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Thermal comfort criteria and building design: Field work in Portugal

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ABSTRACT

The present paper focuses on the issue of thermal comfort adaptive criteria and its relevance to the implementation of passive design strategies, in the context of a field work carried out in Portugal. This field work involved monitoring and questionnaires in office buildings existing in Lisbon, as well as other types of buildings, such as homes for the elderly and educational buildings, during summer, winter and mid-season.

1. Introduction

In Europe, the use of air conditioning has been steadily raising during the past decades, not only in services buildings, but also in other building types, such as the residential sector. The existing conventional comfort standards, that are largely responsible for the use of air conditioning (AC), are based on complex equations resultant from laboratory research. By the very nature of the laboratory derivation of these conventional standards, adaptive processes found in the real world have been limited or eliminated. Alternative comfort criteria have been proposed by various researchers [1,2], developing models based on the so-called adaptive theory of thermal comfort.

Nowadays, adaptive models are beginning to be incorporated in international thermal comfort standards such as ASHRAE 55 [3] or EN 15251 [4].

The implementation of this alternative comfort criterion is dependent upon contextual factors specific to each region. There is still a need to verify in the field the adequacy of the proposed models [1,2], and particularly further investigate the role of human adaptation and the changing patterns in the use of AC, in the achievement of thermal comfort. Although very important studies have been carried out throughout Europe with this objective, namely the PASCOOL survey [5] and the SCATs Project [2], research is still required to further explore the complex process of thermal comfort.

2. The field studies: objectives and methodology

So far there is a limited number of research studies available in this area in Portugal [6], and only concerning office buildings. Therefore an ongoing research study[1] began to be carried out at the National Laboratory of Civil Engineering (LNEC), in the sequence of the results achieved in a previous research.[2] The objective is to adapt or develop an adaptive approach oriented to the definition of indoor thermal comfort requirements applicable to Portuguese buildings. These will consider climate, social and cultural habits, and adequate constructive solutions. Behavioural aspects are being given a major attention in this study and will deserve a detailed environmental psychology approach.

Besides office buildings, educational buildings and homes for the elderly are also included. Geographical location has also been considered in order to take into account different Portuguese summer and winter climatic zones.

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[1] Included in the research project *Development of sustainable thermal and visual comfort models* funded by the Portuguese Foundation for Science and Technology (FCT) PTDC/ECM/71914/2006.

[2] This field work was part of a Ph.D. research developed between 1996 and 2000, at the Martin Centre for Architectural and Urban Studies, Faculty of Architecture, University of Cambridge, under the Supervision of Dr. Nick Baker [6]. The research, involving monitoring in 26 office buildings during the two consecutive summers of 1996 and 1997, aimed at assessing the relationships between the workers' adaptive behaviour and their comfort votes in each building type. This adaptive behaviour concerned both physical adaptation, i.e. the adaptive actions that the workers reported to carry out to make themselves more comfortable, and psychological adaptation processes, such as the workers' perceived freedom to control the thermal environment.

Table 1
Subjective scales used in the questionnaire.

Thermal sensation (*TSi*)		Thermal preference (*TPi*)	
−3	Cold	−3	Much cooler
−2	Cool	−2	Cooler
−1	Slightly cool	−1	Slightly cooler
0	Neither cool nor warm	0	Like it is
+1	Slightly warm	+1	Slightly warmer
+2	Warm	+2	Warmer
+3	Hot	+3	Much warmer

The field survey involves the measurement of indoor environment parameters, namely air temperature (T_a), operative temperature (T_{op}), air speed (v_a) and relative humidity (RH), during summer, but also including winter and mid-season.

Simultaneously, occupants have been requested to complete a questionnaire specifically developed for this research project [7].

Questionnaires aimed at assessing the influence of the several factors on human thermal sensation. In that sense, subjective opinion scales were defined [6–8] which allow the respondents to vote on their sensations (neutrality, preference, satisfaction level) regarding the surrounding thermal environment. Table 1 presents subjective scales used in the questionnaire, respectively, thermal sensation evaluation, *TSi*, and thermal preference, *TPi*, concerning the thermal environment.

3. Summary of results

During the first field campaign (summer of 2006, July–September) seven office buildings and sixteen homes for the elderly were surveyed in different cities in Portugal (Guimarães, Coimbra, Leiria, Lisbon and Faro). Educational buildings were not included because there were no summer classes going on.

During the winter campaign (November 2006 to February 2007) new surveys were performed in the same buildings and, in addition, six University buildings were also included.

Table 2 presents relevant personal characteristics, namely age, estimated metabolic rate (M) and clothing insulation (I_{cl}) of the sample subjects inquired during the two campaigns in the three types of surveyed buildings.

Table 3 reports the total sample of performed surveys and completed questionnaires during summer and winter field campaigns. The distribution of the naturally ventilated (NV) and air-conditioned (AC) spaces was similar in terms of areas.

Table 4 indicates the percentage of heating and cooling systems switched on during the thermal surveys performed in each season campaign, considering separately those rooms where the air temperature was below or above the reference thermal comfort conditions specified in the Portuguese building thermal regulation (summer: 25 °C; winter: 20 °C).

Table 2
Summary of personal parameters.

Building type	Gender	*N* (%)	Age (years)	Activity *M*, (met)	Clothing insulation, I_{cl} (clo)	
					Summer	Winter
Elderly home	F	75	82		0.59	1.3
	M	25	77		0.60	1.3
	Total	100	81	1.0	0.59	1.3
Office	F	69	41		0.56	1.0
	M	31	37		0.63	1.0
	Total	100	40	1.3	0.59	1.0
Educational	F	28	22		–	1.1
	M	72	23		–	1.0
	Total	100	23	1.2	–	1.1

Table 3
Sample building and field surveys distribution.

Building type	Surveys		Questionnaires	
	Summer	*Winter*	*Summer*	*Winter*
Elderly home (16)	34	29	242	278
Office (7)	52	52	192	252
Educational (6)	–	18	–	480
Total	*185*		*1444*	

The analysis of the contents of Table 4 points out the following aspects:

1. The system was switched on during the surveys, whilst in homes for the elderly, 50% of rooms were mechanically cooled but only when the temperature was above the maximum limit specified for the summer season (25 °C).
2. During the winter period a high percentage (about 80%) of office rooms were heated no matter what the indoor temperature was (on NV mode). For the other building types (homes for the elderly and universities) more than 50% of the rooms were heated when the indoor temperatures were lower than the minimum reference value (20 °C). When the indoor temperature was above 20 °C, the percentage of use of the heating system was low (30%).
3. Another interesting feature in winter results was that about 15% of office buildings were cooled even when the indoor temperature was lower than 20 °C.

Relying on the information that the subjects of homes for the elderly can switch on the cooling system if they wish, the different pattern of use of the cooling system in homes for the elderly, during summer surveys, seems to indicate that their occupants are more tolerant than the respondents in offices buildings.

In the office buildings, during the two season campaigns, there was a significant use of heating and cooling systems, independently of the indoor conditions (on NV mode). This fact allows to assume that there is unnecessary energy consumption, as found in a previous field study [6].

3.1. Thermal sensation (TSi) vs. thermal preference (TPi)

Tables 4 and 5 present the relationships between individual thermal *sensation* (*TSi*) and thermal *preference* (*TPi*) votes, according to subjective scales defined in Table 1, for the summer (Table 5) and winter campaigns (Table 6).

In both seasons when $TSi = 0$ ("*neither cool nor warm*"), the occupants main preference (summer: 79%; winter: 76%) is to keep the thermal environment "*like it is*" ($TPi = 0$). Nevertheless 20% of

Table 4
Heating and cooling systems use.

Building type	Cooling system (%)		Heating system (%)	
	$T_a \leq 25$ °C	$T_a > 25$ °C	$T_a < 20$ °C	$T_a \geq 20$ °C
Summer				
Elderly home	0	50	–	0
Office	85	82	–	0
Winter				
Elderly home	0	–	69	30
Office	14	–	78	85
Educational	0	–	50	30