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Thermal comfort of patients in hospital ward areas

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SUMMARY

The patient is identified as being of prime importance for comfort standards in hospital ward areas, other ward users being expected to adjust their dress to suit the conditions necessary for patient comfort. A study to identify the optimum steady state conditions for patient comfort is then described.

Although this study raises some doubts as to the applicability of the standard thermal comfort assessment techniques to ward areas, it is felt that its results give a good indication of the steady-state conditions preferred by the patients. These were an air temperature of between 21·5° and 22° C and a relative humidity of between 30 % and 70 %, where the air velocity was less than 0·1 m/s and the mean radiant temperature was close to air temperature.

INTRODUCTION

Over the years an extensive amount of work, generally concentrating on steady-state conditions, has been carried out on thermal comfort. We have been unable, however, to locate any previous studies on thermal comfort in hospital wards.

Legg (1971) has suggested that there are four categories of ward user to be considered. First there are the patients in the ward, who may be in bed or ambulant but will generally be involved in a minimum of activity. Secondly, there are the nursing and medical staff who may be either working hard physically, as when making beds, or carrying out tasks involving little physical exertion such as medical inspections or clerical work. Thirdly, there are the domestic staff of the ward, who do a lot of hard physical work. Finally, there are visitors and staff from other hospital departments who are only in the ward for short periods.

Owing to their different activity levels and clothing habits, the thermal comfort requirements of these different groups of users will differ and some form of compromise has to be struck so that the majority will be satisfied. On inspection the clothing habits of hospital patients are found to be rigid enough to form a 'uniform', comprising pyjamas or night-gown when in bed, and pyjamas or night-gown with a heavy traditional dressing-gown or house-coat when ambulant. As the patients are the reason for the existence of the ward, it is reasonable that the thermal conditions be such as to maximize their comfort in this 'uniform', and that the other users of the ward be expected to adjust the weight of their own clothing so that they are comfortable.

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It should be possible, once the population clothing and activity factors have been determined, to estimate the conditions for optimum thermal comfort in any given situation from the results of previous studies (e.g. Fanger, 1970). Owing to the peculiarities of the hospital ward environment, it was however felt necessary to conduct a separate survey to determine the conditions preferred by hospital patients.

THE SURVEY

The experimental ward

The survey was carried out at the B.S.R.U. Experimental Ward Unit at Hairmyres Hospital, East Kilbride. This is a modern, 'racetrack' design, air-conditioned general surgery ward, with accommodation for 46 patients, half of which is normally devoted to male and half to female patients. The ward unit has been described in detail elsewhere (B.S.R.U. Technical Report No. 5, 1968; Legg, 1970).

The ward unit is served by four separate air-conditioning plants which deal with the intensive care, treatment room, central core and corridor, and main ward areas respectively. As testing was carried out in the main ward area only, the treatment room, central core and corridor, and intensive care areas were all maintained at 21° C. and 55% r.h. throughout the tests.

The air supply temperature of the main ward air-conditioning plant was altered, normally every 2 days, to produce the required test conditions. The relative humidity in the main ward area proved to be particularly difficult to control, and as a result was usually allowed to vary randomly.

Measuring equipment and techniques

The dry-bulb air temperature was measured using mercury-in-glass thermometers. Three thermometers were mounted on a stand at nominal heights from the floor of 160, 80 and 10 cm, hereafter referred to as 'head', 'bed' and 'floor' height, respectively. This stand was placed as close as possible to a patient being interviewed, and the temperature at each height recorded immediately after the interview.

Standard 6 in diameter black globes, with mercury-in-glass thermometers, were used for measuring globe temperature. Each globe was mounted on a stand at interviewee head height and as close as possible to the interviewee. Its temperature was recorded as soon after the interview as the globe's stabilization time allowed.

The wet-bulb temperature in each room was measured with an Assman aspirated hygrometer, normally just after the interviews in that room had been completed.

The thermometers used for all of these measurements were correct to $\pm 0{\cdot}1^\circ$ C.

Air velocities in the rooms were measured using a 'Tinsley' hot-wire anemometer and specially constructed associated circuitry. Readings were not taken at each interview, but use was made of a recent survey of air velocities in the rooms. In this survey, five readings were taken at 2 min intervals at the top and bottom of each bed in rotation round the rooms and then the entire process was repeated, giving a total of 20 readings for each bed. These values were averaged and used as the air velocity both for that bed and for the patient positions immediately adjacent to it.

Interviewing methods

The interviewing methods used for the study have been described elsewhere (Rae & Smith, 1976). The basis of each interview was a questionnaire concerning the temperature, humidity and odour aspects of the environment in the ward.

The questions included in the questionnaire which are of interest here are those in which the patient was asked to rate his or her perception of the environment on the seven point 'ASHRAE' thermal comfort scale of cold (1), cool (2), slightly cool (3), comfortable (4), slightly warm (5), warm (6), and hot (7), and on a three-point humidity perception scale of too dry (1), just right for moisture content (2), and too moist (3). Patients were shown the alternatives for each scale printed vertically on a 10 cm × 14 cm card. Some attempt was made to circumvent order effects by using on alternate interviews a second set of cards, on which the order of the terms of the scale was reversed.

At the end of each interview the value of each of the relevant physical environmental variables was noted in a special section attached to the questionnaire.

In passing, it is interesting to record that the fact that all the thermometers used in the study read in ° C considerably simplified the interviewers' task of concealing their own feelings, as in general this scale had no meaning for the patients.

RESULTS AND ANALYSIS

The patient sample

A total of 615 interviews were completed on 209 different patients. Of these interviews, 200 were carried out on male patients, whose ages ranged from 12 to 78 years, and 415 on female patients whose ages ranged from 10 to 79 years. The disparity between the number of male and female interviews was due to the generally larger number of women in the ward at any time, and the fact that female patients were more frequently available for interview, because male patients were more frequently absent from the ward for specialized tests, and there appeared to be a higher proportion of them who were so seriously ill that they could not be disturbed.

Test conditions

Throughout the tests the air change rate and proportion of recirculated air were varied in accordance with the demands of concurrent work on odours. The low level of odour complaints found in this work (Rae & Smith 1976) indicates that it is unlikely that these changes had any effect on the tests.

A summary of the conditions encountered during the survey is given in Table 1. The 'average dry-bulb temperature' was computed for each interview as the mean of the three measured dry-bulb temperatures, and the figures in the table are therefore the minimum, mean and maximum of this computed quantity. Similarly

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Table 1. *Summary of test conditions*

Variable and units	Minimum	Mean	Maximum	Standard deviation
Dry-bulb temp., floor (°C)	18·0	21·6	25·9	1·0
Dry-bulb temp., bed (°C)	18·6	22·0	25·5	1·0
Dry-bulb temp., head (°C)	19·2	22·3	26·5	1·1
Average dry-bulb temp., (°C)	18·8	22·0	25·2	1·0
Wet-bulb temp., (°C)	11·5	17·6	21·3	2·0
Vapour Pressure (mB.)	6·85	17·34	23·52	3·53
Globe temp., (°C)	20·0	22·4	27·5	1·1
Mean radiant temp., (°C)	19·2	22·7	29·6	1·3
Air velocity (m/s)	0·035	0·056	0·079	0·008

Table 2. *Intercorrelation matrix for the environmental variables*

	Dry-bulb, floor	Dry-bulb, bed	Dry-bulb head	Av. dry bulb	Wet bulb	Vap. pressure	Globe	MRT	Air velocity
Dry-bulb, floor	1·00								
Dry-bulb, bed	0·83	1·00							
Dry-bulb head	0·67	0·90	1·00						
Av. dry-bulb	0·89	0·98	0·92	1·00					
Wet bulb	0·56	0·36	0·18	0·39	1·00				
Vap. pressure	0·43	0·22	0·04	0·24	0·99	1·00			
Globe	0·73	0·87	0·84	0·87	0·27	0·14	1·00		
MRT	0·60	0·75	0·74	0·75	0·20	0·08	0·98	1·00	
Air velocity	*	−0·02	−0·02	−0·02	0·05	0·05	*	0·02	1·00

* Asterisks in this table denote values of less than 0·01.

the mean radiant temperature for each interview was computed from the relevant values of dry-bulb temperature at the head, globe temperature and air velocity.

The intercorrelation matrix for the variables summarized in Table 1 is given in Table 2. It can be seen from this table that the measured and computed dry-bulb temperatures, the globe temperature, and the mean radiant temperature were all closely related and from this it can be deduced that the environment at any one interviewing point in the ward was fairly uniform, and that little or no thermal asymmetry was encountered during the tests.

Temperature considerations

As a preliminary the thermal comfort data were examined using a Multiple Linear Regression Analysis to identify which variables had affected the patients' comfort votes. This analysis is a stepwise linear regression based on the method of Draper & Smith (1966). The variables which were included in the regression are given in Table 3.

The analysis was carried out three times, once for the complete set of 615 interviews, once for the 200 male interviews, and once for the 415 female interviews, in each case with the patients' votes on the ASHRAE comfort scale of cold (1), cool

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Table 3. *Independent variables in multiple linear regression*

Age of interviewee (years)
Duration of this stay in hospital (days)
Answer to sleep question
Answer to central heating question
Time of day of interview (hours)
Activity at time of interview
Dry-bulb temperature at floor height
Dry-bulb temperature at bed height
Dry-bulb temperature at head height
Wet bulb temperature
Globe temperature
Weather at time of interview
Air velocity
Square root of air velocity
Vapour pressure
Average dry-bulb temperature
Mean radiant temperature

Table 4. *Summary of multiple linear regression analysis dependent variable = comfort vote*

Variables	Data	Total	Male	Female
Dry-bulb temp., head	Coef.	0·37	—	0·49
	%*	8·8	—	11·9
Dry-bulb temp., bed.	Coef.	—	0·18	—
	%*	—	3	—
Activity	Coef.	−0·01	—	−0·15
	%*	0·6	—	1·0
Weather	Coef.	—	—	0·16
	%*	—	—	0·8
Constant		−3·75	0·05	−6·27
Overall P level		<0·001	<0·025	<0·01

* Percentage of variance in data explained by regression on this variable.

(2), slightly cool (3), comfortable (4), slightly warm (5), warm (6) and hot (7) as the dependent variable. A summary of the results is shown in Table 4.

The three different sets of data yielded slightly differing results. For the total data and the female data the variables which affected the patients' comfort votes were the dry-bulb temperature at the head (DB head), the patient's activity, and, for the female patients, the outside weather conditions. The coding systems used to record the patient's activity and the outside weather conditions are given in Table 5, and owing to the extremely low dependence of the patient comfort vote on them they can be dismissed from further consideration. (For example, based on the derived regression equation, if the ward temperature is set to the optimum for a female ward population who are all 'in bed, resting', and this population changes to all 'ambulant' the increase in uncomfortable patients would be only 1 %.)

For the male data the dry-bulb temperature at the bed (DB bed) was the only variable significantly correlated with comfort vote, and this relationship was at a disappointingly low level of explanation.

Table 5. *Patient activity and outside weather conditions coding system*

Patient activity	Outside weather conditions
Awake resting – 1	Sunny – 0
Sitting up in bed –2	Overcast – 1
Sitting out of bed – 3	Raining – 2
Ambulant – 4	Stormy –3
	Snowy – 4

Table 6. *Breakdown of comfort votes cast*

Temp. cond. mid point (°C.)	Comfort vote 1	2	3	4	5	6	7	Total votes cast	Mean vote
20·5	2	0	7	11	1	0	0	21	3·43
21·0	4	6	7	25	9	6	0	57	3·82
21·5	3	5	11	63	8	1	2	93	3·85
22·0	1	4	8	88	19	12	4	136	4·26
22·5	3	7	9	84	18	12	6	139	4·20
23·0	1	2	3	31	8	9	1	55	4·35
23·5	0	2	1	18	7	4	2	34	4·47
24·0	0	2	1	13	7	4	2	29	4·55
24·5	0	2	0	12	4	6	4	28	4·86
Total	14	30	47	345	81	54	21	592	4·17

Fanger (1970) has produced convincing evidence for the equivalence, when similarly clothed, of male and female comfort reactions to thermal conditions, and there is no reason to suspect that the insulation value of the men's clothing was significantly different from that of the women's. Therefore although it appears that the men somehow reacted differently from the women to the experimental situation there is no reason to believe that this indicates a real difference in thermal preference.

In view of this and the high correlation (0·90) between DB bed and DB head it was decided to adopt the latter as the thermal environment index, and consider only the total data. All further analysis of the data has therefore been carried out with DB head as the independent variable, the ASHRAE comfort scale as the dependent variable, and the male and female data grouped together as one set.

Although the multiple regression analysis described above is a good indicator of which variables influenced the patients comfort vote, it will tend, owing to the fact that the bulk of the data was collected towards the middle of the temperature range tested, to underestimate the effects of these variables towards the extremes of this range.

To overcome this difficulty the data were broken down into half-degree temperature bands, and the result of this for the votes on the ASHRAE comfort scale and DB head are shown in Table 6. In this table temperature bands in which fewer than twenty votes were cast have been disregarded.

The data for this table were grouped in two ways. In the first of these groupings

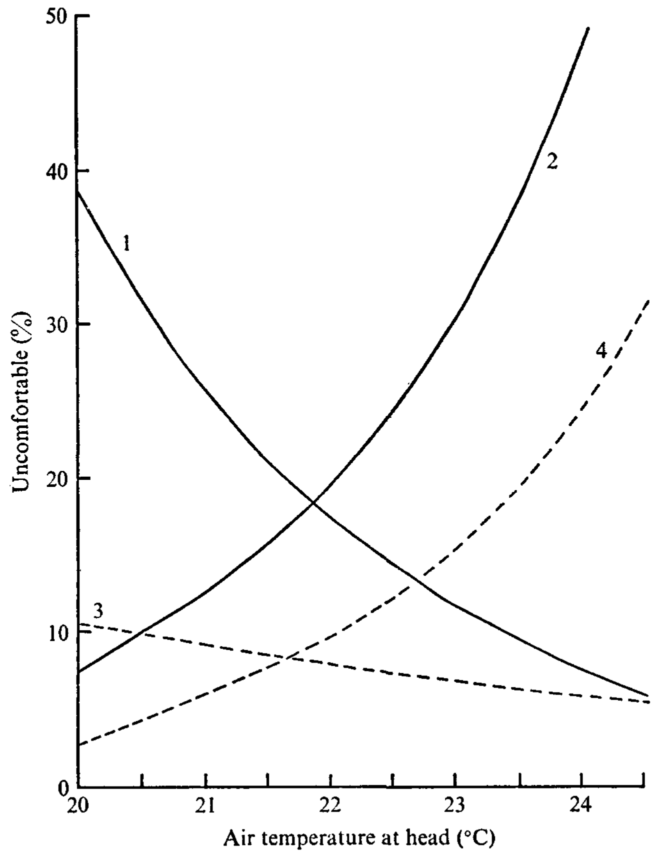

Fig. 1. Percentage of patients voting too hot or too cold at various air temperatures. Curve 1: percentage voting cold, cool, slightly cool. Curve 2: percentage voting slightly warm, warm, hot. Curve 3: percentage voting cold, cool. Curve 4: percentage voting warm, hot.

the normal system of considering votes of 1 and 2 as 'too cold', votes of 3, 4 and 5 as 'comfortable', and votes of 6 and 7 as 'too hot' was used. Secondly, the data were grouped using the more stringent criterion of considering votes of 1, 2 and 3, as 'too cold', votes of 4 as 'comfortable' and votes 5, 6 and 7 as 'too hot'. The percentages of patients voting 'too cold' and 'too hot' in each of these groupings were then graphed against their respective temperatures, and exponentials fitted to the resulting curves using the Honeywell Time-sharing Mark 1 system curve fitting programme 'CURFT'.

The curves are shown in Fig. 1, and from this graph the effect of DB head on the percentage of patients voting 'too cold' or 'too hot' on either criterion can be easily determined.

Humidity considerations

As could be expected from the literature of studies in other environments (Nevins, Rohles, Springer & Feyerherm, 1966; Grandjean & Rhiner, 1963;

Table 7. *Summary of multiple linear regression analysis dependent variable = humidity vote*

Variables	Data	Total	Female
Vapour pressure	Coef.	0·03	0·03
	%*	2·5	3·1
Average dry-bulb temp.	Coef.	−0·10	—
	%*	3·3	—
Dry-bulb temp. bed	Coef.	—	−0·09
	%*	—	3·0
Weather	Coef.	−0·06	−0·07
	%*	0·7	1·5
Patient age	Coef.	—	−0·003
	%*	—	1·0
Constant		3·53	3·47
Overall *P* level		< 0·001	< 0·001

* Percentage of variance in data explained by regression on this variable.

Franzen, 1969; Rasmussen, 1971; Andersen, Lundqvist, Jensen & Proctor, 1974) no effect of humidity appeared in the multiple regression equations for thermal comfort. However, in order to examine whether or not the patients had detected different levels of humidity as humidity differences *per se*, these equations were recalculated with the patients' humidity votes as the dependent variable. First, however, the 26 interviews (8 male and 18 female) in which patients had voted '0' on the humidity scale of too dry (1), just right for moisture content (2), too moist (3) and don't know (0) were excluded from the data. The independent variables used were again those given in Table 3, and a summary of the results is given in Table 7.

The male patients' humidity votes were not found to be significantly related to any of the variables included in the analysis. Although some relationship was found for the Total and Female data, examination of Table 7 shows that this was at a very low level, and in all cases the regression coefficients are close to zero.

This adds further weight to the evidence that man's perception of humidity *per se* is very poor, and that within normal operating conditions of 30–70 % r.h. (this lies within the range of conditions tested) humidity as a factor in itself can be neglected from comfort considerations.

DISCUSSION

There are two points arising from the study which merit further discussion.

First, examination of Table 4 shows that the level of explanation of the patients' comfort votes was low, and although explanation of 20 % of the variance in the data can be considered a fairly good result in this type of investigation, the maximum of 13·7 % attained by the present study is disappointing. It is possible that this is due to imprecision in the method of recording the patients' activity levels, and to differences in the insulation value of the clothing worn by different patients. However, there is little difference, in metabolic terms, between the various activity levels, and the patients clothing ensembles were very similar. It seems more likely therefore, that although the ASHRAE comfort scale is a standard instrument for thermal comfort studies, it is not particularly suited to application by interviewers in hospital wards. It would appear that when used in this way the validity and reliability of the scale are open to question, and require further investigation.

Secondly, as can be seen from Table 6 the lowest temperature band mid-point (DB head) at which sufficient interviews were completed for inclusion in the final analysis was 20·5° C. The reason for this was that at temperatures below this complaints from the patients became extremely vociferous, and any attempt to conduct useful tests at temperatures below this point would have seriously jeopardized the rapport which had been established between the interviewers and the patients, and therefore the whole testing programme.

'Arousal level' is a psychological hypothetical construct which denotes general readiness to respond, and it has been hypothesized (Provins, 1966; Griffiths, 1970 Wyon, 1972) that arousal levels are related to ambient temperature, arousal generally decreasing as temperature increases within the range of ambient temperatures in which we are interested. This theory appeared to be borne out by the tests, the patients complaining loudly at the lower temperatures, and becoming lethargic and dozy at the higher temperatures. It is not possible to infer, therefore, that because the patients 'opted out' of the tests on the cold side of comfort they were more sensitive to cold than hot discomfort. On the contrary it must be assumed that the patients were equally uncomfortable in both situations, but as their arousal level was higher in the cold situation they were more prepared to forcibly do something about their conditon.

Taking both these points into account, it still seems that the curves shown in Fig. 1 give a good estimate of what the patients felt about the various conditions that they experienced during the tests.

For the prediction of optimum steady state conditions there is little to choose between the curves for the stronger or the weaker criterion. In view of what has been said above concerning the patients' reactions to cold conditions, however, we feel that the curves based on the stronger criterion of only votes of '4' being considered as 'comfortable' will provide a better guide to the severity of patient complaints likely to occur under normal operating conditions.

The effect on thermal comfort of air velocities of less than 0·1 m/s is negligible, as at values below this heat losses through forced convection do not occur, and as shown in Table 1 this condition was met during the tests.

From the curves shown in Fig. 1 we can therefore predict that where mean radiant temperature is close to air temperature, air velocity less than 0·1 m/s and humidity maintained at some point between 30 % and 70 % r.h. the optimum ambient air temperature for patient comfort will lie between 21·5° and 22° C.

As mentioned in the introduction there is little previous work available for comparison with these results. They agree well, however, with the ambient air temperature at the head found to be preferred by anaesthetists (22·0° C) and

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scrubbed nurses (21·1° C) in British operating theatres (Wyon, Lidwell & Williams, 1967), and with the figure of 25° C derived, assuming that the patients clothing and activity can be described as 'medium', and 'sedentary' respectively, from Fanger's graphs (Fanger, 1970).

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