

Adaptive models and experimental data: a comparison between surveys' results in offices.

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SUMMARY

The adaptive models could be an useful tool to verify people satisfaction about microclimatic conditions and the results could be applied to other similar situations. An open question is to check the real agreement between instrumental data and subjective answers obtained by questionnaires. The aim of the present paper is to find a relationship between experimental and subjective data, with experimental surveys in moderate environments such as eight offices at the University of Perugia. The selected environments are different for exposure, architectural features, HVAC systems, in room terminals, number of people inside. Indoor measurement sessions are correlated to external conditions, representative of spring season, in two different years. Data from questionnaires are often not in agreement with the instrumental ones: people tend to accentuate the discomfort sensations, both in cold and hot conditions.

KEYWORDS

Thermal comfort, Adaptive models, Workplaces comfort conditions.

INTRODUCTION

Since Fanger's studies of the Seventies, the microclimatic conditions in workplaces were strongly pursued, especially in moderate spaces. Only in the Nineties, thermal comfort studies had a new pragmatic impulse, given by the adaptive models. Many studies in Literature show how dissatisfaction about thermal comfort can cause health problems and decreasing workers' productivity; other studies regarding the conditions offered to people who spend a lot of their working-time sitting on a chair had been carried out. Moreover, the HVAC systems and regulations have to take into account the external conditions, particularly during spring or autumn, when the variation are frequent and people's dress way is various. The aim of this study is to investigate the thermal conditions in some offices, by correlating instrumental surveys and questionnaires answers results. They show that the HVAC systems don't offer to the occupants satisfactory comfort conditions; furthermore, there is a not very good relationship between instrumental data and personal sensation.

METHODS

The indoor measurement sessions were carried out during two spring seasons in March, April and May 2008 and April 2009. The selected rooms were eight offices at the Engineering Faculty of the University of Perugia: Table 1 shows the main features of the offices and the essential survey's data. Each surveys is linked to external conditions.

Two multi channel systems linked to different probes (in compliance with ISO 7726 standard) were used to get the instrumental data set, which were post-processed to obtain the classical comfort indexes PMV and PPD. Two measurement points were chosen into each room considering workers positions (just next to oneself desk), cold or warm vertical and horizontal

surfaces position (i.e. windows or skylights). Each measurement session lasted 10 minutes, with an acquisition rate of twenty seconds; the procedure was repeated twice in each day. While the instruments were recording, people inside the rooms were invited to answer the questionnaires, elaborated in compliance with standard UNI EN ISO 10551. The questionnaires have three sections: personal data (age and sex), thermal aspects (activity carried out in the last minutes, clothing, thermal sensation etc.), individual microclimatic control (interaction possibility on the environmental microclimatic conditions by means of opening and closing doors or windows, HVAC regulations, etc.). During the post processing it was possible to obtain the comfort indexes and preferences by the answers and to calculate the instrumental data output by a software using the I_{cl} values given directly by people. The total number of questionnaires was 66.

Table 1. Offices main features

Office	1	2	3	4	5	6	7	8
External façade orientation	west	south	west	east	east	east	west	west
Floor area (m ²)	33	40	35	35	35	35	30	30
Surveys number	4	8	8	8	8	8	8	8
Questionnaires number	9	11	6	9	9	8	7	7

RESULTS

Hypothesis and post processing

In order to obtain PMV and PPD indexes from both instrumental and questionnaires surveys, an hypothesis about metabolism value was made: all people did a sedentary activity in the previous last hour, so the activity level was supposed equal to 77.5 W/m^2 (1.33 met); no distinction was made between female and male subjects.

A mean value among the two measurement positions for all the classic indoor parameters was calculated: thus a single number could represent the whole indoor microclimatic conditions in the office. The two data sets are divided into the 2008 and the 2009 experimental campaigns. An example is shown in Table 2.

Table 2. Outdoor and indoor mean dry bulb temperatures

Office	1	2	3	4	5	6	7	8
T out, m (2008) (°C)	29,58	29,58	19,55	19,55	22,70	24,77	24,77	26,89
T out, m (2009) (°C)	17,51	17,51	21,98	20,21	20,72	17,17	21,49	17,51
T in, m (2008) (°C)	26,60	26,76	23,85	24,55	21,64	23,20	22,73	24,15
T in, m (2009) (°C)	24,52	23,71	26,57	25,22	25,81	23,01	26,56	25,00

Experimental results

Figure 1a shows PMV instrumental values vs. PMV questionnaires data; the bisector line (PMV instrumental equal to PMV questionnaires) was also sketched. A selection was made in the questionnaires answers, removing the ones strongly uncorrelated: then the mean values were calculated, shared by office. A linear correlation was found, with a not very good fitting ($R^2 = 0.37$). The graph is divided into three zones, generated by the intersection of the trend line both with the bisector line and with the x-axis. The questionnaires data overestimated the discomfort obtained with the instrumental data left from the PMV value of -0.49 on x-axis; in the area defined by the intersection of x-axis and the intersection with the bisector line, the questionnaires data underestimated the comfort sensation; finally the questionnaires data overestimated again the discomfort sensation in the right zone of the graph, starting from the intersection between the trend line and the bisector (PMV = 0.23).

A second relationship between instrumental PPD and questionnaires PPD was found (Figure 1b). It is possible to note that there is a large spread of the experimental data around the trend line ($R^2 = 0.22$). This is due to the marked difference between the two data sets: in fact, people had at their disposal only discrete values of votes (0, ± 1 , ± 2 , ± 3) and when they voted +2, +3 or -2, -3 in the questionnaires, the equation reported in the UNI EN ISO 7730 offers values far from the instrumental ones, even if the thermal sensation was not far from comfort.

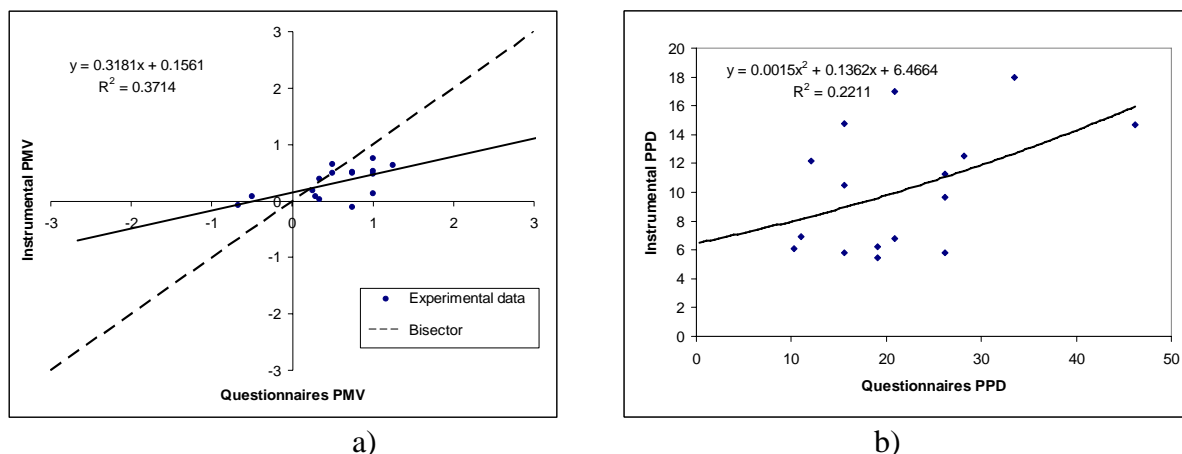


Figure 1. a) Instrumental PMV and Questionnaires PMV with trend line, b) Instrumental PPD and Questionnaires PPD with trend line.

The questionnaires in which the subjects voted $PMV = 0$ were also extrapolated and the corresponding indoor temperature was considered as Comfort Temperature. The indoor Comfort Temperature was correlated to the outdoor temperature (Nicol and Humphreys, 2002), where a linear relationship was proposed (Figure 2a). A different correlation was found for the experimental data, due to HVAC systems that were on during the surveys; the relationship between the two parameters it is in fact referred to free running buildings, while in heated or cooled ones it is more complex and instable; in this case the Indoor Comfort Temperature seems to be decreasing with the outdoor temperature. A further attempt was made to find a relationship between Indoor Comfort Temperature and clothing thermal insulation I_{cl} (Figure 2b): also in this case, it was impossible to obtain a significant relationship, mainly because of the subjects dressing behaviour in spring season. I_{cl} falls in a range between 0.5 and 1 clo, attesting a high variability in a transitional season.

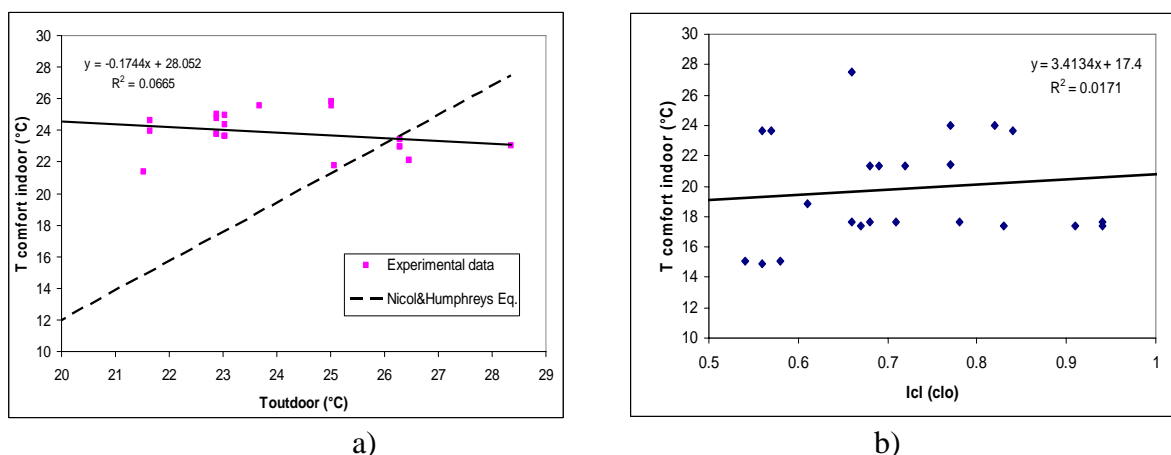


Figure 2. a) Indoor Comfort Temperature vs. Outdoor Temperature in the experimental campaign and in Nicol and Humphreys, b) Indoor Comfort Temperature vs. clothing thermal insulation.

DISCUSSION

The present experimental campaign gives a further confirmation that the adaptive approach takes into account more the personal sensations of the thermal comfort rather than instrumental ones. In fact, during the surveys carried on in the offices of Engineering Faculty of Perugia, the comparison between instrumental results and questionnaires data gives strong differences, showing that instrumental PMV and questionnaires PMV are not very correlated during a transitional season like spring; it is mainly due to the fact that people give discrete values of the votes, while the instrumental data are in a continuous range. Furthermore, in general, people tend to accentuate the discomfort sensations. PPD values follow the same uncorrelated trend. Other considerations could be done about the Indoor Comfort Temperature, which is not correlated to the Outdoor Temperature; it confirms surveys results of Nicol and Humphreys who demonstrated that when HVAC systems are switched on a complex and not clear relation could be found between data. Moreover, the range of clothing thermal insulation offers a wide dressing behaviour, that cannot find a solid relationship with the indoor comfort temperature.

A source of error that may affect the results could be found in the lack of surveys during the free running building period. Another uncertainty is due to the small number of questionnaires, that could enlarge the sample even if the offices studied in the present work represent a significant sample of the whole building subdivision.

CONCLUSIONS

Usually measurement sessions, aiming to verify how HVAC systems works are essentially only based on standard probes results. Often this procedures leads to a not real and complete analysis of the comfort conditions of workers, especially during transitory seasons like spring. A more complete investigation could be provide by taking into account the subjective impression of the regular users of the spaces, in order to better check and regulate the HVAC systems: In addition the subjective analysis could be quite simple to carry out in spaces where there's not a sudden change in the workplaces layout such as offices. For example, the examination could be obtained by a simple check list, repeated in each season and based on the most common question of the adaptive approach questionnaires. The strong possibility to control the microclimatic conditions could allow also building energy savings.

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