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Assessing the ability of PMV model in predicting thermal sensation in naturally ventilated buildings in UK

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Abstract

A study was conducted to investigate the accuracy of the PMV model for predicting thermal comfort sensations in naturally ventilated residential and office buildings in the UK. Sixteen participants participated in identical thermal comfort studies at both their homes and their offices. Environmental variables affecting thermal comfort were recorded while the participants voted their thermal sensation in both locations. The comparison of reported thermal sensation and those predicted using ISO 7730 showed that in general PMV under predicts the thermal sensation of occupants in both environments. The neutral temperatures found in homes and offices were 23.4ºC and 23.2ºC which were respectively 3ºC and 2.5ºC lower than those predicted using ISO 7730. Together with 0.2ºC difference found between reported neutral temperatures at homes and offices, this suggests that there could be a context influence affecting occupants' thermal sensations in home and office environments.

Keywords: Thermal comfort, PMV, Thermal sensation, Context effect

1. Introduction

The predicted mean vote (PMV) equation proposed by Fanger in 1970 has been used in international standards to predict thermal sensation of the occupants since the 1980s (Parsons, 1993). It has been presented in international standards such as ISO 7730 and is widely used by designers to assess moderate indoor thermal environments (Humphreys and Nicol, 2002). The PMV equation uses four environmental parameters; air temperature (°C), mean radiant temperature (MRT) (°C), air velocity (m/s) and relative humidity (RH) (%) and two personal variables; clothing insulation (Clo) and metabolic rate (Met), as the inputs and predicts thermal sensation of occupants on the ASHRAE thermal sensation scale as showed in Figure 1:

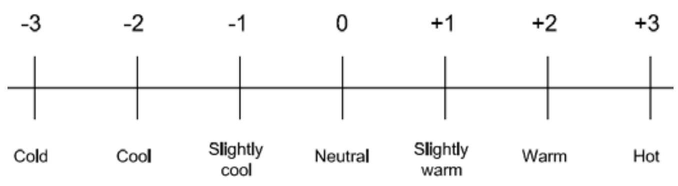

Figure 1: ASHRAE 7 points thermal sensation scale

Fanger's PMV model is based on theoretical analysis of human heat exchange by steady state laboratory experiments in Northern Europe and America (Humphreys and Nicol, 2002). Since the development of the PMV equation, many field studies have been conducted worldwide to investigate its validity in changeable, inconsistent environments of "real buildings" with "real occupants". The PMV model has been validated by the majority of these studies as an accurate predictor in air-conditioned buildings with HVAC systems in different climatic conditions (Fanger, 2002). However, in the case of naturally ventilated (NV) or non air-conditioned buildings, differences have been observed between the thermal sensation reported by the occupants and the predicted thermal comfort derived from the PMV model. Humphrey (1976) and Auliciems (1981) reviewed 30 and 53 field studies respectively and both concluded that PMV generally under estimates thermal sensation and therefore over estimates the actual neutral temperature. Neutral temperature is defined as the temperature at which the person feels thermally neutral. Various other field studies in different climates and environments by Schiller (1990), Kahkonen (1991), Croome et al. (1992), Han et al. (2007) and Hong et al. (2009) also observed the underestimation of thermal sensation by PMV model.

Moreover, several studies have compared the reported neutral temperatures in different environments. Hun and Gidman (1982) found a considerably low operative temperature of 15.8ºC in a national survey in UK houses. Operative temperature is defined as a uniform temperature of a radiantly black enclosure in which an occupant would exchange the same amount of heat by radiation plus convection as in the actual non uniform environment (ASHRAE, 2004). A Study by Pimbert and Fishman (1978) showed neutral temperatures in UK houses up to 2ºC lower compared to UK offices and Cena et al (1990) also found a much lower neutral temperatures in houses (21.1ºC) than offices (23.8ºC) (Brager and de Dear, 1998). However, all these studies were based on different people living and working in different geographical locations.

The majority of researchers have assigned these differences between reported and predicted thermal sensation of occupants to two main factors: a) errors in measurements; and b) contextual effects. Error in measurement refers to inaccuracies in the six input variables required for calculating PMV, especially in calculating the average clothing insulation (clo) values and metabolic rate (met). Clothing insulation tables obtained from laboratory studies and provided in international standards such as ISO9920 (2010) are often used to estimate the clothing insulation value of the occupants. Brager and de Dear (1998) stated that depending on the particular sources of the tables, the calculated clothing insulation value (clo) can differ as much as 20%. Charles (2003) also suggests that the extra insulation of 0.15 to 0.3 from the respondent's chair should be added to the total clothing insulation value, a factor not accounted for in earlier field studies (Charles, 2003). Estimating occupants' metabolic rate is also considered as a significant contributor to the discrepancies between PMV and the actual thermal sensation. Brager and de Dear (1998) state that the standard method of deriving metabolic rates using standard tables is perhaps one of the least developed methods of thermal comfort research. Contextual factors are defined as the non-physical parameters involved in perception of thermal comfort in different environments such as climatic settings, social conditioning and economic considerations (Brager and de Dear, 1998). Researcher such as Oseland (1995) stated that the PMV model is based on studying people in "artificial environments of climate chambers, out of context with their usual environmental settings". Therefore, in order to investigate whether a true context effect exists in explaining the observed discrepancies between the PMV and actual thermal sensation, a more in depth study is needed. This study, therefore, investigates thermal sensation of the same people in the two environments of homes and offices. Occupants were asked to do same level of activities in both environments when steady state conditions have been established in order to keep inaccuracies of estimating metabolic rates low.

2. Methodology

Thermal comfort of the occupants in homes and offices were studied by means of a quantitative survey along with simultaneous measurements of air temperature, humidity, air velocity and MRT in both environments.

2.1 Participants in the study

Sixteen participants were recruited for this study. All participants worked in an open plan office located in the School of Civil and Building Engineering at Loughborough University (UK) and lived in naturally ventilated houses. The participants consisted of six females and ten males and had diverse ethnic origins and nationalities. The majority of participants were in the age range of 22 to 34 as eleven participants fell into this group while there were four subjects in the age range of 35 to 44 and one in the age range of 55 to 64. In order to comply with the requirements of the Loughborough University's ethics committee, the participants were not paid to participate in this experiment. All 16 participants were provided with an information sheet explaining the purposes of the study and consent to participate was obtained using the Universities' standard consent form.

2.2 Experimental Design

The field study was carried out between 10th and 30th July 2011. Each subject took part in two experimental sessions; one at his/her house's living room and one at the office. The experimental design for both environments was the same. Subjective measurements (in form of a thermal comfort questionnaire) and objective measurements were recorded during each session. The sessions lasted for 2 hours, during which the participant was asked to sit down in the office or in living room in their house and do sedentary work or relax. In order to control the metabolic rate, the participants were asked to feel free to do sedentary activities such as reading, chatting but were not allowed to stand up, walk, play computer games, watch television or eat and drink. Figure 2 briefly indicates the experimental design of each 2 hours session.

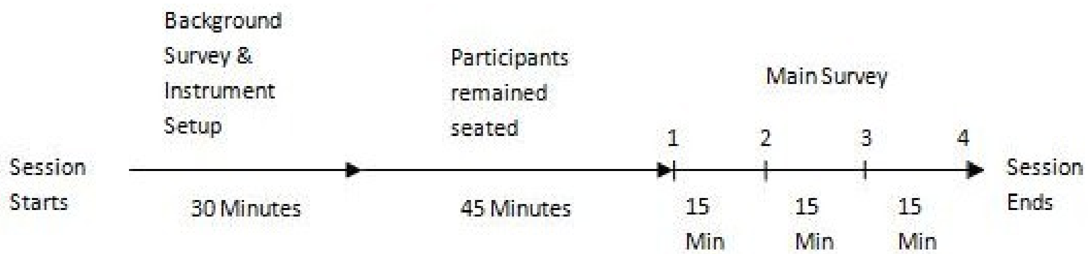

Figure 2: Experimental design during each session

The first 30 minutes of the session was used to set up the measuring equipment, providing the participant information sheets, describing the study to the subjects and the completion of a background survey by the participants. The background survey consisted of questions about the participants' sex, age group, ethnicity, health and time of completing the survey as well as their location within their environment such as next to a window/door or in a chair or sofa. After the first 30 minutes, the participants were asked to remain seated with the same activity level for another 45 minutes in order to reach steady state conditions. The main survey started in the last 45 minutes of each 2 hour session after the participants had been seated for 75 minutes. During the main survey each participant completed a thermal comfort survey every 15 minutes. Therefore 4 sets of survey responses were obtained from each participant (corresponding to times 0, 15, 30 and 45 minutes of the main survey). For 16 subjects, this procedure resulted in a total of 128 survey responses, i.e. 64 survey responses per environment. An alarm clock was used during the sessions in houses to notify the participants to complete the questionnaires, while during the office sessions, a simple program was set up on the participants' computers to pop up a reminder on the screen every 15 minutes to complete the survey.

2.3 Subjective measurements

The questionnaire was developed based on ISO 10551 (2001), adopted from a questionnaire that had been previously produced and tested by Loughborough University. The questionnaire was developed to gauge how participants feel towards their thermal environment in addition to obtain participants' metabolic rate (met) and clothing insulation value (clo).

The metabolic rate of the subjects required in PMV equation based on their activity level they had at the time of completing the survey and metabolic rate values given in Table B.1 in ISO7730 (2005) were obtained from the participants through the questionnaires. In many previous field studies the metabolic rate of the participants in homes and offices simply assumed around 1.2 met to 1.4 met, though the method used in this field study could be more accurate as it estimates the metabolic rate of the participants individually, based on their activity level rather than simply assume that all have the same activity level.

In addition, the participants were asked to rate their thermal sensation on ASHRAE seven point scale presented in Figure 1. This was to gather the quantified thermal sensation of the occupants (from -3 to +3) which is known as Actual Mean Vote (AMV). The participants were instructed to feel free to mark anywhere on the scale and not restrict themselves to the whole numbers. This is the value that Fangers' PMV equation is trying to predict. Therefore in order to investigate the validity of PMV model in each environment, the values obtained were compared to the PMV based on objective measurements explained in section 2.4.

Moreover, the total personal clothing insulation value was calculated by each subject using a list, which is a simplified version of that provided by Table C2, ISO 7730:2005. Both males and females had separate individual clothing lists to make the process of finding individual clothes easier. The clothing lists consisted of typical UK climate clothes and were tested in previous field studies before using in this survey. Participants were asked to calculate their own total thermal insulation of clothing by adding the corresponding insulation values of the clothes they wore at the time of completing the survey. Table 1 shows a part of clothing insulation checklist for men. Full clothing lists used in this study is given in appendix A.

Table 1: Part of clothing insulation checklist for males

Type of Clothing	No sleeve	¼ sleeve	Full sleeve
T-shirt/top	0.1	0.1	0.16
Vest	0.12	-	-
Shirt	-	0.23	0.27
Pyjamas	-	0.42	0.525

In order to include the thermal insulation of the chair or sofa on which the participants were seated, 0.1 clo was added to the total clothing insulation values reported by the participants. In addition, for female subjects, a further 0.4clo was added to include clothing insulation provided by their underwear clothes. This was done because it was considered inappropriate/unethical to ask questions regarding underwear to female participants and therefore clothing insulation values of underwear were not provided in the checklist.

2.4 Objective measurements

A multi-functional measuring instrument, the Testo 400, was used to measure MRT, RH, air velocity (V) and air temperature (T). Measurements were recorded during the main survey. In addition, similar to many field studies such as Han et al (2006) the operative temperature was calculated as the average of MRT and air temperature.

The instrument consisted of a 3 function probe for simultaneous measurement of temperature, humidity and air velocity, a 150 mm globe thermometer to measure radiant heat, a logger for displaying, saving or printing the measuring data and a controller to programme the recording intervals. All probes and logger were arranged in a case making them easily portable but tamper proof. Technical information of the equipment including measuring ranges and accuracies of the probes and globe thermometer are given in Table 2.

Table 2: Measuring equipment technical data

Parameter	Measuring Range	Accuracy
Mean Radiant Temperature (MRT)	0 to +120 ºC	± 0.5ºC (0 to +49.9ºC) ± 1ºC (+50 to +120ºC)
Relative Humidity (RH)	0 to 100%	± 2%
Air Velocity (V)	0 to 10 m/s	± 0.03 m/s
Air Temperature (T)	-20 to +70 ºC	± 0.4ºC (0 to +50ºC) ± 0.5ºC (remaining range)

The accuracies correspond to ISO 7243, ISO 7726, DIN EN27726 and DIN 33403 requirements. All measurements were taken at abdominal level for the seated participants (at a height of 60 cm and distance of 30 cm away from the participants) at 15 minutes intervals.

2.5 PMV Calculation

The measured environmental variables including MRT, RH, air velocity, air temperature along with the estimated metabolic rate and clothing insulation were used to compute the PMV using a spreadsheet based on the algorithm provided in ISO 7730.

3. Results and Discussion

3.1 Summary of indoor measurement results and survey responses at Homes and Offices

Table 3 shows the mean, minimum and maximum values of the indoor environmental variables measured at 16 homes and 16 offices during the field study and the mean clothing insulation values and metabolic rates of the subjects estimated at each environment. In addition, this table shows the mean calculated operative temperature and mean PMV of the occupants in 16 homes and offices. The mean reported thermal sensation of occupants (AMV) in each environment is also included to be compared to mean calculated PMV of that environment.

It should be noted that all the mean, minimum and maximum values presented for each environment in this table are based on 64 measurements and survey responses (4 measurements and survey responses per each of 16 homes or offices).

Table 3: Statistical Summaries of indoor measurements and survey responses at 16 Homes and Offices

Mean conditions and thermal votes in Homes (n=16) and Offices (n=16)				
Parameter	**Unit**	**Mean Value (Min to Max) at Homes**	**Mean Value (Min to Max) at Office**	**Difference between Homes and Offices**
MRT [1]	ºC	22.17 (18.56 to 26.1)	23.65 (21.9 to 25.7)	1.48
RH [1]	%	54.31 (37.9 to 72.8)	40.7 (32.75 to 50.4)	13.61
Air Velocity [1]	m/s	0.007 (0 to 0.1)	0.041 (0 to 0.2)	0.034
Air Temperature [1]	ºC	22.5 (19.09 to 26.3)	23.9 (21.6 to 26)	1.4
Clothing [2]	Clo	0.58 (0.28 to 0.97)	0.71 (0.44 to 1.02)	0.13
Metabolic Rate [3]	Met	1.02 (0.8 to 1.2)	1.09 (0.8 to 1.2)	0.07
Operative Temperature [4]	ºC	22.35 (18.85 to 26.2)	23.78 (21.75 to 25.85)	1.43
PMV [5]	-	-1.15 (-2.7 to 0.5)	-0.25 (-1.6 to 0.5)	0.9
AMV [6]	-	-0.31 (-3 to 1)	0.08 (-1 to 1.5)	0.39

[1] *Environmental variables measured by multi functional measuring instrument*
[2] *Values calculated by participants using clothing insulation lists*
[3] *Values estimated using Table B.1 ISO 7730, 2005 based on subjects' activity level*
[4] *Operative temperature was calculated as: Operative temperature = (MRT + Air Temperature) / 2*
[5] *PMV was calculated using spreadsheet*
[6] *AMV is the quantitative thermal sensation stated by occupants in questionnaires*

Table 3 illustrates significant differences between environments of participants' homes and office. The mean values of MRT (22.17ºC) and air temperature (22.5ºC) in homes are respectively 1.48ºC and 1.4ºC lower than values measured at offices (23.65ºC and 23.9º C respectively). As a result calculated mean operative temperature in homes is 1.43ºC lower than in offices.

According to this data, living rooms in houses were predicted to be rated cooler than the offices, as it can be seen in the mean AMVs in Table 3 recorded by the participants in two environments; mean AMV for the occupants in homes is - 0.31 while in offices it is 0.08. Predicted mean votes also follow the same trend with a mean PMV of -1.14 in homes compared to -0.25 in offices. Previous studies by Cena et al as stated in Oseland (1995) also found lower mean temperatures of 21.1ºC in homes compared with 23.8ºC in offices. Mean relative humidity of 54.3% in homes is much higher compared to 40.7% in offices. Mean air velocities in both environments are negligible by 0.007 m/s and 0.04 m/s in homes and offices respectively. However it shows higher air velocities in average at offices than homes.

Although the mean indoor temperature in homes was found lower than in offices by 1.4ºC and occupants voted their thermal sensation cooler at homes than offices, occupants' mean clothing insulation level in homes are still lower than in offices. It means that people like to wear lighter clothes at homes than at offices even though they feel cooler than neutral. Furthermore, the mean metabolic rate in homes and offices were not found exactly the same and as it was expected, the participants at the office have slightly higher activity level and therefore the mean metabolic rate of the occupants in offices are higher than in houses by a 0.07 Met. In addition, this table shows that the mean AMV is significantly different from mean PMV in both environments (mean AMV= - 0.31 & mean PMV= -1.14 in homes and mean AMV= 0.08 & mean PMV= - 0.24 in offices). This difference confirms that the Fangers' PMV model cannot be very accurate in predicting occupants' thermal sensation in naturally ventilated homes and offices. However, the validity of PMV model has been investigated in section 4.2. Figure 3 plotted the mean air temperature measured every 15 minutes during the survey in homes and offices.

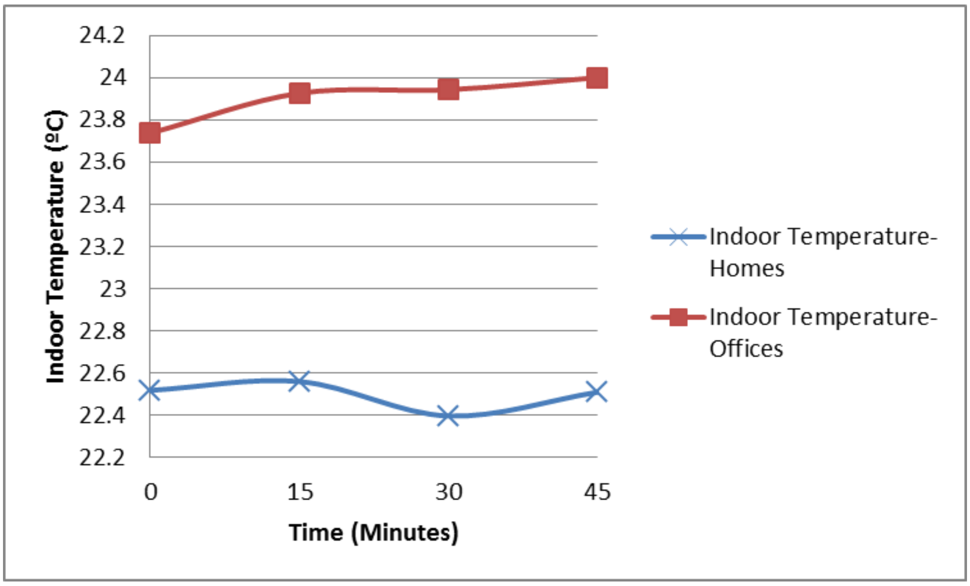

Figure 3: Mean Indoor air temperature measured at Homes and Offices during the main survey

This figure indicates that the variations of air temperature in both environments during the 45 minutes of main survey were lower than 0.25 ºC.

Figure 4 shows the mean AMV rated by the participants every 15 minutes during the main survey in homes and offices. Similar to previous studies such as Fanger (1970) and Oseland (1995), the overall AMV in both environments is rated cooler with the time. AMV decreases from 0.1 to - 0.04 in offices and from - 0.03 to - 0.45 in homes.

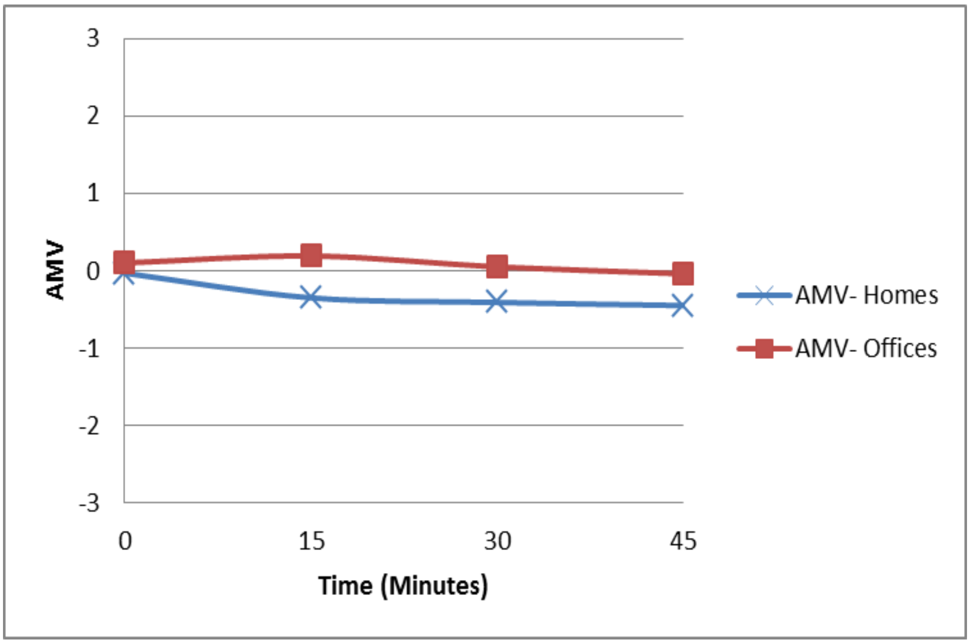

Figure 4: Mean AMV reported at Homes and Offices during the main survey

As the air temperature in both environments does not show a decreasing trend similar to what observed in mean AMVs in Figure 4, a slight reduction in AMVs can be explained by the drop in metabolic rates of the subjects as they had been seated for 2 hours.

3.2 Investigating Validity of PMV model

Figure 5 and 6 indicate the calculated PMV and reported AMV for each participant in this field study at their homes and offices respectively.

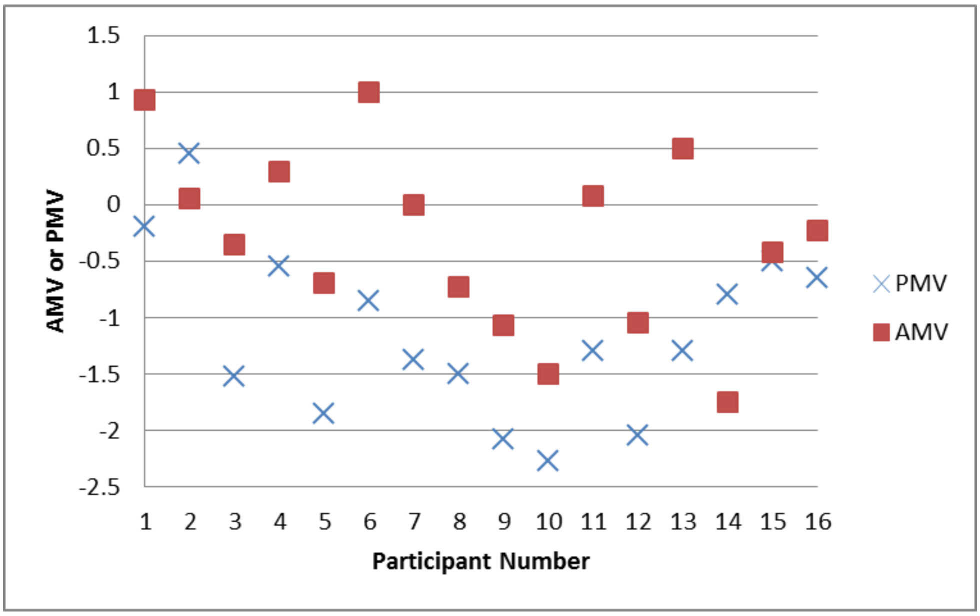

Figure 5: Mean PMV calculated and AMV reported at each house

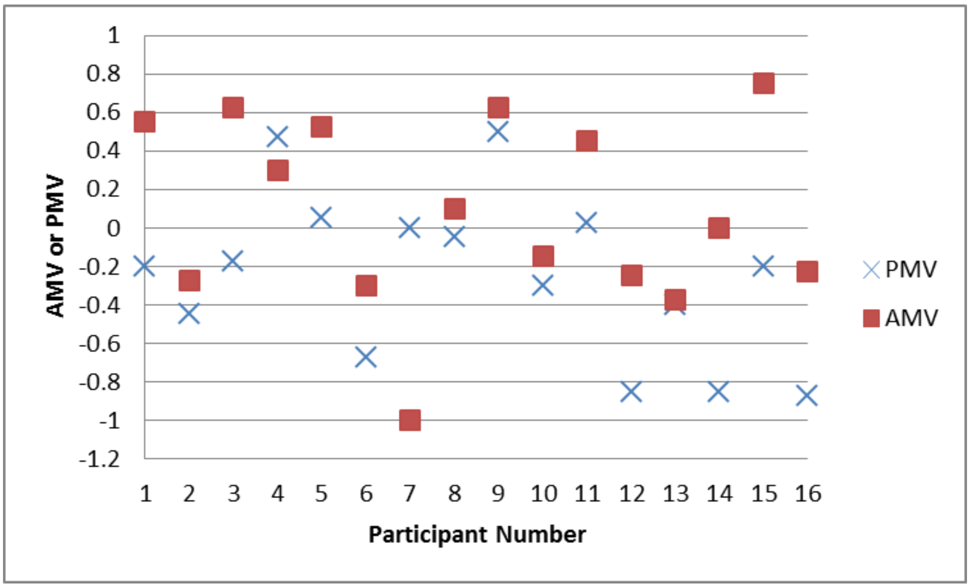

Figure 6: Mean PMV calculated and AMV reported at each office

The PMVs and AMVs used to plot these diagrams are the mean values of 4 PMVs calculated for each subject per environment and 4 AMVs reported by occupants each 15 minutes in each environment. As it can be seen in these two figures, in both environments the Fangers' PMV model under predicts the thermal sensation reported by occupants (AMV).

Figure 7 plots AMV versus PMV for both office and home environments and their regression lines.

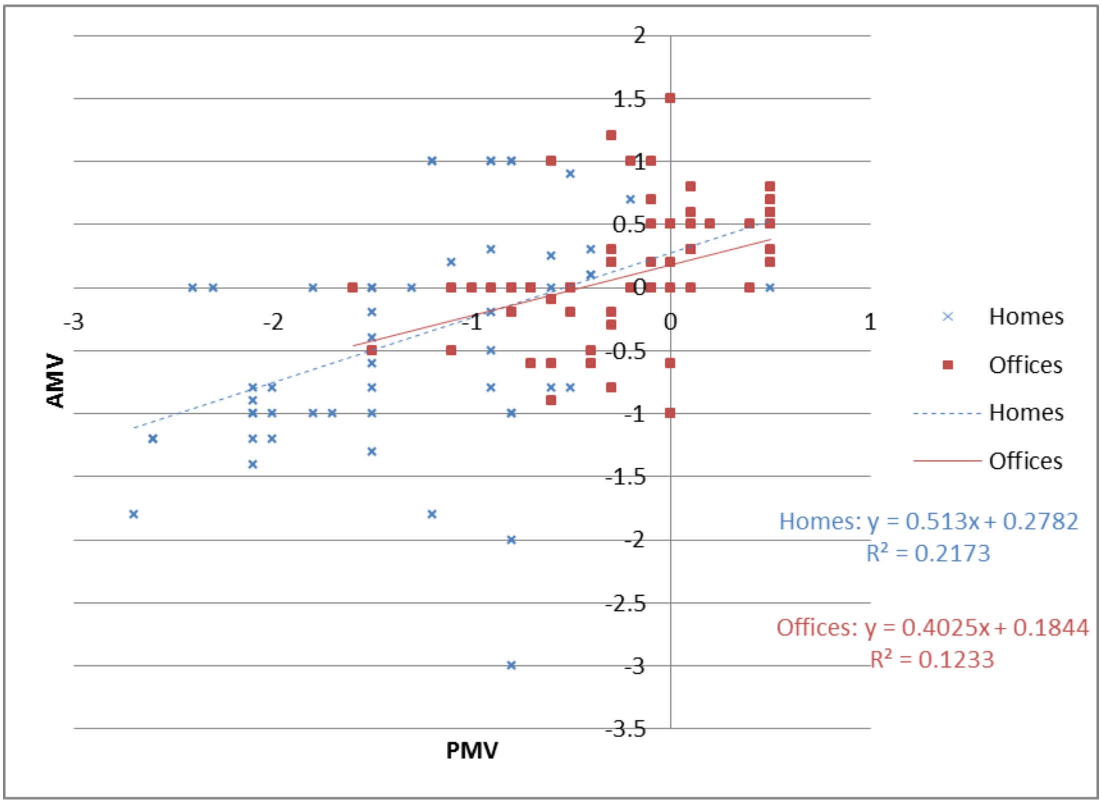

Figure 7: AMV versus PMV in homes and offices and their regression lines

The first observation is that the gradient of each line is lower than unity. This gradient would be equal to unity if PMV was very accurate at predicting thermal sensation of occupants. The gradient of the regression line for homes is 0.513 and for offices is 0.4025. A correlation coefficient of 0.47 and 0.35 (significant at $p<0.01$) between AMV and PMV at homes and offices respectively, which were calculated using IBM SPSS programme show that PMV can only partially predict thermal sensation in naturally ventilated offices and homes. Furthermore, the regression line for both environments show that the PMV equation under predicts the thermal sensation in homes and offices. Discrepancies observed could mean that there are factors involved in thermal comfort of occupants in naturally ventilated buildings which have not been considered in the formulation of PMV by Fanger.

PMV computed according to Fanger's model have been plotted versus operative temperature in homes and offices by Figure 8 and 9 respectively. Operative temperature was calculated as the mean value of MRT and air temperature. These figures reflect the differences between PMV and AMV in neutral temperatures.

As it can be seen in Figure 8 the linear regression equations that best fit the survey data at homes are:

$$AMV = 0.2893\ T_O - 6.7738, \qquad R^2 = 0.3902 \quad (1)$$

$$PMV = 0.2801\ T_O - 7.406, \qquad R^2 = 0.4431 \quad (2)$$

Where T_O is the operative temperature.

The neutrality value for homes is estimated by solving Equation (1) for AMV equal to zero denoting a comfortable thermal environment. The reported neutral operative temperature at homes found to be 23.4ºC. Similarly, the predicted neutral operative temperature by PMV model was found by solving Equation (2) for PMV equal to zero. The predicted neutral operative temperature at homes by PMV model is 26.4ºC which is 3ºC higher than the reported neutral operative temperature found at homes. In addition, as it can be seen in Figure 9 the linear regression equations that best fit the survey data at offices are:

$$AMV = 0.1587\ T_O - 3.6883, \quad R^2 = 0.0662 \quad (3)$$

$$PMV = 0.1249\ T_O - 3.2196, \qquad R^2 = 0.0539 \quad (4)$$

Where again T_O is the operative temperature.

The neutrality value is calculated by solving Equation (3) for AMV equal to zero and the reported neutral operative temperature at offices found equal to be 23.2ºC. Similarly, the predicted neutral operative temperature by PMV model is found by solving Equation (4) for PMV equal to zero. The predicted neutral operative temperature at offices by PMV model was 25.7ºC which is 2.5ºC higher than the actual neutral operative temperature found at offices.

As it was found, the PMV predicted a higher neutral temperature compared to the actual thermal sensation of occupants (AMV) in both environments of homes and offices.

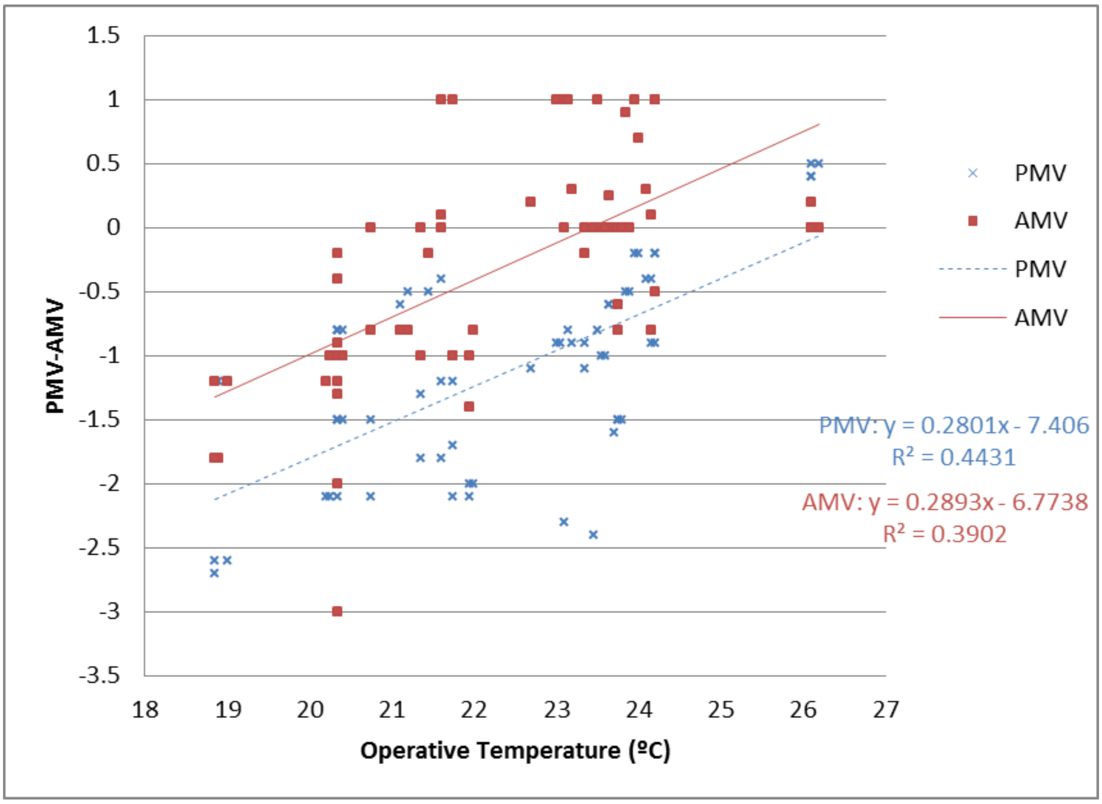

Figure 8: PMV and AMV by operative temperature (T_O) in homes

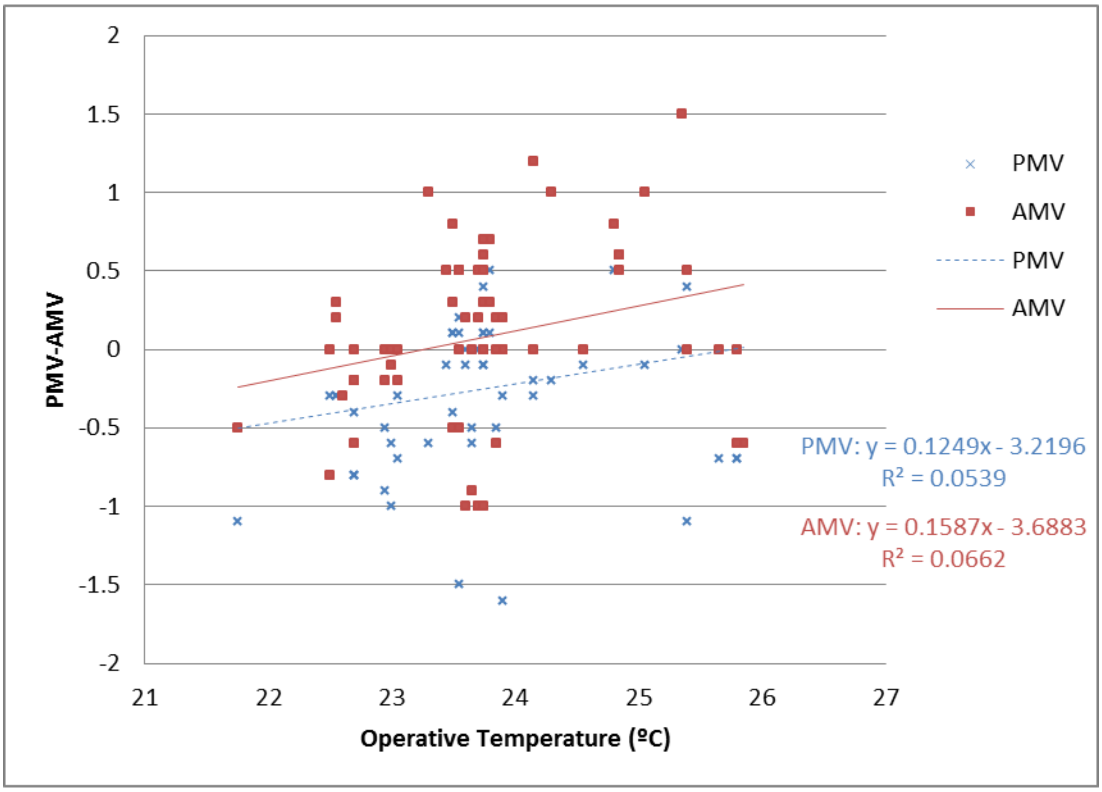

Figure 9: PMV and AMV by operative temperature (T_O) in offices

Table 4 shows the actual and predicted neutral temperatures at homes and offices.

Table 4: Comparison of predicted and actual neutral temperature at homes and offices

Environment	Actual neutral temperature (ºC)	Predicted neutral temperature (ºC)
Homes	23.4	26.4
Offices	23.2	25.7

This result is in agreement with number of studies carried out by Schiller (1990) and Croome et al. (1992) in a number of offices and Oseland (1995) in owner occupied homes which both have found that the PMV generally estimated the thermal sensation lower than the actual thermal sensation in both homes and offices and therefore over predicted the neutral operative temperatures. The 2.5ºC difference between predicted and actual neutral operative temperatures found by this study is in close agreement with the difference of 2.4ºC observed in studies by schiller (1990) and Croome et al at (1992) in offices. However, the difference between predicted and actual neutral operative temperatures in homes was found to be 3ºC lower than the 5.4ºC found by Oseland (1995).

Moreover, independent of the relationship between AMV and PMV, analysis above showed that there is a difference of 0.2 ºC between the neutral temperatures found from reported thermal sensations (calculated from Equations 1 and 3) of the same people in different environments of homes and offices. Even if the estimation of metabolic rate and clothing insulation were inaccurate, it can prove that there is a true context effect on thermal sensation explaining the difference between the reported neutral temperatures found in different environments. However, the difference found in this study (0.2 ºC) is small, and further larger scale studies are needed to confirm the findings in this study.

Furthermore, the majority of more recent studies such as Humphrey (1976), Auliciems (1981), Schiller (1990), Kahkonen (1991), Croome et al (1992), Han et al (2007) and Hong et al (2009) that were carried out in different geographic locations, climatic conditions and types of buildings show that PMV index under predicts the actual thermal comfort conditions and consequently predicts higher neutral temperatures. This study confirms those findings to be true in UK's summer climate and in naturally ventilated houses and offices.

4. Conclusions

Analysis of data collected and findings from a study of thermal comfort in homes and office have been reported in this paper. The study was mainly aimed to investigate the accuracy of PMV model in predicting thermal sensation of the occupants in naturally ventilated houses and offices and to determine whether or not a true context effect exists in explaining the differences between thermal sensations of the occupants in different environments.

The study has shown that the Fanger's PMV model in not accurate enough in predicting people's thermal sensation in naturally ventilated homes and offices in the

UK during the summer and in both homes and offices and the PMV model under predicts the actual thermal comfort conditions and consequently predicts higher neutral temperatures. The neutral temperatures found in homes and offices were 23.4ºC and 23.2ºC which were respectively 3ºC and 2.5ºC lower than those predicted using ISO 7730 (26.4ºC for homes and 25.7ºC for offices). In addition, it shows that differences do exist between people's thermal sensation at homes and in their office since 0.2ºC difference found between reported neutral temperatures at homes and offices. Further work during the winter period in UK is necessary to support this conclusion.

Appendix A: Clothing insulation checklist used in this study

A.1 Men's clothing list

Clothing Insulation Level for Male

******Please retain this with you for your calculation. Calculate a total figure for the clothes that you are wearing and write it down in the Thermal Comfort Questionnaire given to you. After the completion of this study, please destroy this calculation sheet and DO NOT submit this to us or anybody ******

Type of Clothing	Typical insulation levels of clothing					Insulation level of your clothing
	No Sleeve	¼ sleeve	Full sleeve			
T-shirt/top	0.1		0.16			
Vest	0.12					
Shirt		0.23	0.27			
Waistcoat	0.11					
Pyjamas		0.42	0.525			
Jacket	Thin	Medium	Thick			
	0.25	0.35	0.69			
Jumper	0.2	0.28	0.35			
Coat	0.6					
Rain coat	0.31					
Cap	0.01					
Gloves	0.08					
Suit jacket	0.425					
	Short (above knee)	Medium (Below knee)	Long (near Ankle)			
Trousers/jeans			0.206			
Suit trousers	0.206					
Leggings	0.06	0.08	0.117			
Shorts	0.08	0.11				
Thermal under trousers			0.15			
Highly insulated trousers			0.34			
	Thin	Thick				
Ankle socks	0.02	0.05				
Medium socks	0.03	0.03				
Long socks	0.03	0.1				
Singlet	0.04					
Boxers	0.04					
Shoes	0.05					
Trainers	0.02					
Flip flops	0.02					
Boots	0.1					
TOTAL figure for insulation level of the clothes that you are wearing						

A.2 Female's clothing list

Clothing Insulation Level for Female

Type of Clothing	Typical insulation levels of clothing					Insulation level of your clothing
	Sleeveless	¼ sleeve	¾ sleeve	Full sleeve		
T-shirt/top		0.1		0.16		
Vest	0.12					
Shirt		0.23		0.27		
Waistcoat		0.11				
Tube top		0.06				
Blouse			0.27	0.33		
Scoop neck	0.16					
Dress	0.25	0.29		0.4		
Pyjamas		0.14		0.525		
Nightgown	0.14					
	Thin	Medium	Thick			
Jacket	0.25	0.35	0.69			
Suit jacket	0.425					
Jumper	0.2	0.28	0.35			
Coat	0.6					
Rain coat	0.31					
Cap	0.01					
Gloves	0.08					
	Short (above knee)	Medium (Below knee)	Long (near Ankle)			
Trousers/jeans			0.206			
Suit trousers			0.206			
Leggings	0.06	0.08	0.117			
Shorts	0.08	0.11				
Thermal under trousers			0.15			
Highly insulated trousers			0.34			
Skirt	0.1	Thin 0.14, Thick 0.17	Thin 0.23, Thick 0.28			
Tights			0.02			
	Thin	Thick				
Ankle socks	0.02	0.05				
Medium socks	0.03	0.03				
Long socks	0.03	0.1				
Shoes	0.05					
Trainers	0.02					
Flip flops/high heels	0.02					
Boots	0.1					
TOTAL figure for insulation level of the clothes that you are wearing						

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