant relationship between LAMS and LAMP in naturally ventilated living rooms during the warm and humid season. The study concludes that occupant feedback is critical for updating design practices to enhance indoor air movement and thermal comfort. It recommends incorporating air movement perception into thermal comfort standards to improve living conditions in tropical climates.

KEYWORDS: Air movement perception, Natural ventilation; Thermal comfort, Warm and Humid Climate.

1.0 INTRODUCTION

Background to the Study

Air movement is one of six key variables influencing thermal perception in built environments. These include three environmental factors (air temperature, mean radiant temperature, and relative humidity) and two personal factors (metabolic rate and clothing insulation). In warm or hot conditions, air movement can provide desirable cooling effects, though excessive drafts may cause discomfort (Nicol et al., 2014; Nguyen et al., 2012). Detectable air movement is often associated with freshness and pleasantness; however, it can also lead to annoyance when it results in discomfort, prompting behavioral changes. Air movement is a critical factor in thermal comfort perception (Rizk & Henze, 2014) and plays a role in human thermal self-regulation systems (Humphreys et al., 2018). Sensible air movement helps maintain core body temperature by regulating the release of metabolic heat and managing skin temperature (Nicol et al., 2014). It also influences thermal perception (Munonye & Ji, 2021; Atalogbe, 2014). Thermal perception, a psychological response to discomfort drives human behaviors aimed at achieving thermal satisfaction.

Understanding occupants' perceptions of air movement is vital due to its impact on thermal satisfaction and well-being (Ko et al., 2020; Munonye et al., 2018). Numerous studies highlight the relationship between air movement and thermal comfort, noting that occupant feedback on indoor air movement can inform strategies to reduce energy consumption in naturally ventilated spaces (Adunola & Ajiobla, 2016; Olanipekun, 2014; Ezema et al., 2018; Santamouris, 2016). However, limited research exists on air movement perception in naturally ventilated living rooms within high-density housing in Nigeria's warm and humid tropical climate. In ESHDC high-density estates, it was observed that many occupants preferred spending evenings on balconies or terraces rather than in their living rooms. This preference may be linked to inadequate air circulation within living rooms, especially during evenings when living rooms typically serve as hubs for family relaxation, interaction, and entertainment (Marshall, 2012; Ogunola, 2018). Rechavi (2008) emphasizes that living rooms should be spacious, attractive, comfortable, and thermally acceptable to occupants.

Study Objective

This study aims to address this gap by examining air movement perception in naturally ventilated living rooms within ESHDC high-density estates, Enugu Capital Territory, Nigeria, during the peak rainy season. Specific objective is to assess the relationship between air movement perception and

thermal comfort in naturally ventilated living rooms. This investigation was part of a broader research initiative examining the effect of natural ventilation on the thermal conditions of living rooms in these high- density estates.

Study Area

The study was conducted in Enugu Capital Territory, the administrative and commercial capital of Enugu State, located in southeastern Nigeria. Geographically, Enugu Capital Territory lies approximately between latitudes 6°21' and 6°30'N of the equator and longitudes 7°26' and 7°37'E of the Greenwich Meridian. (See Figure 1). The Capital Territory is bounded by Igbo-Etiti and Isi-Uzo Local Government Areas to the north, Udi Local Government Area to the west, Nkanu West Local Government Area to the south, and Nkanu East Local Government Area to the east. Enugu, often referred to as 'Coal City,' derives its name from its topography of rolling hills and the historic discovery of coal in 1909 by British geologists. It is the oldest urban area in southeastern Nigeria and holds significant historical and economic importance. According to the National Population Commission (NPC, 2006), the population of Enugu Capital Territory was projected to double to 4 million by 2025, with a population density of approximately 900 persons per square kilometer. The majority of the population are Igbo, forming the predominant ethnic group, while a mix of other ethnicities contributes to the area's cosmopolitan character (Enugu State Government Diary, 2013). Rapid urbanization in the Capital Territory has resulted from a substantial influx of people seeking economic opportunities. This population growth has placed significant pressure on existing housing stock, public infrastructure, and electricity supply. These challenges have contributed to reduced urban quality and an increase in thermal discomfort in the area (Umeora et al., 2019)

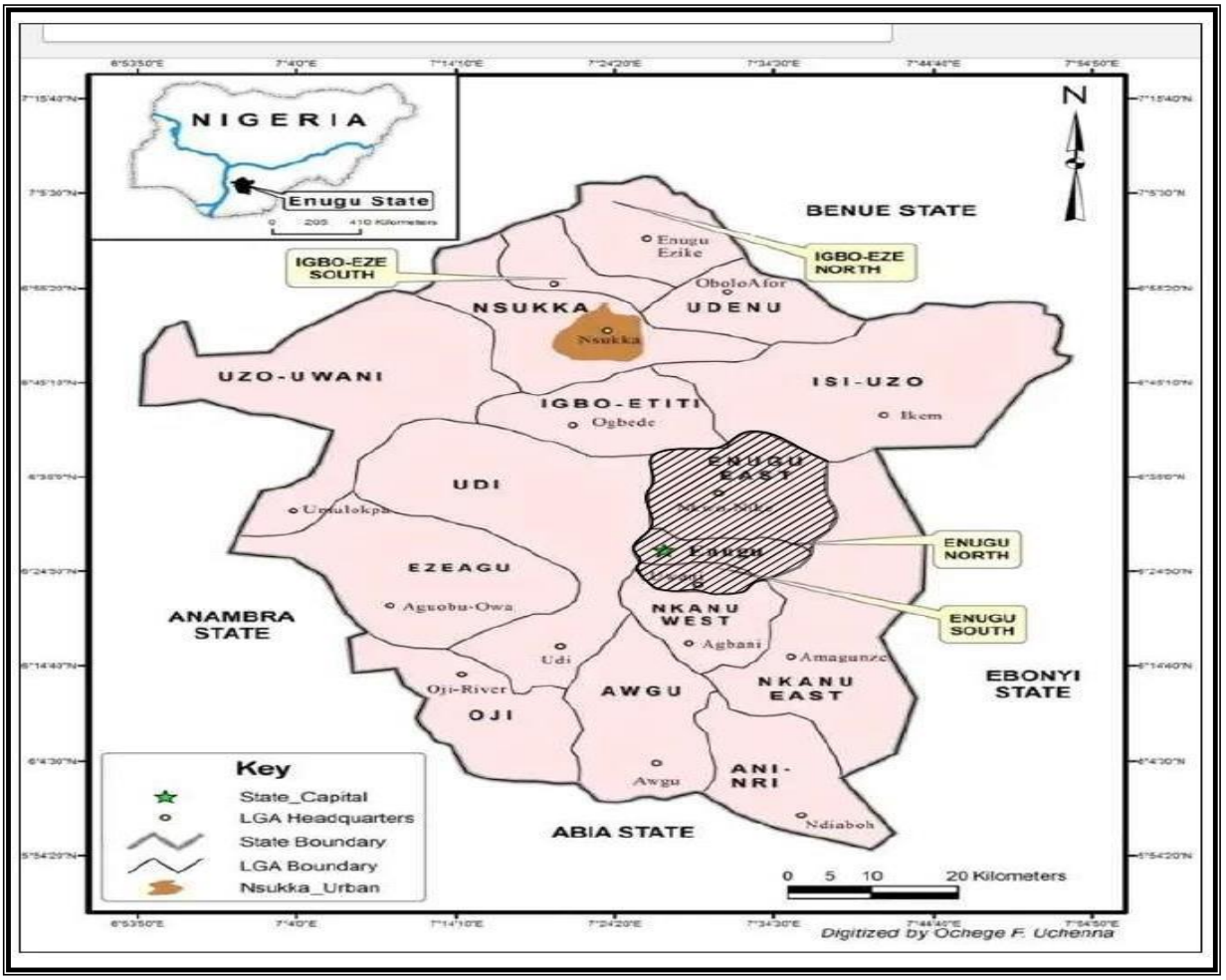

Figure 1: Map of Enugu State showing Enugu Capital Territory (hatched)
Adopted from: Enugu State Government Diary, (2013)

Climatic and Topographic Characteristics of the Study Area

The Capital Territory is characterized by an undulating, hilly topography. It is home to six major rivers: Aria, Asata, Ekulu, Idaw, Nyaba, and Ogbete, which play a significant role in modifying the region's microclimate. According to Köppen's climate classification, Enugu State falls within the Tropical Moist Climate (TMC) zone. The dominant vegetation is tropical rainforest, with elements of derived savannah. Located at an altitude of 304.7 meters above sea level, the

Capital Territory experiences a naturally humid climate. The average maximum temperature hovers around 34.9°C, while average minimum temperatures are about 22.3°C, leading to an annual mean temperature of approximately 26.7°C. The region experiences two distinct seasons: the rainy season and the dry season (Iloeje, 2001).

2.0 LITERATURE REVIEW

Air Movement perception

Air movement is one of the six key variables influencing human thermal comfort. The other five are air temperature, mean radiant temperature, relative humidity, metabolic rate, and clothing insulation. In warm conditions, air movement can have a cooling effect (Nguyen et al., 2012; Kleiven, 2012; Yang & Clements-Croome, 2012), though it may also increase the risk of uncomfortable drafts (Nicol et al., 2014). While detectable air movement is often perceived by occupants as refreshing and pleasant, it can become irritating when it causes discomfort, potentially leading to changes in behavior as well (Humphreys et al., 2018; Fukazawa et al., 2009). The speed of air movement indoors can influence both physiological and psychological responses, ranging from a pleasant sense of coolness to an unpleasant draft, depending on factors such as air temperature, mean radiant temperature, humidity, clothing, metabolic rate, and personal preferences for air movement (Humphreys et al., 2018; Tipton, 2006).

Also, human physiology plays a crucial role in maintaining body heat balance, keeping the core temperature around 98°F (37°C) within the bounds of these six variables. These physical variables regulate the release of metabolic heat by adjusting skin temperature, primarily through changes in skin blood supply and sweating (Ifebi, 2020; Brown et al., 2012), which in turn influences how occupants perceive air movement in an enclosed space. Furthermore, studies have demonstrated that air movement perception is a key component of the adaptive comfort model, which considers sensible, preferable, and acceptable air movement in thermal comfort assessments (Humphreys et al., 2016; Nicol et al., 2014; Rizk & Henze, 2014; Nguyen et al., 2012). Air movement plays a fundamental role in thermal comfort perception, as it is linked to the expression of skin temperature in a given indoor climate (Humphreys et al., 2018). In warm and humid environments, moisture on the skin significantly impacts thermal comfort, as convective heat transfer at the skin depends on air movement across the surface, along with air temperature and relative humidity. As a result, air movement has become a crucial factor in thermal comfort standards, influencing heat loss, skin temperature, skin moisture, thermal sensation, and thermal preference (Humphreys et al., 2018; Nicol et al., 2014; Fukazawa et al., 2009).

Thermal Comfort

ASHRAE Standard 55 (2017) defines thermal comfort as a mental state of satisfaction with the thermal environment, evaluated through subjective methods. This definition highlights thermal comfort as a psychological experience, emphasizing its interpretation through emotional expressions such as sensation, preference, acceptability, pleasantness, comfort, and satisfaction (Lin et al., 2015). Furthermore, thermal perception is often a psychological expression of discomfort, with individuals responding to achieve thermal pleasure. According to Vellei et al. (2021), human behavior is driven by perceived thermal discomfort, prompting individuals to take actions to restore comfort—such as adjusting clothing, switching fans on or off, altering activity levels or location, or consuming hot or cold drinks. Understanding thermal perception and its psychological dimensions help to equip building designers to create adaptive controls that regulate indoor thermal conditions, particularly in naturally ventilated living spaces in high-density estates, like the ESHDC estates in Enugu, Nigeria, where warm and humid climates prevail.

3.0 RESEARCH METHODOLOGY

This study adopted a cross-sectional survey design to collect subjective data on air movement perception in naturally ventilated living rooms during evening hours (4–7 pm) in the rainy season (June– August 2024). The survey aimed to collect subjective data by asking occupants to select from a list of options on five key aspects of air movement perception: sensation, preference, acceptability, satisfaction, and overall comfort, specifically in their living rooms during evening hours.

A stratified sampling technique based on residential density was employed. The sample frame included 433 high-density, three-story multifamily apartment blocks, comprising two-bedroom units and three- bedroom units. A total of 130 residences were randomly selected for the survey (See Table 1). Questionnaires were used to elicit occupant feedback on five dimensions of air movement perception: sensation, preference, acceptability, satisfaction, and overall comfort. Responses were statistically analyzed to evaluate perceptions and their relationship with thermal comfort.

Table 1: ESHDC High-density Estates in Enugu Capital Territory

S/N	NAME OF ESTATE	NUMBER OF HOUSING UNITS
1	African Real Estate	109
2	Maryland Estate	324
	TOTAL	433

Source: Physical Planning Unit, ESDHC, (2023)

To determine the sample size for the study, sampling by ratio and the percentage proportional allocation techniques were applied. According to St. Olaf College (2023), a minimum ratio of 30% is sufficient to ensure equitable representation within a sample. Similarly, Kothari (2014) noted that the percentage proportional allocation technique is effective for reducing a sampling frame to a manageable size, ensuring a representative and efficient study. For this study, 30% of the housing units in each selected estate were randomly sampled, ensuring proportional representation. This approach yielded a sample size of 130 housing units, which was considered sufficient for the survey. The sampling size for both the housing units and the corresponding occupants/respondents is presented in Table 2.

Table 2: Number of Sampled units from each ESHDC High-density Estate

S/N	NAME OF ESTATE	OF HOUSING UNITS	NUMBER OF OCCUPANTS/RESPONDENTS
1	African Real Estate	33	33
2	Maryland Estate	97	97
	TOTAL	130	130

Source: Physical Planning Unit, ESDHC, (2023)

4.0 DISCUSSION OF FINDINGS

The ESHDC high-density estates consist of multi-story apartment buildings, primarily three-story blocks, located on gently sloping terrain with effective natural drainage systems. These estates are situated in two areas: Uwani and Independence Layout, within Enugu South L.G.A. of the Enugu Capital Territory. The building envelopes are made of plastered hollow block walls with operable glazed windows. The ground and first floors feature reinforced concrete slab soffits, while asbestos and aluminum corrugated sheets are used for the ceilings and roofing respectively.

Plate 1 illustrates a view of the real estate in Uwani, showcasing balconies and terraces, exposed earth with undefined parking areas, visible housing transformations, and water storage tanks, which highlight the absence of a reliable public water supply.

Plate 1: Pictorial view of Real Estate, Uwani, Enugu South L.G.A.
Source: Fieldwork (2024)

Plate 2 depicts Maryland Estate in Independence Layout, which is characterized by narrow balconies, expansive hard surfaces, poorly maintained open spaces, narrow streets, designated parking areas, drainage channels, and water storage tanks. In contrast to Uwani, there is no noticeable evidence of housing transformations in Maryland Estate

Plate 2: Maryland Estate – Views of Multi-storey apartment blocks (condominiums)
Source: Fieldwork (2024)

Analysis of Aggregated Data on Level of Air Movement Sensation

The analyzed data, presented in Figure 1, show the frequency and occupant responses regarding their level of air movement sensation across the selected ESHDC high-density estates. The results revealed that more than half of the occupants surveyed responded with 'Just OK' to the question, 'How do you feel about the air movement in this living room?' This response accounted for 55.3% of the responses. In contrast, less than half of the occupants reported a sensation of 'Low' air movement, representing 41.5% of the responses. And very small fraction voted 'High' air movement, representing 3.3% of the responses.

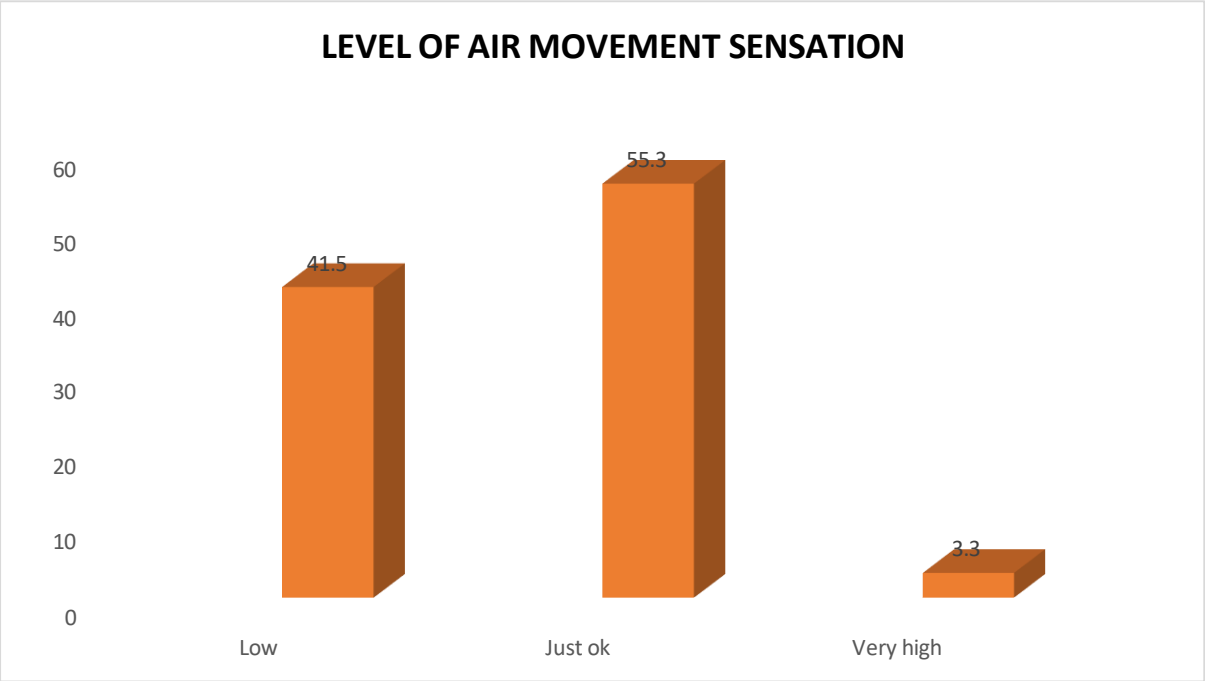

Figure 2: Analysis of aggregated data of level of Air Movement Sensation
Source: Fieldwork (2024)

Analysis of Aggregated Data on Level of Air Movement Preference

The data presented in Figure 2 show the frequency and percentage of responses from occupants regarding their preferred level of air movement in their living rooms across the selected ESHDC high-density estates. The findings

revealed that approximately half of the occupants in both estates indicated a preference for 'More air movement' or 'No change' when asked, 'How do you prefer or want air movement to be in this living room now?' Specifically, 50.4% of respondents preferred 'More air movement,' while 49.6% preferred 'No change.' These results align with previous studies indicating that occupants of naturally ventilated buildings in warm-humid tropical regions often desire increased air movement (Olanipekun, 2014), even during the rainy season, when surface air temperatures are low, and relative humidity is high due to heavy rainfall and extensive cloud cover (World Bank Group, 2021; Charamalapoulos, 2017).

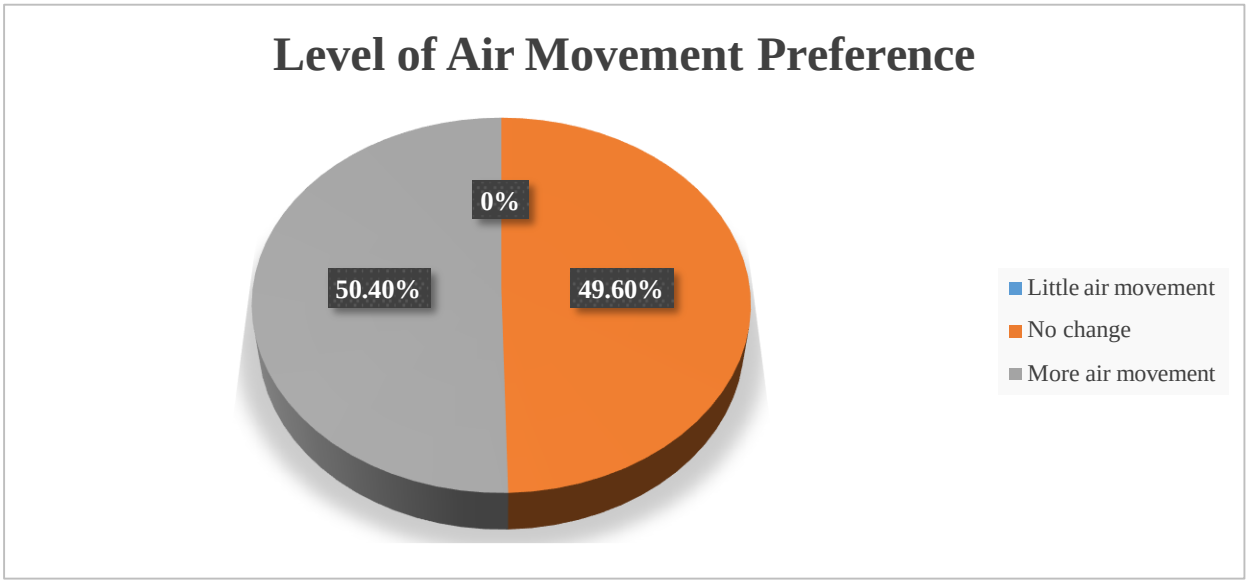

Figure 3: Analysis of aggregated data of Level of Air Movement Preference
Source: Fieldwork (2024)

Test of the relationship between air movement preference and thermal comfort conditions

The relationship between air movement preference and thermal comfort conditions in naturally ventilated living rooms of the ESHDC high-density estates was tested. The variables examined included levels of air movement preference (LAMP) and levels of air movement sensation (LAMS), a measure for thermal comfort. Given that the variables are ordinal, Spearman's Rho correlation analysis was employed to assess the significance of the relationship. The results of the analysis, presented in Table 3, revealed that the correlation coefficient value was: -.722** and Probability Value (p): 0.000. The results indicate a highly positive correlation between levels of air movement preference and levels of air movement sensation. The p-value of 0.000 confirms that this relationship is statistically significant

Table 3: Spearman's Rho Correlation analysis results on relationship between thermal comfort and Air movement perception variables (LAMS & LAMP)

		Level of Air Movement Preference
Level of Air Movement Sensation	Pearson Correlation coefficient value	-.722**
	Sig. (2-tailed)	.000
	N	123
**. Correlation is significant at the 0.01 level (2-tailed)		

Source: Fieldwork (2024)

CONCLUSIONS AND RECOMMENDATIONS

The following conclusions have emerged from the assessment of the role of air movement perception in enhancing thermal comfort in naturally ventilated living rooms in ESHDC high density estates in Enugu Capital Territory, Nigeria:

1. This study has submitted that air movement perception is an important aspect of the adaptive comfort model because the model takes into consideration of building occupant's expression of thermal comfort.
2. This study also asserted air movement perception can boost flexible use of energy by allowing occupant to regulate energy use with help of adaptive controls, to meet the thermal expectation that may vary with times of the day and season.

3. The study has affirmed existence of a positive correlation between levels of air movement preference and levels of air movement sensation. The p-value of 0.000 confirms that this relationship is statistically significant.

Furthermore, these recommendations were drawn from findings of this study and existing related literature.

1. This study aligns and agrees that the air movement perception is an aspect of human self-regulatory behaviour, and a valuable component of passive ventilation architecture that ought to be considered at the initial design stage for achieving acceptable thermal environments.

2. Air movement perception boosts flexible use of energy via proper design of adaptive controls to regulate thermal comfort conditions and determine individual thermal expectations at various times of the day and season.

3. Air movement as an aspect of thermal perception survey that regards occupant feedback as a critical factor updating design practices to enhance indoor air movement and thermal comfort. It recommends incorporating air movement perception into thermal comfort standards to improve living conditions of buildings in the warm and humid tropical climates.

REFERENCES

1. ANSI/ASHRAE: *Thermal Environmental Conditions for Human Occupancy Standard 55-2017.*
2. ASHRAE Atlanta, GA, USA 2017.
3. Atolagbe, A.M.O. (2014). *Natural ventilation and body heat comfort: An evaluation of residents' satisfaction in Ogbomosho, Nigeria*. Retrieved June 20, 2024 from https://www.iiste.org
4. Brown Douglas, J.A., Brugger, H. Boyd, J., Paal, P. (2012) *Accidental Hyperthermia*. New England Journal of Medicine, 367(20) 1930 – 1938. Doi 10.1056/nejmra 1114208 ISSN 0028 – 4793 PMID 23150960 s2CID 205116341
5. Charalampopoulos, L., (2017). *A Preliminary Study on the Effect of Rainfall Events on Human Thermal Comfort under Hot Weather Conditions.* DOI: 10.1007/978-3-319-35o9-0 46
6. Enugu State Ministry of Information (2013): *Enugu State Government Diary (2013).*
7. Fukazawa, Takako, Havenith, George (2009). *Differences in comfort perception in relation to local and whole-body skin wetness.* European Journal of Applied Physiology 106 (1): 15-24, doi: 1007/s 00421-009-0983.
8. Hou, G. (2016). *An investigation of thermal comfort and the use of indoor transitional space*. Thesis for the degree of Doctor of Philosophy. Cardiff University, United Kingdom
9. Humphreys, M.A. & Nicol, J.F. (2018). *Principles of Adaptive Thermal Comfort.* DOI: jc h10.1007/978-10-8465-210
10. Humphreys, M.A., Nicol, J.F. & Roaf, S. (2016). *Thermal Comfort: Foundations and Analysis* ISBN: 978-0-415-6916-1.
11. Ifebi, O. C., (2020). *Assessment of indoor thermal conditions in architecture design studios of universities in Southeast Nigeria* (A Ph.D. Thesis submitted to the Department of Architecture Chukwuemeka Oduemugwu Ojukwu University, Uli, 2020
12. Iloeje, N.P. (2001). *A New Geography of Nigeria*. New Revised Edition, Longman Nig. Ltd., Lagos
13. Kleiven, T. (2012). *Natural ventilation in buildings: architectural consequences and possibilities*, Norwegian University of Science and technology, Trondheim. Klimaatinfo (z.d). Klimaateijfers
14. Ko, W.H., Schiavon, S.,Zhang, H., Graham, L.T. Brager, G. & Mauss, I. (2020). *The Impact of a View form a Window on Thermal Comfort, Emotions, and Cognitive Performance*. Building and Environment, May 2020. https://doi/j.buildenv.2020.106779
15. Kothari, C.R. (2012). *Research Methodology: Methods and Techniques*, New Delhi: New age Techno Press.
16. Lin, Yang, Zhang & Ren (2015). *Study on human physiological adaption of thermal comfort under building environment.* Procedia Engineering 121(2015) 1780 – 1787.
17. Marshall, A. (2012). *History of Living rooms*. www.articles.facility.com
18. Munonye, C.C. & Ji, Y. (2021) *Evaluating the perception of thermal environment in naturally ventilated schools in warm and humid climate in Nigeria.* Building Serv. Eng. Res. Technol 2021, Vol.42(1) 5 -25 Doi:10.1177/0143624420911148journals.sagepub.com/home/bse
19. Munonye, C.C. & Ji, Y. (2018) *Adaptive thermal comfort evaluation of typical public schools in Imo State, Nigeria.* Library-research@salford.ac.uk
20. Nicol, F., Humphreys, M. A. & Roaf, S., (2014), *Adaptive Thermal Comfort: Principles and Practice.* Published by Routledge, London & New York.
21. Nguyen, A.T., Singh, M.K., Reiter, S. (2012). *An adaptive thermal comfort model for hot humid South-east Asia. Building and Environment*. Volume 56, October 2012, pp291 – 300. https://doi.org/10.1016/j.buildenv.2012.03.021
22. Ogunola, A.A. (2018). Socialization and the Nigerian child: Context and Implications. *East African Scholars Journal of Education, Humanities and Literature*. DOI: 1036349/easjehl.2018.v0Li01.006

23. Olanipekun, E. A., (2014). *Thermal Comfort and Occupant Behaviour in a naturally ventilated Hostel in Warm-Humid Climate of Ile-Ife, Nigeria: Field Study Report during Hot Season.* Global Journal of Human –Social Sciences, volume 14 Issue 4 Version 1.0 Year 2014. Online ISSN: 2249-460x & Print ISSN: 0975-587X
24. Rechavi, T.B. (2008). *Journal of Psychology* vol. l29, ISSN 1. https://doi.org/10.1016/J.jenvp.2008.05.001
25. Rizk, A.A. & Henze, G.P. (2014). *Survey of airflow around multiple buildings.* American *Journal of Energy Engineering*. 2,(1),.27-36. doi: 10.11648/j.ajee.20140201.14
26. Santamouris, M. (2016*), Cooling the buildings-past, present and future*, Energy and Building 128(2016) 817-638.
27. St. Olaf College (2023). Sample-size institutional effectiveness and assessment. Retrieved from www.stolaf.edu/iea/sample-size,Accessedon 12/2/23.
28. Umeora, C.O., Olotuah, A.O & Ezeji, K.E. (2019). Average Monthly Income of Residents as a Predictor of Residents' Satisfaction in Private Housing Estates in Enugu, Nigeria. *coouAfrican Journal of Environmental Research*, 1(1), 33-40.
29. Vellei, M., Pigliautile, I., Psello, A. L. (2023). *Effect of time-of-day on human dynamic thermal perception.* National Library of Medicine, National centre for Biotechnology Information, United States Government. doi: 10.1038/s41598-023-29615-8
30. World Bank Group (2021). *Climate Risk Profile: Nigeria. Climate Change Portal (CCKP).* URL:https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/Nigeria%20First/NDC%20INTERIM%20REPORT%20SUBMISSION%20-%20NIGERIA.pdf
31. Yang, T. & Clements-Croome, D.J. (2012), *Natural Ventilation in Built Environment*. https://www.researchgate.net/publication/301975067