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INFLUENCE OF INDOOR AIR TEMPERATURE ON OCCUPANTS' THERMAL SENSATION IN ARCHITECTURE DESIGN STUDIOS OF UNIVERSITIES IN SOUTHEAST NIGERIA

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Abstract

Air temperature is usually the most important environmental variable that affects human sensation in a thermal environment. Determining the effect of the indoor air temperature, on occupants' perception of a thermal environment in design studios where architecture students spend long periods of time daily is therefore important. The study investigated design studios of six institutions that offer architecture in southeast Nigeria, to evaluate the influence of the average daily indoor air temperature on the occupants' thermal sensation. The field survey was carried out during the rainy season (April-October) of the year 2018, for a period of seven months in the undergraduate design studios of the six institutions, which were selected based on, cluster random sampling method. Data loggers were mounted in the architecture design studios to record the daily temperature readings during the survey periods while data on thermal sensation was obtained through the administration of questionnaires to the students as the air temperature reading was collected. Pearson product moment correlation was used to test the nature of relationship between the two variables- average daily indoor air temperature readings and thermal sensation. The result from the analysis shows a moderate and highly significant relationship between the two variables. It follows therefore, that the average daily air temperature significantly influences occupants' thermal sensation in the architecture design studios in southeast Nigeria. The paper recommends that there should be adequate consideration of the number/total area, location and position of openings in architecture design studios to ensure increased air flow, which aids body cooling, and curb the adverse effects of raised indoor air temperature.

Keywords: Architecture design studios, Indoor air temperature, Thermal sensation,

INTRODUCTION

Air temperature is one of the four environmental parameters that affect human sensation in a thermal environment. AHSRAE (2004) defines air temperature which is also known as the dry bulb temperature (DBT) as the temperature of the air surrounding a given person in relation to the temperature of the space. The temperature of an environment at any given time is therefore affected by the air temperature of that space and in turn affects an occupants' feeling of the indoor environment. CIBSE (2006) posit that air temperature is usually the most important environmental variable that affects thermal comfort. Thermal sensation is the apparent physical feeling experienced by occupants of a space in connection to climatic parameters which determine comfort or discomfort in that environment (Velt & Daanen, 2017). The level of an individual's sensation relative to the air temperature of an indoor environment depends on whether the building is centrally air conditioned (AC) or naturally conditioned (NV) (Humphreys, Nicol & Roaf, 2016). According to Humphreys, Nicol and Roaf (2016), the average thermal sensation of building occupants' changes as the temperature of the room changes. Also, studies have shown that humans are not more sensitive to decline in temperature than increase in temperature, and that the higher the temperature, the higher the occupants feeling of discomfort (Velt & Daanen, 2017; Nicol, Humphreys & Roaf, 2012; Alozie, Odim & Alozie, 2015). Building occupants rather, are generally sensitive to both colder and warmer environments and would always seek ways to improve their environment if it becomes unacceptable. A seven-point scale of subjective warmth is usually used to denote sensitivity to the temperature variations (Humphreys, Nicol & Roaf, 2016).

The effect of air temperature on occupants' sensation affects the acceptability or non-acceptability of the indoor environment. According to ASHRAE (2004), a building can only be comfortable if about 80% of its users accept the space as comfortable. Similar study conducted by Alozie, Odim and Alozie (2015) in Umuahia, Nigeria contend that a large percentage (69.3%) of the residents living in the surveyed buildings felt that the temperature was high, based on their votes on the seven-point scale, stating that they did not accept their indoor environment as comfortable. 70.3 percent of the buildings surveyed recorded high temperature when measured, exceeding a temperature range of 20-26 ^{o}C (Alozie, Odim & Alozie, 2015).

The architecture design studios in southeast Nigeria operate like many other design studios, as an integral part of architecture education where students spend time long after school hours undergoing the required training to become architects. Many of the architecture design studio spaces in south east Nigeria are naturally ventilated with fans installed and operated by users as the need arises. Inadequate power supply and high cost of buying and maintaining generators required to power the fans (which would have helped to increase body cooling of design studio occupants' through raised indoor air velocity) have hindered the ability to improve thermal sensation and in turn increase acceptability of thermal environment. It is also vital to note that buildings in tropics are exposed to high solar radiation throughout the year, with all twelve (12) months having a mean temperature above 18^{o}C (Eludoyin, 2014). The architecture design studios in the universities in southeast Nigeria are not exempted from the effect of the year-round high temperatures. The occupants of the architecture design studios in the study area have been observed to become less attentive and irritable during lectures and design classes especially during the noon time when there is no electricity to power the fans.

There is therefore a need to study the air temperature of the architecture design spaces in relation to the occupants' thermal sensation. Fewer studies have been carried out generally in Nigeria on air temperature in classroom environments particularly with emphasis on occupants' thermal sensation. Research shows that higher air temperatures increase the frequency and duration of occurrence of heat waves (Velt & Daanen, 2017). The warmer the environment gets, the greater the impact of high air temperature on building occupants. Increase in indoor air temperature may lead to increased loss of concentration, poor performance, increased irritability, inability to do mental tasks, thermal discomfort, heat stroke and even death (Obeidat & Al-Share, 2012 and

Zeiler & Boxem, 2009; Velt & Daanen, 2017). Review of related literature show other factors that could make an indoor environment unacceptable and uncomfortable include the level of relative humidity, clothing worn by the occupants, occupants' level of activity, mean radiant temperature (Heerwargen, 2004). For the purpose of this study, only air temperature is investigated as it is the most important variable that affects how an individual feels in the environment (Humphreys, Nicol & Roaf, 2012). The objective of this study was therefore, to investigate the influence of air temperature on the thermal sensation of occupants of architecture design studios in southeast Nigeria, with a view to establishing suitable temperature criteria for acceptable environment for studio work. The investigation will provide a standpoint for better planning, designing and construction of studio spaces that will provide acceptable comfort to users. A null hypothesis was proposed which sought to establish the significant relationship between the average daily indoor air temperature and occupants' level of thermal sensation in the architecture design studios of universities in south east, Nigeria.

Study area

This study covered universities in southeast Nigeria. As with all areas in the tropics, Nigeria's climate is seasonally damp and very humid. Nigeria is in the tropics where the climate is seasonally damp and very humid. Southeast Nigeria is made up of five states, namely, (i) Abia, (ii) Anambra, (iii) Ebonyi, (iv) Enugu, and (v) Imo. The climate in south-eastern Nigeria is the wet tropical type climate, with mean annual temperature in the range of between 27° C and 32°C (Uchechukwu, Agunwamba, Tenebe & Bamigboye, 2018). The temperature of the area is usually highest around March- April when the sun passes through Nigeria's latitudes. The area experiences high rainfall between May and September which lowers the effect of temperature in the area. Uchechukwu et al (2018) posits that south-eastern Nigeria rainfall follow the same pattern as other parts of Southern Nigeria with bi-modal rainfall between May-October, that is, wet season and November-April dry season. The rainfall shows a double peak in July and September. Southeast Nigeria enjoys a common temperature pattern with varied insignificant microclimatic differences in some places. The maximum temperature recorded in Anambra State is 32° C, during its hottest months, which is from February to March, while Enugu records a mean daily temperature of 26.7° C (80.1 °F) and usually hot all year round just like the whole of Nigeria, which is in the tropics. Imo state records an annual temperature of 20°C (68 °F). The minimum outdoor temperature for Abia State is 26°C and that is in its coldest period of the dry season. The schools studied and their locations are:

1) The University of Nigeria, Enugu Campus, located in the heart of Enugu, the capital city of Enugu State
2) Nnamdi Azikiwe University, Awka, located in Awka, the capital of Anambra State.
3) Imo State University is located in the centre of Owerri, the capital of Imo State.
4) Chukwuemeka Odumegwu Ojukwu University is located at Uli, which is 81.6 kilometres from Awka the capital city of Anambra state.
5) Caritas University is located at Amorji- Nike, which is about 4 kilometres from the centre of Enugu city.
6) Abia State University is located at Uturu, which is 53.7 kilometres from Umuahia, the capital city of Abia State (Google maps, 2016).

METHODOLOGY

The research is a field survey of thermal comfort. It was based on repeated transverse research, in which the same respondent gave a single comfort response once a month for the period of survey. It is an approach, which combines the virtues of longitudinal and transverse surveys (Nicol, Humphreys & Roaf, 2012). This approach corresponds with the methods used in the European SCAT's project (Nicol, Humphreys & Roaf, 2012) and Pakistan surveys (Nicol, Raja, Allaudin & Jamy, 1999). Questionnaires were administered on students who were the design studio occupants to show their votes on thermal sensation and thermal acceptability in the studios. Thermal sensation vote, was based on the ASHRAE seven-point category scale of, 'cold, cool, slightly cool, neutral, warm, slightly warm and hot' (American Society of Heating, Refrigerating and Air Conditioning Engineers, 2013; Humphreys, Nicol & Roaf, 2016). Data logger, Gemini (TGU- 4500) with accuracy of $\pm$0.5K, for measuring indoor air temperature was used. The data loggers were mounted at 0.9m height above the floor on each day of each month surveyed. The research population for the study included all undergraduate design studios in Departments of architecture found in five out of the eight states in south east, Nigeria. Active studio work starts from 200 level making it three (3) studios for each school in the strata apart from Federal University of Technology, Owerri that offers BSc as a five-year programme. To determine the sample size, stratified random sampling based on the states the universities are located was adopted. Table 1 show the schools that offer architecture in southeast Nigeria, stratified based on states located.

Table 1: List of schools that offer architecture in southeast Nigeria stratified by states located

Abia State	Anambra State	Enugu State	Imo State
Abia State University, Uturu	Nnamdi Azikiwe University, Awka	Enugu State University of Science and Technology	Imo State University, Owerri
	Chukwuemeka Odumegwu Ojukwu University, Uli	University of Nigeria, Nsukka	Federal University of Technology, Owerri
		Caritas University, Enugu	

Source: Fieldwork, 2018

Following the stratification, random sampling by balloting was carried out and the following schools were picked to represent the various states where the schools were located:

i. Abia State - Abia State University, Uturu (ABSU)
ii. Anambra State - Chukwuemeka Odumegwu University, Uli
iii. Enugu State - Enugu State University of Science and Technology (ESUT) and Caritas University,
iv. Imo State - Federal University of Technology, Owerri

The target population was the total population of the seven hundred and one (701) students in the architecture design studios of the selected schools as shown in Table 2.

Table 2: Students population in the architecture Departments of schools sampled

School	ABSU	COOU	ESUT	CARITAS	FUTO
Number of Students	320	110	75	72	124

Source: Fieldwork, 2018

The Cochran formular for finite population was used to obtain the respondents size from the students' population in the architecture Departments of schools sampled:

$n = \frac{z^2 \times \sigma_p^2 \times N}{[N-1]e^2 + z^2 \times \sigma_p^2}$ (Kothari, 2004) --------------------------------Equation 1

Where n = size of sample for finite population; N = research population = 701 students; e = significance level (precision/acceptable error) chosen = 0.05; σ_p =standard deviation of population assumed = 0.5; z = standard variant at a given confidence level = 1.96 for a confidence level of 95% (Kothari, 2004); The sample size of 248 respondents was derived and apportioned to the sampled Departments in the ratio of their contribution as shown in Table 3.

Table 3: Calculated respondents' population in sampled departments

School	**ABSU**	**COOU**	**ESUT**	**CARITAS**	**FUTO**
Number of Students Existing	320	110	75	72	124
Number of Students Sampled	113	39	22	26	44

Source: Fieldwork, 2018

RESULTS AND DISCUSSION

Descriptive summary measures and frequency distribution for each of the variables studied were calculated. The test for the significant relationship between the two interval variables selected from the research data was also carried out with the Pearson's Product Moment Correlation analysis tool using the Statistical Package for Social Sciences.

Analysis of data on average daily indoor air temperature readings

The data obtained from the architecture design studios shows that the average daily indoor air temperature readings of 24 °C -26 °C were recorded in only few (1.5 percent) of the design studios studied as shown in Table 4. The average daily indoor air temperature readings of 28 °C - 30 °C and 30 °C - 32°C were observed in most (48.2 and 32.2 percent) of the architecture design studios surveyed. The average daily indoor air temperature readings of 20 °C - 22°C, 22 °C - 24°C and 32 °C - 34°C were not recorded in any of the studios throughout the period of field survey. Figure 1 illustrates the result of the analysed data.

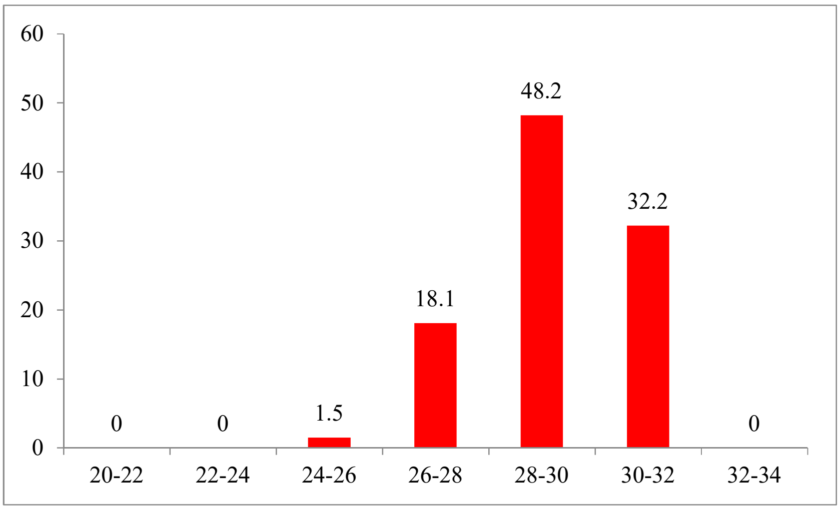

Figure 1: Data on average daily indoor air temperature reading in the institutions surveyed in percentages
Source: Fieldwork, 2018

Analysis of data on level of thermal sensation

The result of the analysed data on level of thermal sensation, shows that, 38.3 % of the architecture design studio users on different days of the studied months, felt ‘a bit warm (1)’ based on the 7-point ASHRAE scale which was used. 22.9 % felt their classroom was ‘warm (2)’, while 17.0%, felt the architecture design studio was ‘okay (0)’. 10.5%, 7.0% and 3.2% felt ‘hot (3)’, ‘a bit cold (-1)’ and ‘cool (-2)’ respectively. Only few respondents (1.1%) felt that the architecture design studio was cold (-3). These are illustrated in Figure 2.

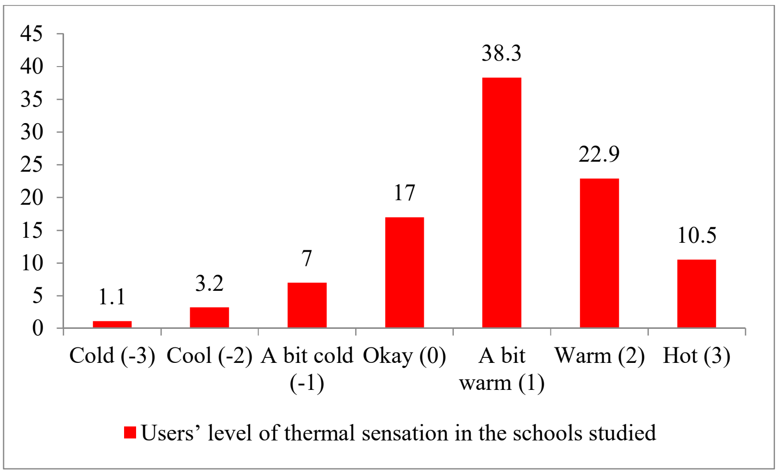

Figure 2: Data on the users’ level of thermal sensation in the schools studied
Source: Fieldwork, 2018

Test of Hypotheses

Testing the significant relationship between daily Average Indoor Temperature reading (AIT) and Occupants' Level of Thermal Sensation (LTS)

The variables in focus were interval variables; hence, Pearson's product moment correlation analysis tool, was used to examine the nature of relationship between the variables. The result from the analysis shows a Pearson's correlation coefficient value of 0.346, with a probability value 0.000. This implies that the magnitude of the relationship between the variables is moderate. The probability value of 0.000 shows it is significant at 5% (95% compliance). It means therefore that the relationship is moderate and highly significant. The null hypothesis is therefore rejected and an alternative hypothesis accepted. This alternative states that *'there is a significant relationship, between indoor air temperature and level of thermal sensation experienced by the occupants of architecture studios in universities in southeast Nigeria'.* The result is illustrated in Table 5.

Table 5: Pearson's product moment correlation coefficient analysis result of relationship between Average daily indoor air temperature (AIT) and Level of thermal sensation (LTS)

		Level of Thermal Sensation
Average daily Indoor Temperature reading	Pearson Correlation	.346**
	Sig. (2-tailed)	.000
	N	1776

Source: Fieldwork, 2018

The relationship between 'average daily indoor air temperature (*AIT*), and acceptability of thermal comfort (temperature) (*ATC*), was also investigated. It is considered relevant here, because, it relates the average daily indoor temperature measured, to the occupants' acceptability/non-acceptability of the sensation, in a thermal environment. The two variables of attention were interval and nominal variables, so Point Biserial correlation analysis tool was used to examine the significance of their relationship. The result from the analysis shows a correlation coefficient value of -0.132 with a probability value 0.000. This implies that, a very weak relationship exists between the two variables. The probability value of 0.000, however, shows that, although the relationship is weak, it is significant. This is seen in Table 6.

Table 6: Point Biserial correlation analysis result of relationship between AIT and ATC

		Acceptability of Thermal Comfort (temperature)
Average Daily Indoor Temperature reading	Pearson Correlation	-.132**
	Sig. (2-tailed)	.000
	N	1776

Source: Fieldwork, 2018

Analysis of data on thermal acceptability

Data obtained as illustrated on Table 7 under this variable, shows that a greater number of students in the institutions, excluding ESUTH and CARITAS, did not accept the temperature in the design studio environment during the survey period. A greater number of respondents accepted the temperature of their design studios in ESUTH and CARITAS. The schools that had greater number of respondents accepting their indoor thermal environment and hence less percentage dissatisfied, were CARITAS (17.8 percent -not accepted, 82.2 percent -accepted) and ESUTH (29.6%-not accepted and 70.4%-accepted). This agrees with Efeoma (2017) which reported about offices spaces in Enugu, where less than 20% were dissatisfied with the thermal conditions surrounding their work environment.

Table 7: Percentage representation of thermal acceptability in different design studios studied

Value label	ABSU	COOU	ESUTH	FUTO	CARITAS
Not accepted	70.6	89.5	29.6	67.5	17.8
Accepted	29.4	10.5	70.4	32.5	82.2
Total	100.0	100.0	100.0	100.0	100.0

Source: Fieldwork, 2018

CONCLUSION

It was found statistically that there is a positive significant relationship between indoor air temperature and level of thermal sensation experienced by the occupants of architecture studios, in universities in southeast Nigeria. This, therefore, implies that increase in indoor air temperature, led to increase in level of thermal sensation within the study population. This surely led to high temperature in the design studio interiors, which impacted negatively on how the design studio occupants feel and accept the temperature of their design studio spaces. An increased indoor air temperature denotes high temperature in indoor spaces, which will result in occupants' discomfort and non- acceptability of indoor spaces.

The study therefore recommends that the number/total area, location and positions of openings in architecture design studios should always be considered in order to increase air movement into the architecture design studios and cooling of the body by air. This will make occupants feel better in the architecture design studio spaces and comfortable. Concerted efforts should also be made to ensure that controls such as fans which have been observed to modify indoor temperature are in good working condition and can easily be operated by the design studio users, if needed. Building design strategies which offer more adaptive opportunities that would increase body cooling and reduce discomfort should be employed so as to positively assist in achieving and maintaining acceptable indoor thermal comfort, in architecture design studios.

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