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ADAPTIVE COMFORT BEHAVIOUR IN IRANIAN COURTYARD HOUSES

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ABSTRACT

In many hot countries courtyard housing has evolved to help people achieve thermal comfort under hot conditions. Field studies have identified several thermal comfort adaptive actions that a person might take to achieve comfort. One of these actions is moving to a different thermal environment from the one causing the discomfort. The present paper examined how people adapt themselves thermally to achieve comfort in Iranian courtyard housing by moving between different spaces in the house during the day.

KEYWORDS

Thermal comfort; housing; courtyards.

INTRODUCTION

There are two main methods of determining thermal comfort: through climate chamber experiments or through field studies (Fanger, 1970; Humphreys, 1976). Differences have been found between field and chamber results, but Humphreys (1994) contends that focussing on the difference between two methods is a misunderstanding of the problem. He argues that attention must be paid to the process of achieving comfort and that many of the differences could be explained by using an adaptive feedback model for thermal comfort, an approached that would need both climatic chamber experiments and field studies. Fountain et al. (1996) have argued that the most immediate line of inquiry should be into adaptation by behavioural or technological adjustments when individuals can directly manipulate heat fluxes that govern overall thermal balance. The various methods used in adapting to thermal environments have been identified (Humphreys, 1994; Nicol et al., 1994; Humphreys and Nicol, 1998). The primary aim of this study was to examine one kind of adaptive behaviour used for achieving thermal comfort in courtyard housing.

METHODOLOGY

This study was performed in Ilam in western Iran. Ilam has a cool winter and hot-dry summer. During the critical summer months relative humidity is low and air temperatures high (15°C to 42°C).

A thermal comfort survey was conducted during the hot season (July / August) in a courtyard house. The house was selected at random from more than twenty in the area. Six subjects, four males and two females, with an average weight of 60 kg and average height of 166 cm, completed questionnaires for seven days for every hour of the day when they were in the house and awake. The mean age of the subjects was 38 years. The questionnaires requested information on thermal sensation (ASHRAE seven point scale), clothing, activity level and the location of the person in the house. Four thermally separate spaces in the house were identified which were: courtyard, Ayvan (closed on five sides and open to the courtyard), main room (room and small open kitchen were together) and basement. Air temperatures were measured in each of these spaces for the duration of the survey. Some 467 data sets were obtained during the one-week longitudinal sampling survey.

RESULTS

Mean clothing insulation was 0.48 clo. The interesting point is that clothing values in the two categories of time were different. Clothing insulation for the heat of the day (10.00-17.00) was 0.42 clo and for other times of day (7.00-9.00 and 18.00-22.00) was 0.52 clo. The average metabolic rate was 1.2 met. During the survey air temperatures were recorded and calculated for two conditions: air temperature measured at the time of the questionnaires and air temperature measured between 7.00- 22.00, which is the active period. Table 1 shows air temperatures in different spaces in the two categories. Throughout the period of the survey outdoor temperatures were also obtained from the meteorological office of Ilam. The mean outdoor temperature during the survey was 28.5°C.

Table 1. Air temperatures (°C) in different spaces

Places		**Mean**	**Max.**	**Min.**
Courtyard (C)	T_q	28.2	31.4	24.1
	T_{ac}	29.8	34.4	24.1
Ayvan (A)	T_q	28.3	31.3	24.5
	T_{ac}	29.7	34.0	24.5
Room	T_q	29.6	32.5	25.3
/Kitchen (R)	T_{ac}	29.9	32.5	25.3
Basement (B)	T_q	28.7	29.3	26.2
	T_{ac}	26.8	29.3	22.4

T_q – measured air temp. at time of questionnaires; T_{ac}- measured air temp. in active period

Table 2. shows the mean thermal sensation response of each subject during a week. Responses varied over three central points of the seven-point scale. All subjects were in a slightly warm condition while Subject (5) had a higher sensation vote than the others. Mean sensation votes for each space during use by the occupants was calculated as shown in Table 3. Table 3 shows that the basement had a high sensation value (0.76) while the Ayvan had a low value (0.29). This is maybe because of high outdoor temperatures during use of the basement, which was the hot time of the day. Alternatively, it may be because of the subject's expectations during the hot period of the day.

Table 2. Mean sensation votes of each subject during survey

Subjects	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**	**All**
Mean S. V.	0.42	0.52	0.25	0.25	0.57	0.52	0.39

Table 3. Mean sensation votes of each space during the survey

Spaces	Courtyard	Ayvan	Room/Kitchen	Basement
Mean s. v.	0.51	0.29	0.38	0.76

The correlation coefficient between sensation votes and air temperatures was high and positive, (0.87). The correlation between air temperature and clothing values was significant and negative (-0.24). This implies people used change of clothing as a kind of adaptive method to achieve thermal comfort conditions. For calculations of neutral temperature a simple linear regression analysis for the sensation votes and air temperature was used. The low slope of sensation line and the value of R^2 (0.7755) are comparable with other surveys. The slope of the regression line was 0.25/°C with an intercept at -6.86. The neutral temperature was 27.5°C with a comfort range of 23.5°C to 31.7°C.

DISCUSSION

Humphreys and Nicol [1998] noted that one reaction of a person to heat is to move from one place to another. One of the questions for the subjects in this survey was about their location in the house. It was explained to them that they should have been in the particular location for at least 15 minutes. From this question the calculation of the mean percentage of use of each space hourly during a week (f_i) was possible, as shown in Table 4, Columns 1,2,3,4. People mainly used the Ayvan as a semi open space and they spent just 5% of their time in the courtyard. Another step was calculating the mean air temperature for each space during the fixed time in the space. This is shown in Table 4, Columns 5,6,7,8. For a clear picture, weighted mean air temperatures depending on hour of use were calculated from:

$$\mathbf{M^*} = \Sigma(\mathbf{f_i} \cdot \mathbf{T_i}) / \Sigma \mathbf{f_i} \qquad (1)$$

where **M*** is weighted mean air temperature; $\mathbf{f_i}$ is percentage of use; $\mathbf{T_i}$ is mean air temperature

Columns 9 to 12 of Table 4 and Table 5 also show the results of this equation. M* shows the air temperatures which subjects were exposed to. One of the interesting points that can be obtained from Table 1 supports this claim. Air temperatures at the time of the questionnaires indicated the air temperatures which subjects were exposed to. In all spaces the range of air temperature at the time of the questionnaires were within the comfort zone. Correlation between air temperature and percentage time of using a space is also important. When the air temperature of a space was below 25.0°C the correlation coefficient was high and positive. This means that when air temperature is close to comfort conditions the percentage use of the space increased. When the air temperature of a space was within comfort zone there was no significant correlation. Finally, when air temperatures exceed 30.0°C the correlation was high but negative. This means that when air temperatures in spaces were higher than the upper limits of the comfort zone then use of such spaces would be reduced. Table 6 shows the correlation coefficients between air temperature of spaces and percentage of space use.

CONCLUSION

This paper has described a week-long study of how and when six people used different thermal spaces in their traditional courtyard house during the hot season. There was some evidence of clothing being used as an adaptive measure. However, the subjects tended to actively seek out more thermally comfortable spaces in the house during the course of a day, suggesting that one of the main forms of adaptation for the subjects was movement from one place to another within their courtyard house.

Table 4. Percentage use of courtyard (C), Ayvan (A), roof (R) and basement (B)

Time	Percentage use				Mean air temp. during use				Calculation of (f_i . T_i)			
	C	**A**	**R**	**B**	**C**	**A**	**R**	**B**	**C**	**A**	**R**	**B**
	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*
7&8	4%	30%	35%	0%	24.7	25.1	25.7	23.1	99	753	899	0
9&10	6%	39%	35%	7%	27.6	27.1	27.9	25.6	165	1057	976	179
11&12	2%	47%	32%	6%	30.8	29.3	29.4	27.0	61	1377	940	162
13&14	0%	0%	65%	18%	33.3	32.2	31.3	27.9	0	0	2034	502
15&16	0%	0%	20%	65%	34.3	33.8	32.1	28.9	0	0	642	1878
17&18	12%	20%	20%	35%	32.2	32.0	32.3	29.1	386	640	646	1018
19&20	7%	85%	2%	0%	28.6	29.8	31.2	27.8	200	2533	62	0
21&22	7%	62%	5%	0%	26.6	27.9	28.9	25.1	186	1729	144	0

Table 5- Amount of M* in the fixed time

Time→	*7&8*	*9&10*	*11&12*	*13&14*	*15&16*	*17&18*	*19&20*	*21&22*
Σ(f_i . T_i)	1751	2377	2540	2536	2520	2690	2795	2059
Σf_i	69	87	87	83	85	87	94	74
M*	25.4	27.3	29.2	30.5	29.6	30.9	29.7	27.8

Table 6. Correlation coefficient between air temperature and percentage of space use

Air temp. T_a	$T_a < 25.0$°C	25.0<T_a<27.5°C	27.5 °C <T_a<30.0°C	Ta>30.0°C
Corr. coeff.	0.57	0.03	0.24	-0.65

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