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COPING WITH NATURE

(Ten years thermal comfort studies in Iran)

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Abstract

In order to define the thermal comfort needs of people, it is necessary to look at their living conditions, life style and their behavior. In Iran people are mainly concern of two widely separated communities. They are: traditional people who are living in traditional life style and modern people who are living in modern ways. But, the interesting point is that, thermal acceptability of both groups of people does not show a remarkable difference. This paper presents the results of thermal comfort field surveys in fifteen cities of Iran at four different climatic zones as a thermal comfort data base in Iran to show the impact of some adaptation behavior to achieve comfort condition. About 5000 sets of data were collected in Iran by the author and his collogues during the past 10 years. The findings of the study revealed how the adaptive actions vary with outdoor temperature and shift the neutral temperature. Subjects showed little discomfort when indoor temperature varied between large ranges. It means, the comfort temperature was not only influenced by season but by the degree of personal actions.

The indoor comfort temperature (T_c), which is dependent on outdoor temperature (T_{om}), could be found from the following equation:

$$T_c = 17.8 + 0.30\ T_{om}$$

In addition to other points, these studies show that the expectation concept explained by Fanger, is not valid.

Keywords: Thermal comfort; comfort expectations; Energy use in building; Adaptive model; people behavior,

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Introduction

Up to the Industrial Revolution, thermal comfort was not a practical issue, as there were very few tools available to influence it. When it was cold, a fire was lit to ameliorate the conditions, when it was hot; the use of hand-fans was the only relief. Our generations lived in harsh climates without abundant sources of energy. The assessment of the thermal environment as one of the oldest judgments made by man, commenting on the prevailing weather by comparatively evaluating in everyday conversation. Haldane, in the U.K. [1], carried out the first systematic study on thermal comfort with regard to the effect of high temperatures. In the early 1920s a basic study was carried out in the U.S.A. It was an attempt to find a comfort zone according to humidity level and air temperature. In England, the motivation came from industrial hygiene: the limits of environmental conditions for work. Vernon and Warner [2] in 1932 and Bedford [3] in 1936 carried out empirical studies among factory works. Extensive field surveys of thermal conditions by Bedford produced the equivalent temperature scale. Gagge [4] did analytical work in the U.S.A. and made a significant contribution to this topic. A fundamental report by Victor Olgyay [5] was the first to bring together findings of the various disciplines and interpret these for practical (Architectural) purposes in the form of a Bioclimatic Chart. This Chart represents the combination of dry bulb temperatures on a vertical axis and relative humiditys on a horizontal axis, composing the comfort zone in the centre. The chart is applicable to inhabitants wearing a typical business suit (1.0 clo) and performing sedentary or light work (1.2 met) in a warm climate. Six years later, Givoni [6] has been developed another Building Bioclimatic Chart to address the weakness identified in Olgyay's Chart. It evaluates the comfort requirements and suggests the applications used for building design. The Building Bioclimatic Chart is later revised by taking account of the effects of acclimatisation, various design strategies and passive cooling systems. The temperature ranges of acceptable conditions in still air for people living in developed countries are 18-25°C in winter and 20-27°C in summer. The upper temperature limits are applicable at low humidity levels. For people living in hot hot-developing countries, the upper temperature limit can be increased 2°C. Apart from both Charts, several researchers mentioned the comfort zone in their findings. Among researchers, Fanger [7] defined comfort zones corresponding to wide temperature intervals and recommended for the optimal comfort that the number of dissatisfied persons must not be more than half as large as the minimum value, i.e., the PPD = 7.5%; and therefore, the PMV must lie between -0.35 and +0.35. Such a limit will be linked with a design meteorological condition and be determined the capacity of the environmental system [8]. However, with regard to new building technology and modern heating and cooling systems one of the main questions is “what conditions for people are comfortable?” and then “what must we aim to provide?”

There are two methods for ascertaining people’s thermal comfort, which are based on questionnaires: experimental work carried out in a climatic chamber and field studies carried out in the real world. The methodology of the climatic chamber’s experiments is basically conducted in environmental test chambers which can be altered a range of climatic conditions, including all relevant combinations of air temperature, air humidity, mean radiant temperature and air velocity. The test subjects are clothed in uniform clothing, and are seated and asked to perform quiet activities such as to read or study. On the other hand, field studies are a method of field surveys of subjective thermal responses from human subjects, and at the same time, the climatic environmental measurements are taken. The aim of this methodology is to study thermal comfort in the real world where all subjects are left to suit themselves in their choices of clothing, their uses of environmental controls, their postures, and activities and so on.

Humphreys [9] stated that there is no definite conclusion can be made about which method is most appropriate for predicting thermal comfort conditions. The doubt is cast upon both studies of that neither the sophisticated combination of environmental variables in laboratory experiments, nor the common analytical method in the field can produce credible comfort temperatures. Although the crisis of thermal comfort is often perceived as a conflict between these two methodologies, both are important and necessary.

The objective of present study will be a systematic investigation of thermal comfort in different regions of Iran. This paper, however, describes some field studies of thermal comfort conducted in different parts of Iran. Thus, the field study of thermal comfort is the methodology used for the study. Some comparative analysis between two methodologies will be made.

Climate of Iran

Iran has a complex climate, ranging from subtropical to sub-polar. In winter, a high pressure belt slashes west and south to the interior of Iran, while low-pressure systems develop over the warm waters of the Caspian, the Persian Gulf, and the Mediterranean. During the summer the winds are dominated by the Indian monsoon system. Its direction over most of Iran is again more or less from north or north-west, but topography plays a great part in modifying this general picture. On the other hand because of the special disposition of the mountain ranges and the influences of the seas, air temperature is different from one place to another. In the summer, temperatures vary from a high of 55°C in the central of desert, to a low of 1°C in the north-west of the country. Precipitation also varies greatly, ranging from less than 25 mm in the south-east to about 200 mm in the Caspian region. From time to time, the country is exposed to the movement of air masses that originate in distant places and are therefore initially of totally different temperatures from those prevailing in Iran. Such air masses can exert a great influence on the pattern of temperature distribution within Iran. The middle of summer time is July and August, which are the warmest months of the year. January and February are also the coldest months.

The thermal comfort field studies

During past ten years, more than 5000 subjects in their naturally ventilated offices/houses filled the questionnaires about their thermal sensation. Overall 2960 set of data were collected during the hot season and about 2050 during cool season in the three different climatic zones of fifteen Iranian cities. Seven cities out of fifteen were lies in an extremely hot and arid region, three in the cold part and six other in the hot and humid zone. The climatic condition of the first group was hot and dry in summer with temperatures varying between 20°C to 45°C, giving a large diurnal temperature swing with a relative humidity almost less than 50%. The climate of the two was extremely cold in winter and moderate in summer and the climate of other cities was hot and humid in summer with a temperature variations between a maximum of 35°C and a minimum of 25°C. The relative humidity was very high almost more than 75%.

During the all surveys indoor air temperatures were obtained from Skye Data Hog, data-loggers that gathered and stored results automatically. Its accuracy is 0.2°C (maximum error over 0°C to 60°C). Air velocity past the body also were recorded with an airflow meter, Solomat MPM 500e (accuracy 2% rdg ± 0.15 m/s; -10°C to 70°C). Clothing values as an important individual variable were recorded. The questionnaires contained some questions. Two of those which have been used in this study are in order of thermal sensation, using a seven point ASHRAE scale and preference vote using a three point McIntyre scale.

Data and analysis

The summaries of the data in their means, ranges and standard deviation for each climate are tabulated in Table (1). In addition mean daily outdoor temperature was obtained from metrological office.

Table 1- Summaries of the data during field measurements

		Summer		***Winter***		
Climate		Hot and Dry	Hot and Humid	Hot and Dry	Hot and Humid	Cold
Indoor air temperature	*SD*	1.42	2.46	1.73	1.30	1.74
	Ave.	30.2	27.8	20.2	24.8	20.0
	Max	34.0	33.8	22.6	27.3	23.1
	Min	25.4	23.0	15.1	21.8	15.4
Indoor air velocity	*SD*	*0.08*	*0.09*	*0.02*	*0.049*	*0.015*
	Ave.	*0.13*	*0.19*	*0.01*	*0.15*	*0.018*
	Max	*0.56*	*0.37*	*0.09*	*0.24*	*0.07*
	Min	*0.01*	*0.01*	*0*	*0.05*	*0*
Clothing value	*SD*	0.108	0.12	0.32	0.092	0.34
	Ave.	0.49	0.62	1.02	0.86	1.49
	Max	0.99	1	1.75	1.14	2.19
	Min	0.35	0.42	0.42	0.72	0.9
Sensation vote 7 point ASHRAE Scale	*SD*	0.53	0.48	0.63	0.65	0.79
	Ave.	0.38	0.14	-0.098	-0.18	-0.34
	Max	2	2	1	1	1
	Min	0	-1	-2	-2	-2
Preference vote 3 point McIntyre Scale	*SD*	0.49	0.35	0.53	0.51	0.63
	Ave.	-0.32	-0.14	0.50	0.48	0.65
	Max	0	0	1	1	1
	Min	-1	-1	-1	-1	-1

In this study air temperatures were measured in all spaces but globe temperatures often were only collected at indoor conditions during hot season. The correlation coefficient of the globe temperature with air temperature was very high and positive [r (T_a, T_g) = 0.98] while the mean value of air temperature was nearly the same as globe temperature.

Indoor air temperatures ranged from a low of 15.1°C during the cool season to a high of 34°C during the hot season in the hot and dry cities. The low and high temperatures during the cool season for cold cities were 15.4°C and 23.1°C respectively. Temperatures averaging around 29°C for all spaces with 7°C differences between hot and cool seasons (around 22°C in cool season) makes a good opportunity for significant results in the study.

Mean indoor air velocity in all cities were same as 0.15 $(m/s)^{0.5}$ in hot condition while it was 0.5$(m/s)^{0.5}$ in cool season. Clearly indoor air velocities of hot season and cool season are generally different.

Clothing value as physical data has a great effect on thermal comfort. It is individual and has a difference from one person to another. Mean clothing value of warm side was about 0.47 clo while mean clothing value of cold side was 1.18 clo. In fact, the amount of clothing in all groups had been increased in the cool season and there was a difference between them in each group.

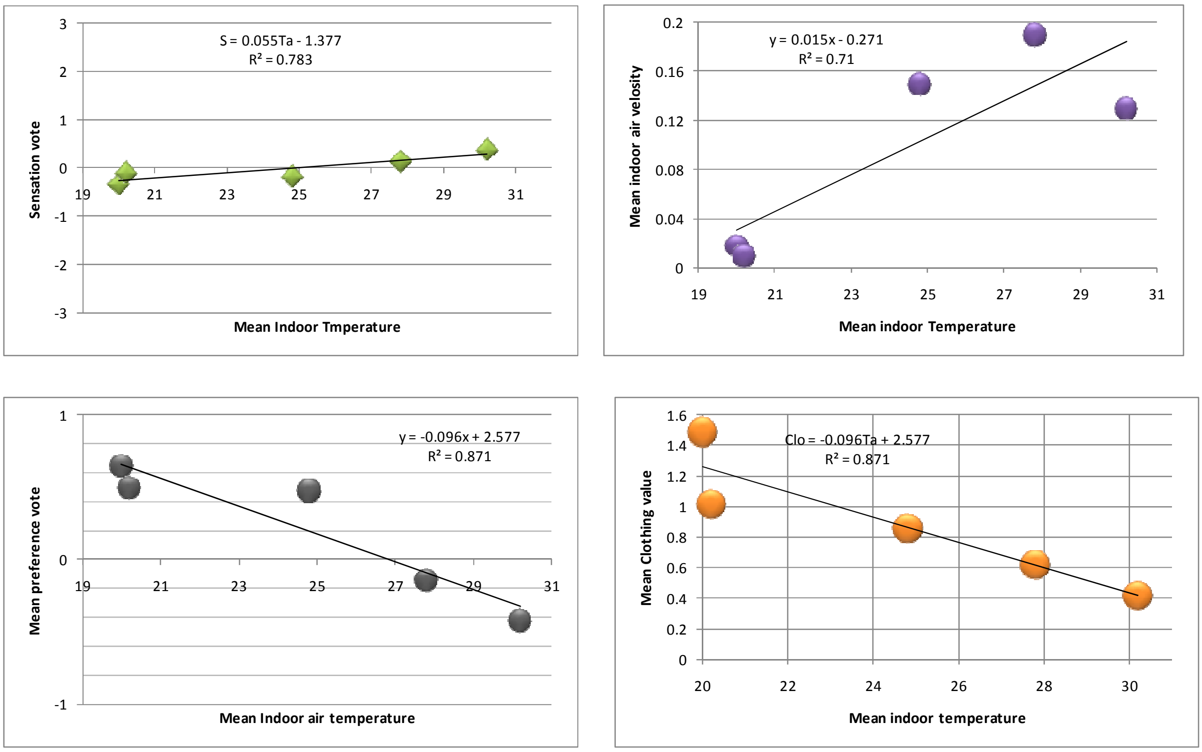
In terms of sensation vote, the first and important point is that over 90% of subject votes during both seasons in indoor conditions indicated one of three central categories, between slightly cool and slightly warm. It is surprising according to the range of air temperature during both seasons that this is enough for the range of comfortable condition. It is also shown that people can be comfortable in many environmental conditions. However the distribution of votes is different for both seasons and as well for cities. The mean sensation votes on the ASHRAE scale were 0.27 in hot season (slightly warm). In the cool season this vote was –0.18 or slightly cool.

The mean preference votes on the 3-point McIntyre scale were -0.27 in hot season and it was 0.57 in cool season.

Relationship between mean of variables

Figures (1), (2) and (3) show the scatter diagrams of air temperatures with sensation votes, preference votes and air velocity in five groups of responses during both seasons. There is a high and positive relationship between air temperature and sensation votes, the higher the temperatures the warmer the sensation. Furthermore it is interesting that the range of the mean sensation votes are in the comfort range (slightly cool to slightly warm). Such a relationship also exists between air temperatures and preference votes but negative.

Figure (4) shows the scatter diagram between mean value of clothing insulation and mean air temperature. There is a high and negative relationship between these variables. Lower temperatures are related to higher clothing insulation.



Figures (1, 2, 3 and 4)- Relation between air temperature and sensation votes, air velocity, preference vote and clothing values (mean of all groups)

Correlation coefficient

Correlation coefficient is a statistical technique used to explore the relationship between two variables. A correlation coefficient of (+1) or (-1) implies that all the points fall on a straight line; when it is equal to zero (0) they are scattered and give no evidence of a linear relationship. Any other value between (-1) and (+1) suggested the degree to which the points tend to be linearly related. The square of the correlation coefficient gives a measure of the proportion of the variation the value of variable which can be explained by the variation of the other [10]. It is noticeable that the correlation coefficients in the present study signify their statistically significant level beyond 0.05, 0.01 and 0.001.

Air velocity does consistently correlate with air temperature except in the cold cities during cool season. It is interesting, when the temperatures are highest; the air movement is higher especially in hot conditions. The important point is that four correlations out of five are highly significant.

Table 2- correlation coefficient between all variables

	Summer		Winter		
	Hot & Humid	Hot & Dry	Hot & Humid	Hot & Dry	Cold
T_a:S	0.54	0.40	0.65	0.71	0.67
T_a:P	-0.49	-0.32	-0.45	-0.39	-0.50
T_a:V	0.60	0.43	0.15	0.16	0.06
T_a:Clo	-0.32	-0.27	-0.77	-0.51	-0.61
S:P	-0.47	-0.47	-0.39	-0.38	-0.60
S:V	0.23	-0.03	-0.04	0.16	0.05
S:Clo	-0.18	-0.11	-0.46	-0.32	-0.44
P:V	-0.06	0.22	-0.10	-0.13	-0.09
P:Clo	0.14	0.16	0.33	0.36	0.30
V:Clo	-0.58	0.16	-0.10	-0.17	-0.14

The correlation between sensation and preference votes is relatively high as might be expected. The sensations votes also are well correlated with air temperature and in all spaces were significant. However sensation votes also are correlated with vapour pressures during cool seasons. From Table (2), it seems that the correlation of preference with air temperature is high, similar to sensation votes. Preference generally shows a slightly lower correlation with air temperature than does sensation [10].

The correlation coefficient between clothing insulation and air temperature is interesting. The higher negative correlation between air temperature and clo- value during the cool season shows a very good relationship between these two variables. The warmer it is the less people wear. It is an indication that the subjects were using clothing as a way of adjusting to the thermal environment in cool season.

The correlation coefficient between clothing and indoor air temperature were r = -0.27 for hot and dry cities and r = -0.32 for hot and humid cities during hot season. The reason for such correlations is that the clothing worn was a minimum as much as possible.

Neutral temperature and acceptable condition

One recognised method to predict the subjective comfort which results from a given temperature, or combination of environmental variables, is regression analysis [11]. The simple linear regression formulated by simple equation:

$Y = aX + b$
where (in thermal comfort study):
Y is thermal response
X is air or globe temperature
a is slope
b is regression constant

Simple linear regression was performed of the ASHRAE scale responses versus air temperature to determine the strength of the relationship between them.

Figures (5, 6, 7, 8, and 9) and Table (3) show the relationship between air temperature and sensation votes in all groups. As shown in Table (3) the slope of sensation responses in all groups is less than 0.33/°C [between 0.11/°C and 0.33/°C]. Nicol [11] reported that 0.25/°C is the most common regression slope in field surveys, Humphreys [12] also found a slope of 0.22/°C from a world- wide field studies review. Such slopes are less steep than the slope of 0.33/°C by Fanger [7] from his climate chamber experiments. According to Humphreys [12] the lower values of the slope suggest the occurrence of adaptation of respondents to their thermal environments. Wynn [13] suggested that in different environments the regression slope relating the reported thermal sensation to temperature will vary due to differences in expectations of that environment, thus different neutral temperatures will be produced.

The neutral temperature during the hot season was about 27°C and during the cool season was nearly 21°C except in the hot and humid cities which was 25°C. They are comparable with neutral temperatures from other field studies in different regions.

The range of acceptable conditions from the present study is much wider than that predicted by standards such as ISO-7730 (1994).

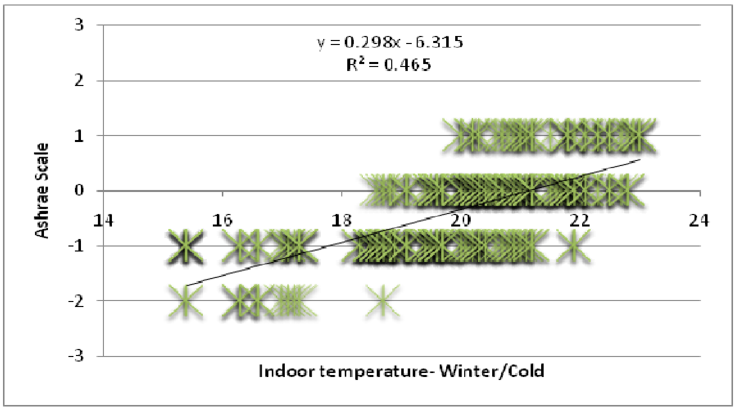


Figure 5- scatter between indoor temperature and sensation vote (cold cities –winter)

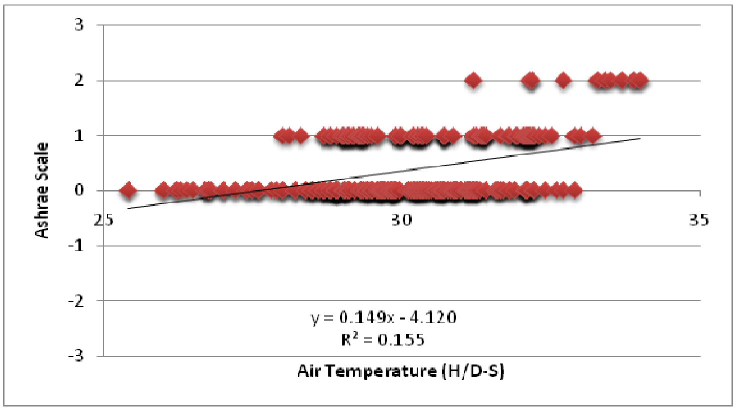


Figure 6- scatter between indoor temperature and sensation vote (hot and dry cities –summer)

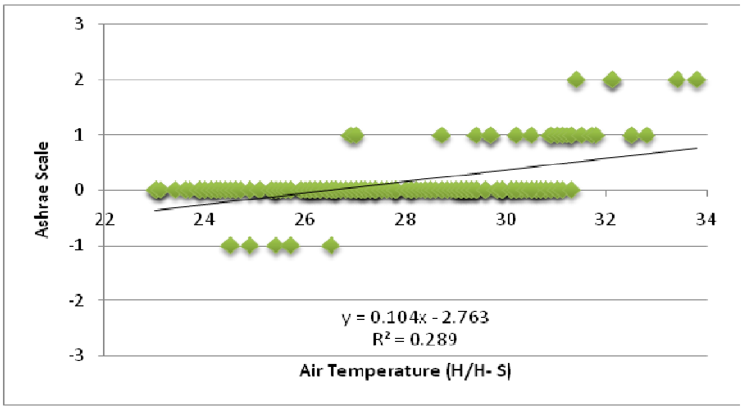


Figure 7- scatter between indoor temperature and sensation vote (hot and humid cities –summer)

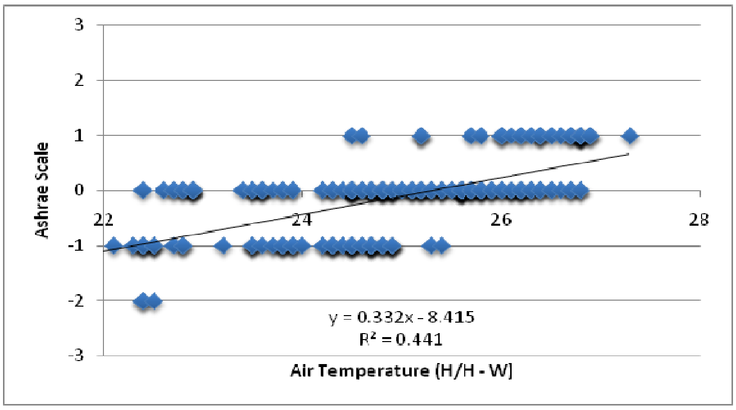


Figure 8- scatter between indoor temperature and sensation vote (hot and humid cities –winter)

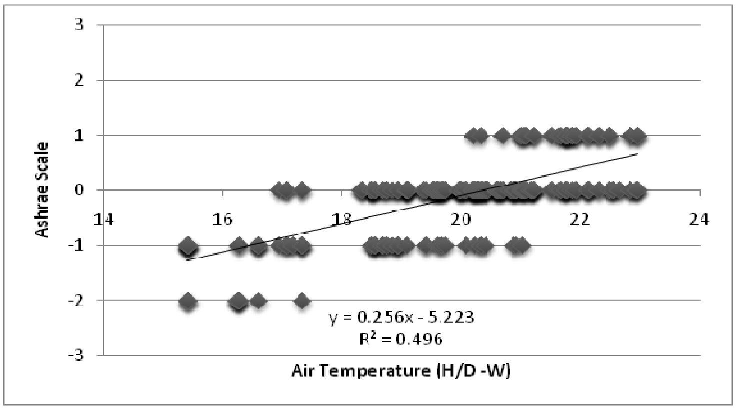


Figure 9- scatter between indoor temperature and sensation vote (hot and dry cities –winter)

Table 3- Summaries of the data during field measurements

	Summer		Winter		
	Hot and Dry	Hot and Humid	Hot and Dry	Hot and Humid	Cold
Slop	0.15	0.11	0.26	0.33	0.30
intercept	4.1	2.8	5.2	8.4	6.3
R^2	0.16	0.29	0.50	0.44	0.47
Neutral Tem.	**27.7**	**26.6**	**20.4**	**25.4**	**21.2**
Acceptability(lower limit)	20.9	17.0	16.5	22.3	17.8
Acceptability(upper limit)	34.3	36.2	25.6	29.6	24.6

[The lower values of the slope suggest the occurrence of adaptation of respondents to their thermal environments] [Humphreys1976 [12]]

Discussion

Neutral temperature and mean indoor temperature: Humphreys [12] showed a strong relationship between the mean indoor temperature and neutral temperature. The simple regression equation is:

$T_n = 0.831\ T_i + 2.6$ (eq.1)

T_n is the neutral temperature

T_i is the mean indoor temperature

Auliciems et al [14] developed another equation. They used minimum group discomfort as a function of mean indoor air temperatures by simple linear regression analysis. This equation is:

$T_n = 0.73T_i + 5.41$ (eq.2)

From all experimental data in the present study equation (3) can be derived:

$T_n = 0.71\ T_i + 6.9$ (eq.3)

T_n is neutral temperature

T_i is indoor temperature

This equation is close to Auliciems' equation in terms of slope and intercept. The lower slope in equation (3) than slope of Humphreys' equation indicated that adaptation processes are not complete. In other words, one of the principal findings of the adaptive model is that the comfort temperature reflects the mean temperature experienced [10].

Neutral temperature and mean monthly outdoor temperature: Humphreys [15] indicated a strong relationship between the outdoor temperatures and the comfort indoors. This model shows that there is a strong linear relationship between the monthly mean outdoor temperatures (T_{om}) and the indoor comfort temperatures (T_n) for the "free-running" buildings, but a fairly strong curvilinear line for other buildings. The regression equation for free-running buildings is:

$$T_c = 11.9 + 0.534\ T_{om} \qquad \text{(eq.4)}$$

T_c is comfort temperature
T_{om} is outdoor temperature

Neutral temperature from Humphreys' equation can be estimated with knowledge of mean monthly air temperature. Auliciems and deDear [14] proposed a single line for all buildings. The relationship they found between comfort temperature and outdoor mean monthly temperature (for $5°C < T_{om} < 30°C$) was:

$$T_c = 17.6 + 0.31\ T_{om} \qquad \text{(eq.5)}$$

From the actual data of these studies and mean monthly outdoor temperatures during the field studies equation (6) can be derived:

$$T_c = 17.8 + 0.30\ T_{om} \qquad \text{(eq. 6)}$$

This equation is very close to Auliciems' equation.

Indoor air velocity: Mean indoor air velocity is most important indication of behavioural adjustment to indoor temperature. Building occupants, particularly in naturally ventilated buildings, might be expected to increase general air movement within their occupied zone, either through open able windows or fans, as air temperatures increased [16]. The ceiling fans are a common device for occupant's cooling. People also can open windows to improve their comfort. A very high and negative correlation coefficient (Table 2) between air velocity and clothing value during cool season is very interesting. It implies that people use both behaviours to achieve comfort condition and some things like culture or different climatic zone cannot effect to such circumant. The correlation coefficient between air velocity and air temperature during summer time is also interesting. The higher positive correlation shows a very good relationship between these two variables (Figures 10 and 11).

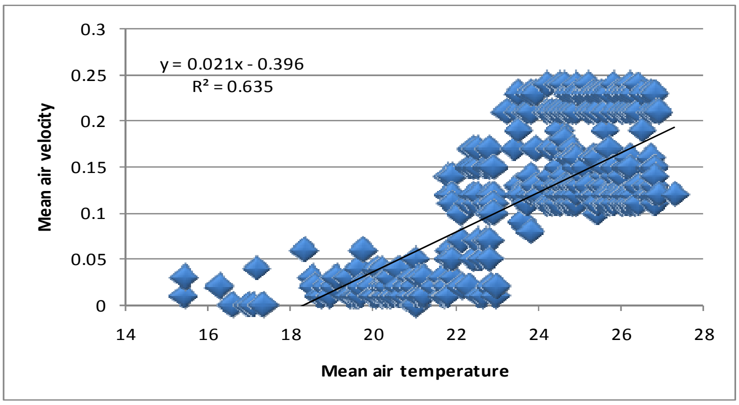


Figure 10- Scatter between mean indoor temperature and mean air velocity (all subjects- cool season)

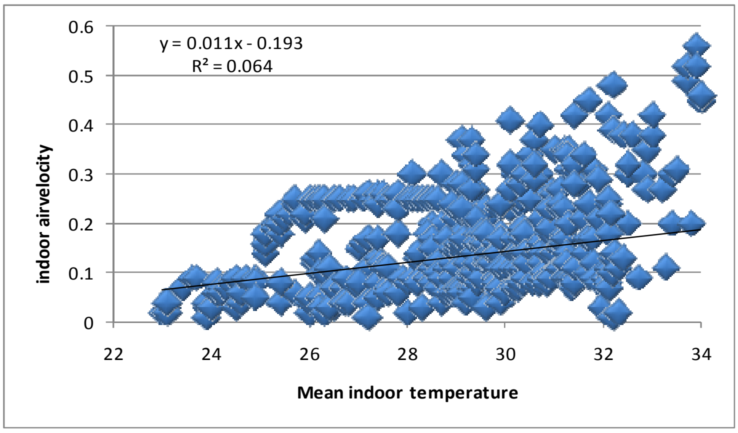


Figure 11- Scatter between mean indoor temperature and mean air velocity (all subjects- hot season)

However, in hot season, the rate of air movement was one of the best means of improving thermal comfort. In general, when people were warmer, they preferred more air movement, when felt cooler, they preferred less air movement.

Clothing insulation: In all surveys relationship between clothing values and air temperature were significant. Clothing insulation had a strong linear dependence on air temperature which subjects were exposed to it. Figures (12 and 13) show scatter diagram between air temperature and clothing value of all subjects, which indicated that value of clothing insulation, is related to air temperature. It is possible from Figures to suggest that removing clothing is an adaptation option down to a certain clothing level.

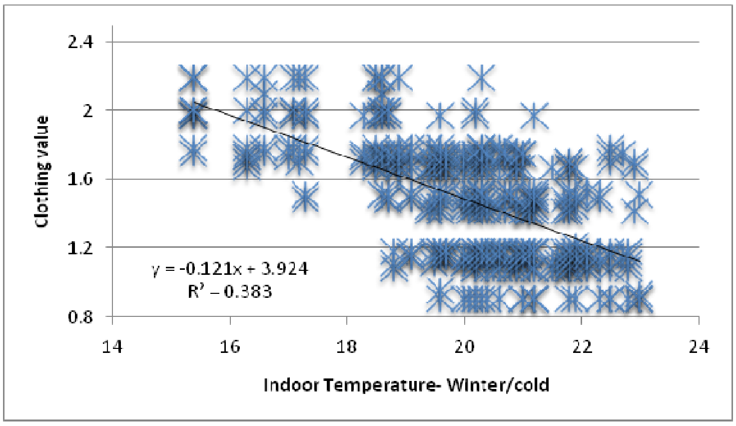


Figure 12- Scatter between mean indoor temperature and clothing values (cold climate- winter)

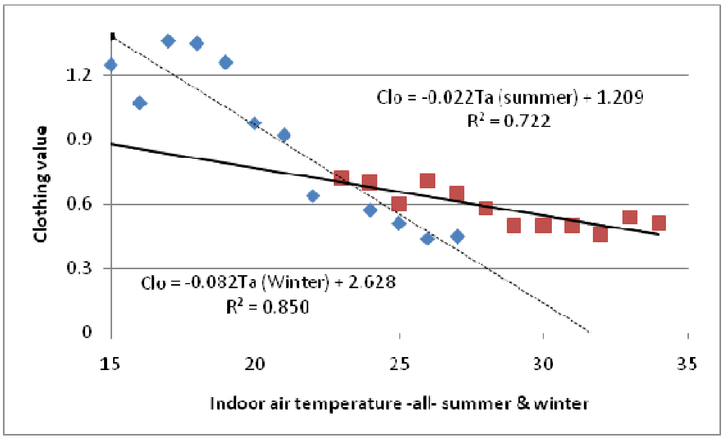


Figure 13- Scatter between mean indoor temperature and clothing values (all subject- winter and summer)

Such findings revelant that in real world people do not wear standard clothing and are free to modify its clothing value to reduce discomfort. The renge of clothing in present study was about 0.6 clo (between hot season and cool season) adjust the comfort temperature about 4K. In adition to defference in air velocity, between two conditions and some other adaptive behavioure can be explain the wide renge of neutral temperature. Figure (14) shows the relation between clothing, air velocity and indoor temperature in summer.

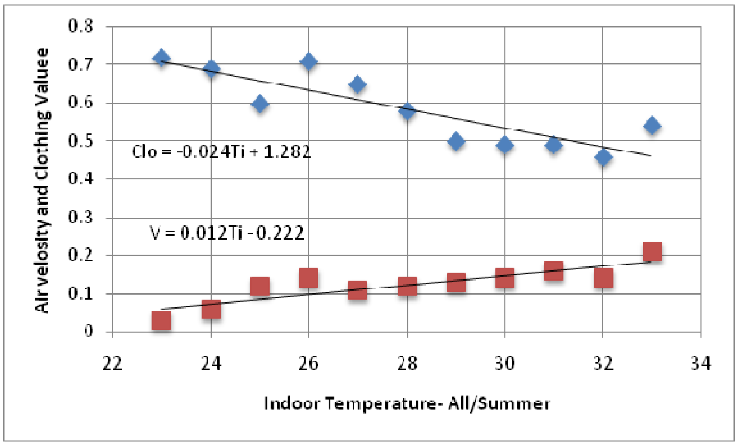


Figure 14- scatter diagram between clothing, air velocity and indoor temperature- all subject-summer

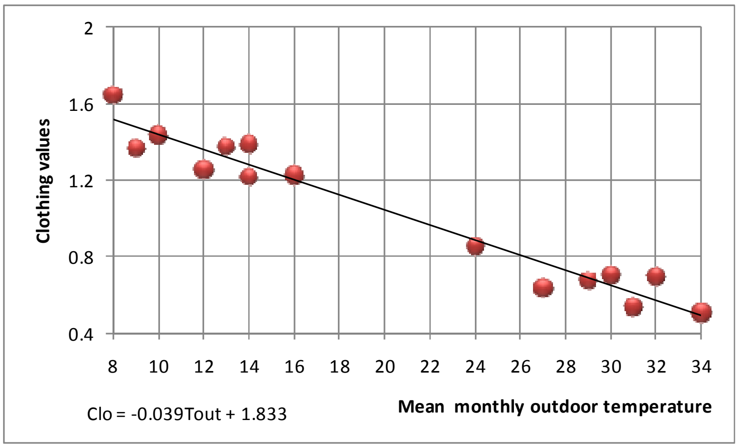


Figure 15- scatter diagram between mean monthly outdoor temperature and clothing value in all individual surveys

Nicol and Raja [20] found that clothing change were more strangly dependent on the succession of outdoor temperature than occurred prior to measurments, compared to the instaneous or daily mean outdoor temperature. In this study, it was not possible to access to mean outdoor temperature of day before the surveys. However, Figure (15) shows a strong relationship between mean monthly outdoor temperature and mean clothing value in all individual surveys. The Figure support the hypothesis that the statistical dependence of indoor neutrally on outdoor climate may be due to behavioural adjustments that directly affect the heat balance.

Thermal Preference

A preferred temperature obtained from the preference scale sometimes differs from a corresponding neutral temperature obtained from a seven-point scale of warmth [17]. Nicol et al [10] reported differences of a degree centigrade while Feriadi and Wong [18] reported a larger difference about 3°C. Table (4) shows the result of present study in Iran, neutral temperature from a seven-point ASHRAE scale and from three-point preference scale.

Table 4- Neutral temperature from two different methods

	Summer		***Winter***		
	Hot and Dry	Hot and Humid	Hot and Dry	Hot and Humid	Cold
Neutral Temperature 7-point ASHRAE scale	**27.7**	**26.6**	**20.4**	**25.4**	**21.2**
Neutral Temperature 3-point Preference scale	26.5	26.0	22.3	27.6	23.6

In summer's surveys the preferred temperature was about 1°C lower than the neutral temperature in the hot and dry cities, while it was 0.6°C in the hot and humid part of Iran. For cool season, such discrepancy was about 2°C for all groups. However, these result supported this fact that in regions having cold winter and hot summers, the preferred point on the scale undergoes a seasonal shift [17]. Figures (16 and 17) show a cross graph of a thermal preference scale (3-point) against the ASHRAE scale (7-point). It can be seen that in summer, subject voting neutral want the temperature cooler while in winter they want warmer. These results are in agreement with McIntyre [21] idea that culture and climate affect people's description of sensation- though not necessarily the sensation itself.

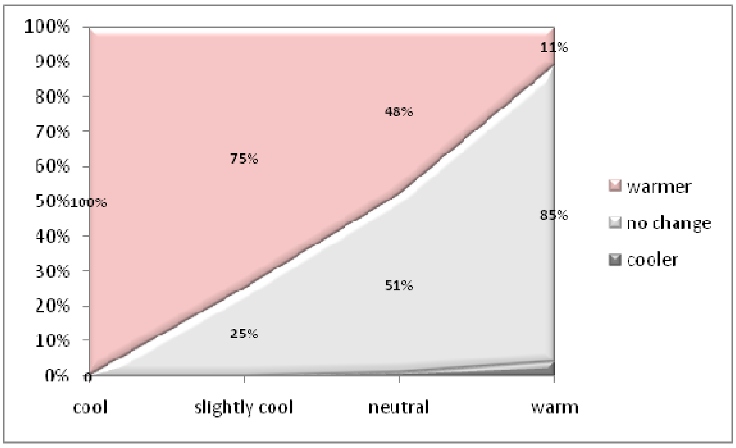


Figure 16- sensation vote against preference vote- winter season

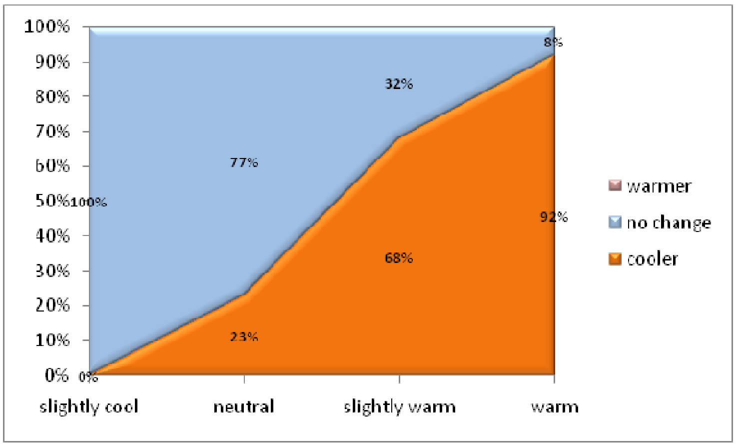


Figure 17- sensation vote against preference vote- summer season

Conclusions

The objective of present study was a systematic investigation of people comfort in their buildings in the different climatic conditions (but same religion and same culture) of Iran to determine the neutral temperature, thermal acceptability and to find out the relationship between neutral temperature, indoor and outdoor temperature and identify some of the adaptive behaviours used by people for providing comfort conditions. There were some remarkable points. In particular:

- The pattern of sensation votes showed that more than 90% of voters indicated one of three central categories on the seven point ASHRAE scale
- Occupants in buildings were tolerant of a significantly wider range of temperatures covering a range more than 14°C in hot season and 7°C in cool season. Seasonally shift was more than 7°C in hot and dry cities
- The results showed a good relationship between neutral temperature and mean indoor temperature and also between outdoor temperature and neutral temperature in all climatic conditions
- The indoor comfort temperature (T_c), which is dependent on outdoor temperature (T_{om}), could be found from the following equation:

$$T_c = 17.8 + 0.30\ T_{om}$$

- In different field surveys, there was about 4K shifts in neutral temperature from hot-dry cities to cold cities during winter
- The findings of the study revealed that people could achieve comfort at higher indoor air temperatures compared with the recommendations by international standards
- There was some evidence of clothing being used as an adaptive measure. The study showed a high relationship (but negative) between clothing insulation and indoor temperature. The lower temperatures were related to higher clothing insulation
- Clothing value had a strong dependent on outdoor weather and season
- There is no problem for Iranian people being comfortable at more than 30°C in hot season and less than 20°C in cool period

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References

[1]- Auliciems and Szokolay (1997) Thermal Comfort, note 3, Department of architecture, The University of Queensland, Brisbane.

[2]- Vernon and Warner (1932) Referenced by Auliciems and Szokolay [1]

[3]- Bedford, T. (1936) *Warmth Factor in Comfort at Work.* Medical Research Council, Industrial Health Research Board, report **76**, HMSO, London.

[4]- Gagge, A. P., G. M. Rapp and J. D. Hardy (1964) Mean radiant and operative temperature for high-temperature sources of radiant heat, *ASHRAE Transactions.* **70**, pp. 419-424.

[5]- Olgyay, V. (1963) *Design with Climate.* Princeton University Press, Princeton, New Jersey.

[6]- Givoni, B. (1976) *Man, Climate and Architecture.* 2nd edition, Applied Science Publishers, London.

[7]- Fanger, P. O. (1970) *Thermal Comfort.* Danish Technical Press, Copenhagen.

[8]- Jitkhajornwanich, J (1999) *Expectation and Experience of Thermal Comfort in Transitional Spaces*, Ph.D Thesis, University of Sheffield

[9]- Humphreys, M. A. (1994) Field studies and climate chamber experiments in thermal comfort research, *Thermal Comfort: Past, Present and Future.* Proceedings of a conference held at the Building Research Establishment, Garston, 9-10 June 1993, pp. 52-72.

[10]- Nicol, J. F., G. N. Jamy, O. Sykes, M. A. Humphreys, S. Roaf and M. Hancock (1994) *A Survey of Thermal Comfort in Pakistan.* Final report, July 1994, School of Architecture, Oxford Brookes University, Oxford.

[11]- Nicol, J. F. (1993) *Thermal Comfort- A Handbook for Field Studies toward An Adaptive Model.* School of Architecture, University of East London, London.

[12]- Humphreys, M. A. (1976) Field studies of thermal comfort: compared and applied, *Building Services Engineer,* **44**, pp. 5-27.

[13]- Wyonn, D. P. (1994) Assessment of human thermal requirements in the thermal comfort region *Thermal Comfort: Past, Present and Future.* Proceedings of a conference held at the Building Research Establishment, Garston, 9-10 June 1993, pp. 144-156.

[14]- Auliciems, A. and R. de Dear (1986) Air-conditioning in Australia I - human thermal factors, *Architectural Science Review.* **29** no. 3, pp. 67-75.

[15]- Humphreys, M. A. (1978) The influence of season and ambient temperature on human clothing behaviour, *Proceedings of the International Climate Symposium.* Copenhagen.

[16]- De Dear, R. J. and G. S. Brager (1998) Developing an adaptive model of thermal comfort and preference, *Field Studies of Thermal Comfort and Adaptation.* ASHRAE Technical Data Bulletin. **14** no. 1, pp. 27-49.

[17]- Humphreys, M. A. and Nicol, J. F. (2004) Do people like to feel neutral? Response to the ASHRAE scale of subjective warmth in relation to thermal preference, indoor and outdoor temperature, *ASHRAE Transactions: Symposia*- NA-04-2-4 PP. 569-577

[18]- Feriadi, H. and N. K. Wong (2002) Thermal comfort for naturally ventilated houses in Indonesia. *Building Research and the Sustainability of the Built Environment in Tropics*. Pp 215-227.

[19]- Nicol, J. F. and Humphreys, M. A. (2002), Adaptive thermal comfort and sustainable thermal standards for buildings, *Energy and Buildings*- 34- pp.563-572

[20]- Nicol, J. F. and I. Raja (1996) *Thermal Comfort, Time and Posture.* School of Architecture, Oxford Brookes University, Oxford.

[21]- McIntyre, D. A. (1982) Chamber studies- reductio ad absurdum ?” *Energy and Buildings.* **5** no. 2, pp. 89-96.