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TURN ON THE FAN PROFESSOR..."
A POST-OCCUPANCY ANALYSIS OF THERMAL COMFORT IN A UNIVERSITY LABORATORY

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Abstract

Throughout the history of work, the human body has been adapting to different working environments and the changes that occurred in it, creating its own mechanisms that provide a better feeling of thermal comfort to these environments. Currently, several activities are performed in closed environments that, in turn, being poorly designed, generate ergonomic problems, poor lighting and poor use of natural and artificial ventilation. Nowadays, there is already a concern to make changes in the workplaces so that they adapt to their users. Therefore, it became necessary to invest in research on thermal comfort. Therefore, this article aims to analyze thermal comfort in a laboratory at the facilities of a university located in the Midwest region of Minas Gerais, seeking to identify how the design of a space can influence the thermal sensation. The results found showed that modifications without prior analysis in the environment in question, increased the points of thermal non-conformity by 20%, remaining outside the comfort range (-0.82 <VME <0.82)..

Keywords: Thermal comfort; Workplace; Laboratory.

1. Introduction

Throughout the history of work, the human body has adapted to different work environments and to the changes that occurred in it, creating its own mechanisms that provided a better feeling of thermal comfort to these environments. Currently, several activities are performed indoors which, in turn, being poorly designed, generate ergonomic problems, poor lighting and poor use of natural and artificial ventilation (Sevegnani; Son; Silva, 1994).

Some work activities are subject to using spaces with artificially constructed or mechanized air conditioning, providing relative "comfort", so that they can perform their activities with the best possible performance, adapting and relating the thermal sensation to well-being at work, expressed by satisfaction with the organizational environment (Leite, 2003).

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Due to the large number of activities developed indoors, thermal comfort studies are important, which seek to offer guidelines that satisfy man in all environments (Andreasi, 2009), which, according to Batiz et al., (2009), is the intuitive search for man's natural feeling of being.

According to Frota and Schiffer (2001), it is known that man has better health conditions and performance with maximum capacity when the body works without stress or thermal fatigue, evidencing the need to develop studies that address the subject. They also state that it is part of the objective of architecture to provide thermal conditions that are compatible with thermal comfort, allowing heat exchanges to occur between the human body and the environment, without great effort from individuals.

Thus, the research seeks to analyze and establish the necessary conditions to evaluate and design an environment suitable for human activities and occupations, and also to establish methods that perform a more detailed thermal analysis. The studies are based on man's satisfaction with being in a thermally comfortable environment, human performance and also energy conservation, due to the mechanization and industrialization of the current population (Lamberts, 2011).

Therefore, the following study aims to analyze the thermal comfort in a laboratory at the facilities of a university located in the Midwest region of Minas Gerais, after the occupation of the space, seeking to identify how the conception can influence the thermal sensation, considering the natural and artificial ventilations.

According to the *American Society of Heating, Refrigeration and Air Conditioning Engineers* (ASHRAE), thermal comfort is the state of mind that expresses man's satisfaction with the thermal environment that surrounds him as a result of the satisfactory combination of temperatures that surround him (Lamberts, 2014).

For Ruas (1999), the first considerations for the establishment of thermal comfort criteria were made at the beginning of the twentieth century. Studies show that comfort is related to the thermal balance of the human body and that it involves personal and environmental factors.

According to Frota and Schiffer (2001), the well-being of people in the environments in which they are inserted also depends on the heat induced by machines and equipment used during the process carried out in the work activity, the presence of other people, artificial lighting and solar heat.

Existing studies are not sufficient to adopt values as being adequate for the population in general, because we must consider that people have different perceptions and that sensations are subjective. Perception plays an important role in allowing the individual to attribute meanings to things, actions and deeds (BATIZ et al., 2009).

According to ISO 7730/94, the combination of several factors is the main determinant of the feeling of thermal comfort or discomfort (Oliveira et al., 2010). Therefore, well-being depends on factors that interfere with the functioning of the thermoregulatory system; causing indisposition and insufficiency at work, can lead to an increase in the probability of accidents (Ruas, 1999; 2001).

From a teaching point of view, it is important to emphasize that attention plays an important role in understanding and learning, making it vital to analyze factors that can interfere, such as heat, noise, poor lighting, etc. "Attention is a mental process that allows people to focus on a certain stimulus or relevant information" (Batiz et al., 2009). It also acts as a prerequisite for the functioning of complex cognitive processes, since it is not possible to evaluate perception or any other mental activity without considering attention processes (Batiz et al., 2009).

According to Wargocki et al. (2005), the increase in temperature and air quality reduce teaching performance, negatively influencing learning capacity. It is also identified that many studies do not consider all thermal variables, as many evaluate only the air temperature, which influences their results (Batiz et. al., 2009). According to Lorsch and Abdou (1994, apud Andreasi, 2009) better thermal conditions increase productivity and human performance.

As previously evidenced, some variables, associated with the activity performed, influence our thermal comfort, determining whether there is comfort or discomfort. The variables are divided into two groups presented below: environmental variables and human variables.

Environmental variables: Air temperature (ta) or Dry bulb temperature (Tbs): When the temperature is lower than that of the skin, heat removal by convection occurs. If the temperature of the air is higher than that of the skin, it will give heat to the body; Mean radiant temperature (trm): It is uniform in an imaginary environment in which the exchange of heat for radiation is equal to the actual non-uniform environment; Relative humidity (RH): Provides the amount of water vapor in the air relative to the maximum amount it can contain at a given temperature. e Relative air velocity (vr): Air velocity alters heat exchanges by convection and evaporation (Lamberts, 2014; Ruas, 1999).

Human variables: Metabolism rate: It is through metabolism that the body acquires the necessary energy. The release of this energy varies according to muscle activity; Clothing used: Imposes a thermal resistance, as if it were a barrier to heat exchange, between the body and the environment (Lamberts, 2014).

Once the relationship between thermal discomfort, loss of productivity of workers and dissatisfaction with the work environment was established, it became necessary to carry out studies to establish corrective and/or preventive measures in the projects of the workspaces, seeking to adapt them to the needs of their users. The first studies appeared in the Post-Occupation Assessment from the 70s (Nogueira et. Al., 2005) and show that:

Modern conceptions for organization and production, generated by globalization, have brought new concerns, which have become new topics of study related to environmental comfort, such as energy efficiency, occupational health and productivity (Lamerts et al., 1997, apud Nogueira; Duarte & Nogueira, 2005, p.39).

The Post-Occupancy Evaluation (POE) is a systematized and rigorous process in the control of the quality of environments after some time of their construction and occupation, and its main characteristic is the participation of users in the analysis process (Rheingantz et. al., 2006). The results of the analyses are based on the crossing of user information with technical reports in the interpretation of the answers (Filho, 2008).

It is also a methodology that is already applied in developed countries and focuses on the occupants of the environment and their needs. From this, ideas are elaborated about the consequences of the project on the building (Rheingantz; Cosenza & Lima, 2006).

An efficient practice in controlling the quality of the environment, feeding projects with new information and can be used to identify ergonomic, constructive, aesthetic and comfort problems in an environment in use. This allows finding solutions that can minimize problems and provide greater comfort to users (Ferraz, 2010). According to Rocha (2007), research in POE gives priority to the use, maintenance and operation of space from the user's perspective, being recurrent for evaluating the performance of built environments.

The general principles of the Post-Occupancy Evaluation encompass two spheres: the intervention on the built environment, minimizing or eliminating the problems raised and enhancing the positive aspects evidenced by the users, contributing to the maintenance and improvement of the quality of life in a given built space; the informative sphere, based on the creation of databases, systematization of results, based on the surveys carried out (graphs, tables) (Rocha, 2007, p.9).

Thus, POE can be an efficient method for the development and process of an environment, based on the use of prior knowledge about the needs of users and early identification of satisfaction levels (Rheingantz; Cosenza & Lima, 2006).

2. Methods

Fanger's model (apud Ruas, 1999) was followed, where he created a Comfort Diagram, with the help of computers, to determine the various combinations of variables that provide comfort. To complete the evaluation, a criterion called Estimated Average Vote (VME) was also created to ascertain the discomfort of the population under analysis. This method classifies the environment into seven different sensation perceptions: -3 (very cold), -2 (cold), -1 (slightly cold), 0 (comfort), +1 (slightly hot), +2 (heat) and +3 (very hot) (Ruas, 2001).

Due to the complexity involved in calculating the VME, ISO 7730 (1994) brings, in addition to the formula, a set of tables that facilitate obtaining it. This is possible through the combination of various environmental and personal factors, making it possible to determine the thermal sensation of a given group (Ruas, 2001).

The standard also shows how to calculate an index of the percentage of people dissatisfied with the environment (PPD) and presents a graph that can be used to determine it. The application of the method adopted by the international standard makes it possible to verify whether the environment fits the acceptable conditions of thermal comfort, to establish greater limits of acceptability in environments where this is possible and to provide combinations of variables that enable the sensation of thermal neutrality (Lamberts, 2011).

Studies show that there were differences in the application of existing methods for thermal comfort assessment, requiring a correction factor. A new model proposed by Humphreys and Nicol (2002) and Fanger and Toftum (2002) called the "adaptive method" (Andreasi, 2009) emerged.

Considering that people have different thermal perceptions, that sensations are subjective and that it is not possible to please 100% of the population under study, the final value of the VME must be between -0.82 and 0.82 in order to say that the environment is considered thermally comfortable for at least 80% of the people present in the environment (Ruas, 1999).

Therefore, these standards seek to provide information, guidance and recommendations on how to consider the adaptation of people to the environment when evaluating and designing buildings, systems and work environments (Lamberts, 2011).

To apply the method and estimate the thermal sensation of the people who use the space to be analyzed, we need (based on ISO 7730/1994): Define the study location; Survey the characteristics of the study site; Know the type of clothing used; Know what type of activity is performed at the site under study; Divide the occupied area into equal squares; and Set the measurement points in the center of these squares.

With this information, we will carry out measurements of temperatures and relative air velocities. Measurements should be taken 0.60 m from the floor for seated persons and 1.10 m from the floor for standing persons. Air temperature measurement can be done using mercury thermometers, resistance thermometers or thermocouples. The average radiant temperature is measured using the globe thermometer (tg) (it can also be used to measure air temperature). And the air velocity is measured using the thermoanemometer with the capacity to measure speeds of the order of 0.05 m/s.

After the measurements, we need to organize the values found in a table (**Table 1**) in which the first three columns contain the values found during the measurements. After filling in the first columns, we calculated the VME for trm = ta using values from the table of physical activity degree according to the activity performed. For some VME values it is necessary to do double linear interpolation, for others it is enough to use the value established in the tables. Below, the double interpolation formulas (iii) used and a model

of the table to be used to organize the calculations (Ruas, 1999): Initially, it is interpolated in $z = \underline{f}(x, y)$, obtaining the equation (i)

$$\underline{f}(x_{j-1}, y_c) = f(x_{j-1}, y_{i-1}) + \frac{y_c - y_{i-1}}{y_i - y_{i-1}}\left[f(x_{j-1}, y_i) - f(x_{j-1}, y_{i-1})\right] \quad \text{(i)}$$

Subsequently, it must be interpolated at $z = \underline{f}(x_j, y_c)$, obtaining the equation (ii)

$$\underline{f}(x_j, y_c) = f(x_j, y_{i-1}) + \frac{y_c - y_{i-1}}{y_i - y_{i-1}}\left[f(x_j, y_i) - f(x_j, y_{i-1})\right] \quad \text{(ii)}$$

Finally, by associating equations (i) and (ii), double linear interpolation is obtained in

$$z = f(x_c, y_c).$$

$$f(x_c, y_c) = f(x_{j-1}, y_c) + \frac{x_c - x_{j-1}}{x_j - x_{j-1}}[f(x_j, y_c) - f(x_{j-1}, y_c)] \quad \text{(iii)}$$

As the VME values correspond to the condition in which trm = ta, it is necessary to correct them. For this correction, we need the values obtained from the graphs ΔVME/°C trm established by the standard for the type of activity under study, as a function of the thermal insulation of the clothing and the air velocity (m/s). With these values we fill in column 5 of the table and, thus, perform the calculations of the first correction by multiplying column 2 by column 5 and the result is in column 6. Finishing the correction to find the VME , we add the values in column 4 (values initially obtained) with the actual values in column 6 and fill in column 7 with the results.

As defined by FUNDACENTRO, the values obtained in column 7 are analyzed to verify that they are between -0.82 and 0.82, which are the values considered ideal for the thermal comfort of at least 80% of the people in the enclosure. Based on the results, we will evaluate whether the environment presents thermal comfort conditions or if we need to make modifications so that comfort is achieved.

3. Results and discussion

The first step was to determine the place where the measurements would be taken. In informal conversations with some teachers, it was recommended to carry them out in a Hydraulics and Pneumatics laboratory. The space under study was made of masonry, has no windows, has only one door and machines and equipment that emit heat and noise during operation. It was established through analysis that the employee's activity is characterized as sedentary () and thermal insulation of light clothing (0.5 clo) (Lamberts, 2011; Ruas, 1999, p. 16-30).58 $\frac{W}{m^2} - 1met$

The space was then divided into 10 distinct uniform points to make the measurements of temperature and air velocity, in the afternoon between 2 pm and 5 pm, using a TAFR-180 digital anemometer and a TGD-400 globe thermometer. The procedure was performed twice, once with the door open and once with the door open and the fan on (frequent conditions of use according to the occupants of the place).

Below is a sketch of the laboratory with the demarcated points and two tables (**Tables 2 and 3**) with the data collected during the measurement.

After data collection, calculations could be performed to arrive at the necessary parameters of which control measures should be adopted in the work environment (**Tables 4 and 5**). The calculations were made with the help of the Excel program and the table below presents the final results obtained for both situations.

According to the values found, we noticed that two of the ten points evaluated in the first analysis (environment without a fan) present values outside the adequate limit ($-0.82 < \text{VME} < 0.82$) of thermal comfort, representing 20% of the total.

In the second situation analyzed, although the environment has a fan, it is noted that four of the ten points do not comply with the specified limit ($-0.82 < \text{VME} < 0.82$), representing 40% of the total.

The apparently contradictory result demonstrates the ineffectiveness of applying a thermal comfort control methodology, without in-depth a *priori analysis*, because the modification adopted can worsen the situation instead of improving it. This fact is evidenced by the worsening of the environment with the fan on, corresponding to a 20% increase in the points of non-compliance, from the first to the second situation.

It is worth mentioning that the measurements took place during the autumn, a period when temperatures are milder in some locations. And, also, that the discomfort can be due to low temperatures. This fact is corroborated by the fact that the lower boundary of the boundary ($\text{EMV} < -0.82$) has been exceeded.

The results obtained indicate that the existing ventilation system is not effective to maintain thermal comfort at all points of the environment, and it is necessary to adopt control measures to reverse the non-compliant data. The adoption of these measures should be done through future studies that define a ventilation system that is capable of providing thermal comfort at these points without causing any disturbance at the points that already meet the thermal satisfaction requirements.

The need for improvements is also justified based on what is established in NR 17, which requires that the environmental conditions of work must be adequate to the psychophysiological characteristics of the workers and the nature of the work to be performed, thus avoiding both discomfort and loss of productivity.

In order to seek alternatives to solve the non-conformities, we can suggest some possible solutions. For example, the installation of windows in the environment to be able to take advantage of natural ventilation, and as we have seen that the fan present is not fully effective, we can install ceiling fans, with speed regulation, so that ventilation is uniform throughout the environment and offering options for hotter days and colder days.

We must also remember that any modification to be carried out must undergo validation studies to verify their efficiency, always seeking to ensure the best environmental condition for its employees and all users of the environment.

4. Conclusions

The present study focused on meeting the initial objective, to evaluate the thermal comfort of an environment, seeking to identify how the design of the space can influence the thermal sensation and possible measures to be considered to obtain a better environment for its users.

We found that, although the measurements did not occur in the hottest period of the year, we obtained a significant number of non-compliant values. This was due to the fact that non-compliance also occurs when there are low temperatures. In the first situation, we obtained two non-conforming points and in the second there were four points, which shows that the modification made (insertion of the fan) is not efficient to control the non-conformity. One of the points initially not in conformity (point 5) became compliant, but other points became non-compliant.

The data also show that the situation could be more critical, due to the design of the environment and if the study had been carried out in warmer or colder periods, in extreme situations. We can say that the place needs adjustments, so we have proposed some modifications to be made, but which need to be validated in future studies so that we can verify the feasibility of such adjustments.

In order to complement the study and for comparison, we could have carried out measurements at different times of the year. During the summer, intense heat in the region, during autumn as it was carried out (transition period) and also during winter, with low temperatures. It would be important for us to check how the environment behaves under different temperatures and situations, even to check if the suggested modifications would be efficient for the whole year.

As we saw earlier, the comfort or discomfort of users of an environment can influence performance and job satisfaction, in a negative or positive way. In case of increased satisfaction, we can, as a result, increase yield, reduce production costs, absenteeism and turnover and increase the quality of products. In the case of education, providing thermal comfort means increasing the ability to concentrate in most students, increasing their performance and interest in the subjects discussed in the classroom. All these factors show us the importance and justification of investments in thermal comfort.

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