Assessment of PMV accuracy for different geographic locations using the ASHRAE Thermal Comfort Database II

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Abstract

Energy use minimization and cost reduction are common goals when talking about indoor climates. However, it is also necessary to assure indoor air quality and thermal comfort. The Predicted Mean Vote (PMV), as presented in the International Standard ISO 7730, is the most widely used thermal comfort index for assessing indoor thermal environments. This index takes into account indoor environmental parameters, including air temperature, radiant heat, relative humidity, air velocity, and personal parameters such as metabolism rate as well as clothing.
Despite its wide application, this index was developed for a particular group of people in a specific region, not taking into account personal preferences, and, for these reasons, the accuracy of this model has been questioned. A solution proposed to overcome this discrepancy consists in applying a regional factor that generalizes the PMV to a specific region. Consequently, several studies have been carried out to verify the deviations between the index prediction and the actual thermal comfort. ASHRAE took the initiative to create a database with several studies that included thermal comfort and predictive indices. Thus, the study aims to access the database and to find patterns between the Predicted Mean Vote and the Actual Mean Vote, evaluate the accuracy of the index for different regions, comparing countries with different climatic conditions and characteristics to check for inconsistencies. In this way, it is intended to map European Countries in clutches according to their climatic zone and evaluate the PMV differences. This approach allows performing a correlation for specific climatic zones and obtaining an adjustment factor to apply in future calculations of the PMV index. The results show that the accuracy of the thermal comfort models decreases for regions further from comfort, pointing the need for adjustment of the model.

Keywords: Thermal Comfort; AMV; PMV; Database; Climate.

1. Introduction

Thermal comfort is part of everyday life, as people naturally seek the best living conditions. Comfort not only promotes a better quality of life but is also essential in a healthy and productive work environment [1]. The same is defined as the state of mind where a person expresses satisfaction with the surrounding thermal environment. The PMV, as presented in the International Standard ISO 7730 [2], is the most widely used thermal comfort index for assessing indoor thermal environments[3]. To be more precise the PMV expresses the quality of the thermal environment as a mean value of the votes on the ASHRAE seven-point thermal sensation scale (+3 hot, +2 warm, +1 slightly warm, 0 neutral, –1 slightly cool, –2 cool, –3 cold) [4]. Despite its wide application, the accuracy of this model has been questioned [3]. Consequently, several studies have been carried out to verify the deviations between the index prediction and the actual thermal comfort. ASHRAE took the initiative to create a database with several studies that included thermal comfort and predictive indices.

1.1. PMV precision used for thermal comfort evaluation

Since Fanger defined PMV as the index that predicts the mean thermal sensation vote, there have been many

investigations of the thermal comfort of individuals in regular daily existence that have incorporated all the data expected to compute PMV. A portion of these examinations has given support to PMV while others have found discrepancies.
The following methods are the most used to predict the accuracy of the PMV [3]. One of the methods is the linear relation between the predicted (PMV) and actual mean (thermal sensation) votes, where is possible to determine the slope and linear regression, the coefficient of determination (R^2), and the error terms. With this technique, it's possible to understand the relation between predicted and perceived thermal sensation [5]. Is shown that the relation between the subject's Actual Mean Vote (AMV) and PMV trends has a relation between the parameters in the study, more precisely, the city, building types, climate classification, ventilation strategy, and season [6].
Another process is the relation between PMV and the predicted percentage of dissatisfaction (PPD). The PMV-PPD model is a broadly utilized plan instrument integrated into thermal comfort norms that can be applied to various structure types and environments. Different studies have explored the connection between PMV and PPD or Actual Percentage of Dissatisfied, for example, Humphreys and Nicol [7], have found an unexpected relation compared to the one depicted by Fanger. Another issue that is being raised is whether the connection between PMV and PPD is altogether symmetric, both on the cooler and the hotter side. Especially on the hotter side, fewer individuals show dissatisfaction considering the PMV-PPD connection [8]. Additionally, Fanger's PPD curve may presumably be to some degree too steep, potentially reflecting issues in the meaning of dissatisfied subjects.
The last technique assesses the contrast between AMV and PMV for every specific characteristic. As indicated by Humphreys and Nicol, the PMV model could be considered free from bias if the distribution mean of the difference between AMV and PMV is within −0.25 and + 0.25 units on the thermal sensation scale [7]. In other words, when is "Neutral" conditions are predicted the model is free from bias while in the other conditions of thermal sensation, the prediction is biased. Since PMV predicts the mean comfort vote of an enormous group of individuals within a similar thermal environment, it's basically on the right track to expect that PMV is similarly solid for individual expectations for all intents and purposes for groups of inhabitants. Albeit the mean contrast is useful to decide unbiased PMV expectations, it doesn't give precise measures or blunder terms inside the conveyance.
In this case, it will be shown a direct comparison between PMV and AMV.

1.2. Objectives

The point is to track down patterns between the Predicted Mean Vote and the Actual Mean Vote and assess the exactness of the index for various regions, with various climatic conditions and attributes to check for irregularities. Through the discoveries, the adjustments of the PMV will allow increased accuracy of the building needs to ensure thermal comfort to the occupants, and underlying that, health, performance, and safety.
Several authors have performed far-reaching writing surveys or investigations of joined results from distributed works, however, these too are restricted by limited admittance to crude information from original and conflicting techniques across field studies. For that same reason, a better interpretation and complexity of the Database provided by ASHRAE represents the largest thermal comfort database, which will allow it to make it a more precise and complete study.
The different climates, the vast number of buildings, the assortment of building types, the different types of cooling strategies, and the thorough measurement of the thermal environments combine to make this ASHRAE database excellent to study the PMV.

2. Methods

The Comfort Database is used to evaluate the prediction accuracy of the original PMV model. Besides that, the study uses Köppen climate classification, a global classification system of five climate types: Tropical (group A), Arid (group B), Temperate (group C), Continental (group D), and Polar (group E), for an initial clustering to assess the PMV accuracy. The analyses focus on groups C and D. Then, within the European region, the differences between the PMV and AMV will be verified in the most represented countries. For the analyses the thermal sensation scale had to be binned in discrete scale, i.e. binned predicted mean vote (PMVbin), following the respective binning criteria: Cold < −2.5, −2.5 ≤ Cool < −1.5, −1.5 ≤ Slightly cool < −0.5, −0.5 ≤ Neutral ≤ 0.5, 0.5 < Slightly Warm ≤ 1.5, 1.5 < Warm ≤ 2.5, Hot > 2.5.
This study focuses on the overall accuracy of PMV in relation to AMV, more precisely PMVbin. After filtering the data based on the requirements mentioned, any type of data that results in NA, not available, was removed for more considerable precision of the analysis. In addition, the countries that resulted in a sample size of less than 385 were excluded from further analysis to ensure reliability. This value is calculated by the simple sample size (SS) equation 1:

$$SS \geq \left(\frac{Z \times SD}{E}\right)^2 \quad (1)$$

where, Z-score (Z) = 1.96 (95% confidence level for standard normal distribution) and the standard deviation (SD) = 0.5, the maximum estimation error (E) = 0.05. The SS result is of 384.16 which with rounding up resulted in 385. All statistical analyses were performed in IBM® SPSS® software, which offers advanced statistical analysis, a vast library of machine learning algorithms, text analysis, open-source extensibility, integration with big data, and seamless deployment into applications [9]. In this analysis, it was calculated the linear regression, the boxplot of rounded coefficients, the mean absolute error (MAE), and the precision for each thermal sensation level between the observed and predicted indices.

3. ASHRAE Database II analysis

This section presents the theoretical concepts about the ASHRAE database II, resulting from the collection of data from the existing literature, in order to frame the subject under study.
The database addressed had its origin in the ASHRAE Thermal Comfort Database I, carried out in the late 1990s [10], with the simple purpose of testing the adaptive thermal comfort hypothesis and developing a new model [11] which, in 2004, resulted in support for ASHRAE's adaptive thermal comfort for closed and naturally conditioned spaces.
This project collected high-quality instrumental measurements of indoor thermal environments and also thermal comfort assessments from 52 studies carried out in 160 buildings worldwide, mainly in commercial offices, between 1982 and 1997. The database brought together a large and rigorous amount of data available for the time in a single repository. Upon completion of the project, the research leaders made the database available to the global thermal comfort research community via the Internet.
Over time, its creation has been explored in different ways in order to understand its purpose, and it has resulted in extensive research to produce several articles, case studies, and projects about its content. In addition, ASHRAE Thermal Comfort Database I has become the solution to many issues related to thermal comfort and HVAC, heating, ventilation, and air conditioning, i.e. the basic and primary functions of HVAC systems. These projects triggered more data and therefore the database grew over time, which led to the adaptation of a new medium, ASHRAE Global Thermal Comfort Database II [12].
The ASHRAE Global Thermal Comfort Database II project was developed by the University of California and the University of Sydney, in order to provide the query of various thermal comfort data in various environments [13]. Online access was provided to more than 107,463 data regarding thermal comfort votes and other data.

3.1. Data quality validation

The fact that the database serves as a support to many research requires the information contained therein to be reliable and, for this very reason, its adherence has to go through a set of decisions in order to certify the viability of the data.
Figure 1 shows the data collection process flowchart.

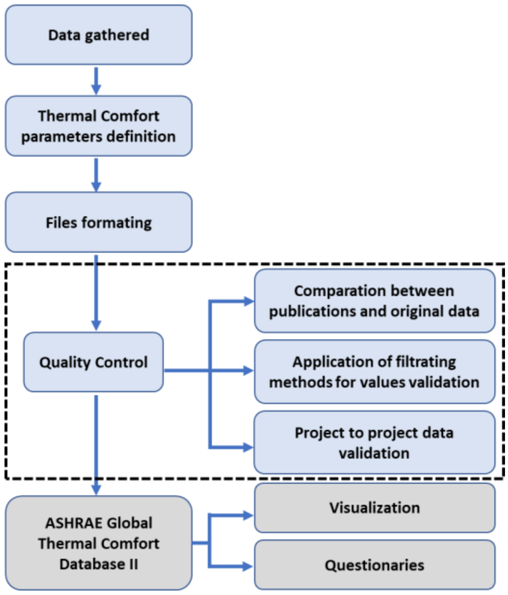


Figure 1 - Flowchart of the data collection and quality assurance processes

Firstly, data have to be obtained from a field of experience and not from a climate chamber research area. The information is collected from instrumental and subjective data, in particular in the same space and at the same time. The database has to consist of data provided by the principal investigators. All the information collected needs a code book, where the coding required for the data to be formatted in ASHRAE Global Thermal Comfort Database II is entered in detail. The study in question both has to be published in a peer-reviewed journal or conference paper.
The data then undergoes a rigorous quality assurance process. To facilitate this, the data are organized into folders based on their origin, including researcher name, country and sample size. In more detail, each folder contains the supplementary codebook and publications to provide details about the case under study, such as geographical location, building type, cooling strategy, climate and many more.
The quality assurance process initially consists of the certification of the acquired data, enabling a comparison between the existing data and that found in the publication provided by the researcher, avoiding transition errors.
Within the quality assurance process (dashed line enclosure) there is the systematic quality control, in which in a first stage the values are visualized in order to identify anomalies and in a second stage the data are transposed in a CROSS-PLOTS chart of two variables in order to check for inconsistency in the data. Finally, a few lines from each study are randomly selected with

the intention of certifying the consistency between the original dataset and the standardized database.

3.2. Database constitution

The ASHRAE research team created ASHRAE Global Thermal Comfort Database II file, through the standardized formatting of a spreadsheet, where several lines with a set of information characterized as follows:

- Basic identifiers, such as building code, geographical location, year of measurements, and heating/cooling strategy;
- Personal information about the subjects participating in the studies, such as gender, age, height, and weight;
- Subjective questionnaire on thermal comfort, such as thermal sensation, acceptability, and preference, as well as metabolic rate and level of thermal insulation of clothing;
- Instrumental measurements of indoor climate, taking into account various types of temperatures, air velocity, and relative humidity;
- Indices of thermal comfort, included average predictable vote (PMV), Predictable Percentage of Dissatisfied (PPD), and Standard Effective Temperature (SET) calculated uniformly based on ISO 7730 (2005) in the case of PMV and PPD calculation, and ASHRAE/ANSI 55 (2017) [14] standard regarding SET index;
- Control of the occupied internal environment (blinds, fan, door, heater);
- Information about outdoor metrology.

4. Subset environmental factors analysis

The analysis factors range from the type of class and subclass concerning the Köppen climate to the European countries belonging to the database.

The Köppen climate classification system organizes climate zones in general by vegetation. Wladimir Köppen, a German botanist and climatologist, first fostered this system toward the finish of the nineteenth hundred years, putting it together for prior logical biome research. These researchers discovered that vegetation and climate are complicatedly connected. The vegetation that fills in a locale is subject to the temperature and precipitation there, which are two basic elements of climate.

The system isolates the world into five climate zones given rules, typically temperature, which considers different vegetation development. Köppen's guide utilized various varieties and shades to address the different climate zones of the world, as can be seen in figure 2. The zones are as per the following:

Zone A: tropical or equatorial zone
Zone B: arid or dry zone
Zone C: warm/mild temperate zone
Zone D: continental zone
Zone E: polar zone

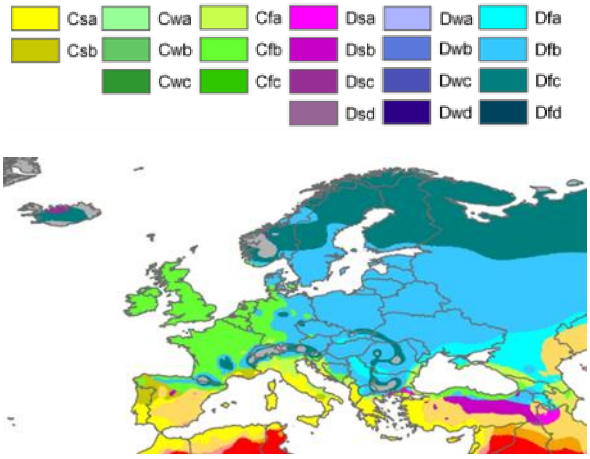


Figure 2 - Europe Köppen Map Source [15]

As it can be seen from figure 2 the type of climates predominant in Europe are C and D. These types of climates are normal along the edge of the mainland. Occasional changes aren't generally so outrageous as dry climates. On the off chance that the normal temperature of the hottest month is higher than 10 °C and the coldest month is somewhere in the range of 18° and 0 °C, then, at that point, it's viewed as a temperate climate. Also, comparable to zone D, Continental climates, are generally arranged inside of landmasses. They have no less than one month with a typical temperature beneath 0 °C. Moreover, something like one-month midpoints over 10 °C. It additionally encounters radical movements during occasional changes. Normally, mainland climates range from 40° to 75° scopes in the northern and southern halves of the globe.

Table 1 shows the European countries included in the ASHRAE database II. In the table, it is possible to visualize the number of available AMV and PMV elements in the database, and N represents the number of cases that exists correspondence between the PMV and AMV.

Table 1 - European Countries present in ASHRAE Database II

Country	N_PMV	N_AMV	N
Belgium	0	85	0
Denmark	0	168	0
France	432	480	432
Germany	206	1046	205
Greece	708	1931	708
Italy	0	1553	0
Portugal	1549	1558	1549
Slovakia	0	457	0
Sweden	939	939	939
UK	22557	25350	22482

Equation 1 previously mentioned was used to define the considerable size, so the yellow countries are the ones that are below the value initially indicated and the green ones are per the presented metrics, and they will be the ones under analysis.
Using the ASHRAE database II as support, the countries and their respective subclasses selected for this study are presented in Table 2.

Table 2 - Type of climate according to Köppen climate classification

Country	Type of Climate			
	Csa	Cfb	Csb	Dfb
France		x		
Greece	x			
Portugal	x		x	
Sweden		x		
UK	x	x		x

The predominant subclasses are Csa, Cfb, Csb, and Dfb, all of which have the coldest month averaging above 0 °C. Csa, the Hot-summer Mediterranean climate, has one month's normal temperature over 22 °C, and no less than four months averaging over 10 °C. Somewhere around threefold the amount of precipitation in the wettest month of winter as in the driest month of summer. Cfb, a Temperate oceanic climate, has in all months an average of temperatures below 22 °C, besides that there is no significant precipitation difference between seasons. In Csb, a Warm-summer Mediterranean climate, all months with average temperatures below 22 °C, and at least four months averaging above 10 °C. Regarding the precipitation, at least three times as much in the wettest month of winter as in the driest month of summer. Finally, Dfb, Warm-Summer humid continental climate, has similar characteristics as Csb besides the fact that there's no significant precipitation between seasons.
It should be noted the presence of other countries in the database, but the sample size does not have a relevant dimension or is even non-existent.

5. Results and Discussion

The main findings of the present analysis regarding the performance of the PMV model in predicting thermal sensation are shown in this section.
The analysis consisted in assessing the AMV and checking how it varied with PMV. In this case, the analysis was performed in five countries: France, Greece, Portugal, Sweden, and United Kingdom (Table 1).
In all cases, the red line represents the linear regression that was generated and then overplotted in boxplots, representing the linear association between PMV and AMV.
The linear regression model requires the analysis of the correlation coefficient between the variables, such as Pearson's correlation coefficient (R). Later, linear regression is performed to establish a linear association, the cause-effect relationship between the variables. The coefficient of determination, more commonly known as R-squared (or R^2) is a measure of the closeness of association of the points in a scatter plot to a linear regression line based on those points and can provide us with a proportional reduction in uncertainty [16]. This coefficient is an indicator of the quality of fit to a regression model, as it identifies the amount of variability in the data explained by the model when accounting for errors or deviations from the estimated line, where a value of 1.0 indicates a perfect fit while a value of 0.0 would indicate that the calculation fails to accurately model the data at all. Although a good fit has an R^2 close to 1.0, this number alone cannot determine whether the data points or predictions are biased.
Concerning the expectation precision of PMV, where is possible to see the proportion of AMV for each PMV bin scale. This representation is a viable method for evaluating PMV execution since it shows AMV dispersion for each condition that PMV predicts at each sensation. Besides that, it's possible to see the percentage of correct predictions.

5.1. Case I - France

Figure 3 plots the linear relation per category of binned PMV for every individual case. It shows the broad AMV reactions, from -3 to 3, across the full PMV scale.
The correlation coefficient (R) between AMV and PMV is 0.41, which indicates that there is a moderate linear association between the two variables. As the slope of the line is positive (when PMV increases, AMV increases), thus it can be assumed that there is a moderate positive linear association between the two variables. However, from a causal point of view, the linear regression model with PMV, as an explanatory variable, can only explain 17% of the true variation in AMV, hence the model has a low explanation capacity.
The boxplot shows the AMV for each binned PMV (PMVbin). Considering that the environment is thermally comparable according to the perspective of the PMV model, we would anticipate a close match between PMVbin and AMV.
Most AMV values were found inside the category frequently referred to as neutral, varying between cool (-1) to warm (+1). Based on median values, the PMV model was found to match AMV at the vote for neutrality (PMVbin = 0) while just misjudging on the "Warm" bin. This proposes that individuals feel neutral or slightly cool/warm in conditions that are not anticipated by PMV. It's likewise shown that balance is absent in the relation between PMVbin and AMV for both the hot and cold side, with more responses towards a hot sensation.

On the other hand, the presence of outliers also contributes to the decrease of the coefficient of determination (R^2) due to the greater distance between the outliers and the regression line.

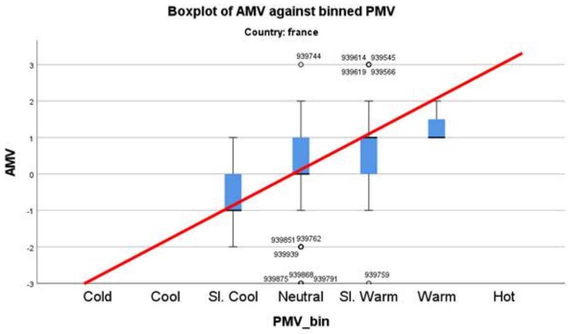


Figure 3 - AMV by binned PMV in France.

Figure 4 shows the proportion of binned thermal sensation votes by each PMVbin scale. This representation is a successful method for surveying PMV accuracy since it shows the AMV for each condition that PMV predicts a similar sensation. The level of right forecast between the AMV and PMVbin information is given along the top axis. The global expectation precision was 42.13%, calculated from the division of possible cases with the sample size. In terms of the hot side sensations, PVM tends to be more accurate for the "Sl. Warm" sensation with an accuracy of 46.5% and less for the "Warm" sensation, 33.3%. It accurately predicts thermal sensation only about two-fifths of the time, and even at neutrality, its accuracy is 39.6%. The empty sensation votes are explained by the absence of votes.

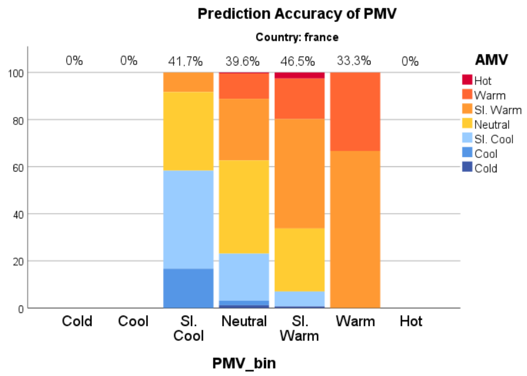


Figure 4 –Prediction Accuracy of PMV in France

5.2. Case II - Greece

In Greece's case, figure 5 a) shows with the regression line that the "Cold" sensation (-3) and "Hot" sensation (+3) for the PMV scale had a corresponding AMV value of -0.9, and +1 respectively. So, when PMV predicted "Cold" or "Hot" sensations, the average occupant felt only "Sl. cold" (-0.9) or "Sl. warm" (+1). Besides that, it has an even more poor relation between AMV and PMV than in the case of France. The correlation coefficient (R) is, approximately, 0.21, i.e. there is a weak positive linear association between the two variables. With an R^2=0.04, the PMV model was able to explain only 4% of the variance in AMV in the Comfort Database, and the model has practically no explanation capacity (hence the line has lost slope and is almost flat compared to France).

However, as can be seen in figure 5b), the relation between the AMV and PMV the total accuracy in Greece is about 40.96%, being "Neutral" and "Sl. Warm" is the most compatible and people tend to say that even when PMVbin was predicting an "Sl. cool" or "cool" condition, more than 50% of the AMV data were voting "neutral", as can be seen in yellow color column. PVM tends to be more accurate for the "Neutral" sensation with an accuracy of 46.7% and less for the "Warm" sensation, 8.3%.
On the other hand, in this case, can be seen a huge number of outliers in three different categories, "Sl. Cool", "Neutral" and "Sl. Warm", which decreases the coefficient of determination because the distance between the outlier and the line is greater.

a)

b)

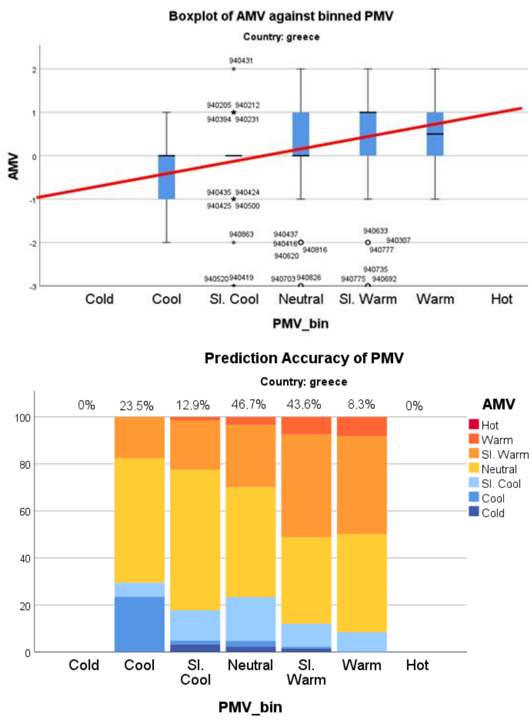


Figure 5 - a) AMV per category of binned PMV and **b)** Prediction Accuracy of PMV in Greece

5.3. Case III-Portugal

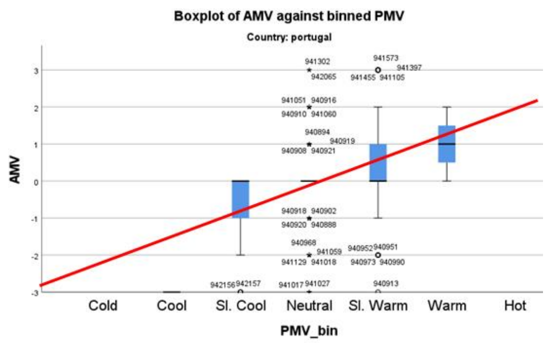
Analyzing figure 6a), in Portugal the linear relation and the boxplot of AMV per binned has a correlation coefficient (R) of approximately 0.33, i.e. there is a weak positive linear association between the two variables. With an R^2=0.11, the model has a low explanation capacity (but still, the line "gained" slope), which is better than Greece but still low.

In terms of prediction from the linear relation shows that when PMV is “cold” or “Hot”, the average occupant felt only “cool” or “warm”.

Regarding the prediction accuracy, figure 5b), Portugal has a total of 50%, showing a good accuracy in relation to other countries. Again, the thermal sensation is more accurate in the “Neutral”, being 67.4%, and people feel more neutral on the warmer side and too cold in the cool zone. The lowest accuracy is when PMVbin is cool.

On the other hand, in this case, can be seen a huge number of outliers in three different categories, Sl. Cool, Neutral and Sl. Warm, which decreases the coefficient of determination because the distance between the outlier and the line is greater.

a)



b)

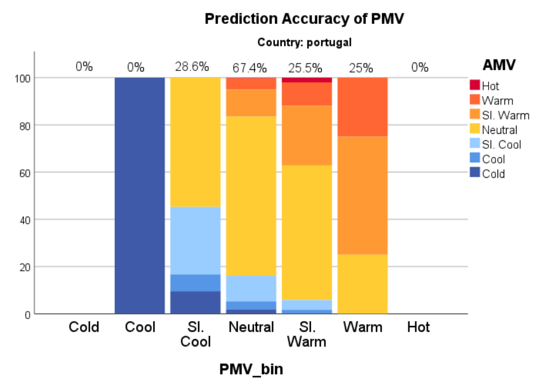


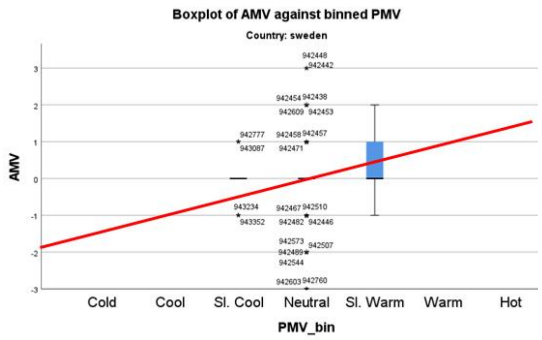
Figure 6 - a) AMV by of binned PMV and **b)** Prediction Accuracy of PMV in Portugal

5.4. Case IV - Sweden

For this situation, it can be seen in figure 7a) that the thermal sensation only had votes between “Sl. Cool” and “Sl. Warm”. The figure 7a) also shows that there is a lack of symmetry in the relation between PMVbin and AMV for both the warm side and cool sides. When PMVbin is towards Cold conditions, people more commonly voted slightly cool, while in Hot PMVbin conditions, more often voted slightly Warm but with greater dispersion. Sweden also has a very low coefficient of correlation (R), approximately 0.18. It is very weak or non-existent and probably the outliers seen in the graph are responsible for this. With an R^2=0.03, the model has a reduced or non-existent explanatory capacity.

Figure 7b) shows that the overall prediction accuracy is 66.3% which is the best of all countries in Europe, when PMVbin is neutral the accuracy in relation to AMV is 69.4% but when the PMV is “Sl. Cool” only 10.5% correspond to AMV. And more time is shown that people tend to feel “neutral” between the “Sl. Warm” and “Sl. Cool” sides.

a)



b)

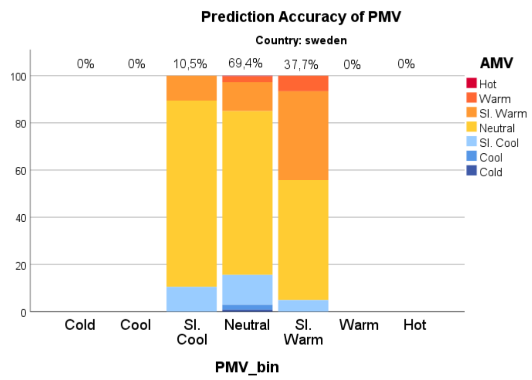


Figure 7 - a) AMV by of binned PMV and **b)** Prediction Accuracy of PMV in Sweden

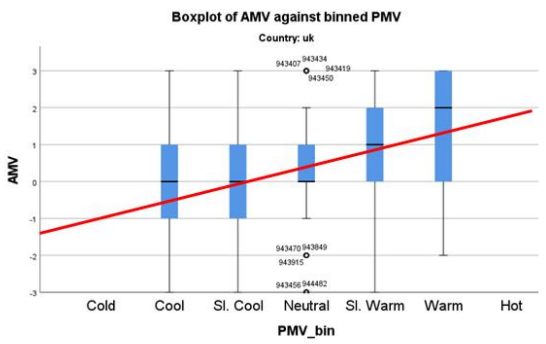
5.5. Case V - United Kingdom

In the last case (UK), figure 8a) shows a wider range of thermal sensations. In addition, the correlation coefficient is R=0.19, corresponding to a very weak or non-existent positive linear association between AMV and PMV (R^2 =0.04), meaning the PMV model was able to explain only 4% of the variance in AMV in the Comfort Database. According to the regression line, the minimum (-3) and maximum (+3) ends of the PMV scale had an AMV value corresponding to “Sl. cool” (-1) and “Warm” (+2) respectively.

Regarding figure 8a), the range of response is very large for areas outside comfort zones, larger even than in other countries. In “Neutral” response, respondents

are more consistent, with some outliers appearing for more uncomfortable votes, above +2 and below -1.
In terms of the total PMV accuracy, figure 8b), the UK presents the lowest of them all, with a value of 26.64% and people tend to feel "neutral" on the colder side. And the level with more accuracy is the "neutral". The highest accuracy is when PMVbin is the "Neutral" vote and the lowest "Cool" vote.

a)



b)

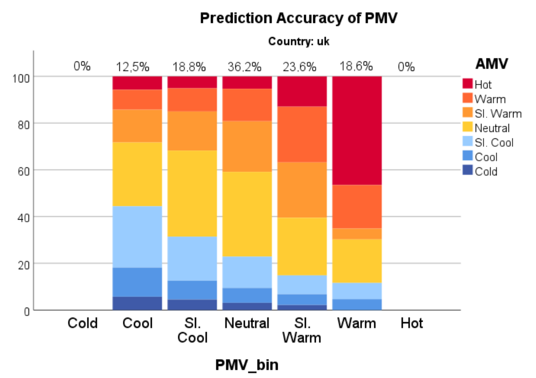


Figure 8 - a) AMV per category of binned PMV and **b)** Prediction Accuracy of PMV in the United Kingdom

Table 3 shows all the data collected from the analysis concerning the linear relation (R), coefficient of determination (R^2), slope, the value of regression when PMVbin=0 (Int.), and the absolute mean vote (MAE).

Table 3 - The data collected from the correlation coefficient, determination coefficient, line information and MAE.

Country	Relation AMV-PMV				
	R	R^2	Slope	Int.	MAE
France	0.41	0.17	0.96	0.07	0.75
Greece	0.21	0.04	0.28	0.11	0.81
Portugal	0.33	0.11	0.70	-0.11	0.66
Sweden	0.18	0.03	0.47	0.02	0.50
UK	0.19	0.04	0.45	0.38	1.17

In table 3 can be seen firstly the correlation coefficient, and in France the R-value is 0.41, corresponding to a moderate positive linear association. In Greece and in Portugal the R-value is 0.21 and 0.33, respectively, and it corresponds to a weak positive linear association. In Sweden and UK, the R-value is 0.18 and 0.19, respectively, and it corresponds to a very weak positive linear or even a non-existent association.
Through the coefficient of determination values show that the analyses are not very strong, so the linear regression has a poor significance.
The smaller the MAE value is, it means that the respondent's vote (AMV) coincides with the PMV. Therefore, looking at the table, Sweden has the smallest deviation between PMV and AMV, while the UK has the largest deviation.
In table 4, it is possible to see the PMV accuracy based on the AMV votes.

Table 4 – Accuracy of PMV according to country and thermal scale.

		Countries				
		F	**GR**	**P**	**S**	**UK**
PMV Accuracy (%)	**-3**	0	0	0	0	0
	-2	0	23.50	0	0	12.50
	-1	41.70	12.90	28.60	10.50	18.80
	0	39.60	**46.70**	**67.40**	**69.40**	**36.20**
	+1	**46.50**	43.60	25.20	37.70	23.60
	+2	33.30	8.30	25	0	18.60
	+3	0	0	0	0	0
	Total	42.13	40.96	50.00	66.13	26.64

F- France | **GR** – Greece | **P**-Portugal | **S** – Sweden|
UK - United Kingdom

The results show that in Europe, the thermal sensation scale presented only values between the "Cool" (-2) and "Warm" (+2). In terms of accuracy, the PMV tends to show more precision in the neutral sensation, the exception of France, and only has more than 50% accuracy in Portugal and Sweden.
In terms of the total precision, the same countries show higher values. In France and Greece, the accuracy is 42.3% and 40,96%, respectively. The United Kingdom presents the lowest accuracy, a value of 26.64%.

6. Conclusions

The linear correlation between PMV and AMV is very poor in Sweden and the UK, poor in Greece and Portugal, and moderate only in France. The PMV index is inconsistent in the prediction, showing a higher precision for the cases of thermal neutrality except for France.
This PMV analysis is not very deterministic, since there is a strong psychological component or even a socio-cultural influence that affects the respondent's thermal sensation. Another possible explanation is that people can effectively identify a situation of comfort, but when they are uncomfortable, this quantification varies from person to person, as can be seen by the dispersion shown in the boxplots.

The dispersion results also point to the study of Humphreys that the PMV-PPD relation may be different from Fanger findings, pointing out for a possible adjust.

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