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Understanding the relationship between indoor environmental parameters and thermal sensation of users via statistical analysis

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Abstract

Thermal comfort in indoor environments has a significant effect on user's health and wellbeing. Its effect becomes crucial especially in classrooms since it affects students' performance with respect to attention, comprehension and learning levels. This study assesses thermal comfort conditions via field measurements and subjective surveys. A university building, which is located in the Mediterranean climatic region of Turkey, was selected as a test site and the study was performed for ten days in the heating season. Indoor air temperature, mean radiant temperature, relative humidity and air velocity were monitored to obtain the Predicted Mean Vote (PMV) whereas a total of 235 subjective surveys were conducted to obtain the Actual Mean Vote (AMV). The comparison of PMV and AMV as well as the robustness of the relationship between PMV and AMV were analyzed via the t-test and Pearson correlation coefficient, respectively. In addition, the effect of users' relative humidity and air velocity perceptions on the thermal sensation and thermal acceptability were evaluated via cross tabulation and chi-square independence tests. The results show that the difference between the PMV and AMV values is statistically significant and the relationship between PMV and AMV has a very strong positive correlation. The results of the chi-square tests indicated that the thermal sensation and thermal acceptability are depended on users' relative humidity and air velocity perceptions.

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Keywords: AMV; PMV; statistical analysis; thermal comfort; thermal sensation.

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1. Introduction

Thermal comfort in indoor environments has a significant effect on user's health and wellbeing. Its effect becomes crucial especially in classrooms due to the fact that students spend approximately 30% of their lives in classrooms and thermal comfort conditions have direct impact on students' performance with respect to attention, comprehension and learning levels [1]. The most frequently used thermal comfort standards [2, 3] are based on the Predicted Mean Vote (PMV) model to assess thermal comfort conditions in classrooms [4-8]. The PMV model is taking into account indoor environmental parameters including indoor air temperature, mean radiant temperature, relative humidity and air velocity as well as users' clothing levels and activity levels. These parameters also affect the actual thermal sensation of users, which are derived from the Actual Mean Vote (AMV). The AMV value is calculated based on surveys, which is then used to evaluate thermal comfort conditions subjectively. Pereira et al. [4] conducted a study in secondary classrooms which are located in the Mediterranean climate. The results show that perception of users was either (much) warmer or (much) cooler compared to the perception suggested by the PMV model. Besides, a study conducted in the Mediterranean climate [5] show that the PMV model was not able to detect thermal unacceptability in neither heating nor cooling seasons in university classrooms. Due to the fact that PMV values might not correspond to the actual thermal sensation of users, and, thus, the AMV values, further studies are required to understand how these values are correlated.

In addition, it is assumed that indoor air temperature is the one of the most dominant parameters with respect to thermal sensation of users [9]. However, several studies report that relative humidity and air velocity also have effects on thermal sensation. Jing et al. [10] indicate that relative humidity has a significant effect on users' thermal sensation and thermal acceptability in warm environments. The results of another study conducted at university dormitory buildings show that relative humidity effects thermal sensation of users especially at low and high temperatures [11]. Air velocity is also reported to have effects on thermal sensation [11-15]. Therefore, in order to have a comprehensive understanding of thermal comfort, it is also essential to investigate the impact of relative humidity and air velocity on thermal sensation.

This study aims at comparing the PMV and AMV values as well as investigating the relationship between these values. In addition, the effect of users' relative humidity and air velocity perceptions on the thermal sensation and thermal acceptability are evaluated via statistical analyses.The following section of the paper describes materials and methodology. Then, findings and conclusions are presented.

2. Materials and Methodology

2.1. Data collection

In this study, a university building, which is located in Izmir, Turkey, was selected as a test site. Under the Köppen climate classification, Izmir is included in the C zone and Csa type which is known as the Mediterranean climate. The study was conducted for ten weekdays in November 2016 which represents heating season for Izmir.

Field measurements and subjective surveys were performed simultaneously in the most commonly used classroom during occupied hours. Indoor air temperature, mean radiant temperature, relative humidity and air velocity were measured with one minute intervals at a height of 1.1 m from the ground level as prescribed in the ASHRAE 55-2013 [2]. The measurements presented in Table 1, were used to calculate the PMV values via ASHRAE thermal comfort tool [16].