

# 408: Adaptive comfort and climate-sensitive architecture: How occupants feel in their homes?

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**ABSTRACT:** Temperate continental climates present considerable daily and seasonal temperature variations in a range that goes from 0-15°C in winter and can reach up to 18-36°C in summer with a low relative humidity (30-50%). These characteristics sometimes compromise architectural solutions but also, if climatic features are taken as design opportunities, architecture can advantage of its richness. Unluckily, most of existent buildings were only designed to protect from the exterior environment often with the help of auxiliary energy, and not to work with it in an environment friendly way. It is important to take into account that the way in which occupants evaluate the indoor thermal environment is context dependent and varies with time. That is directly related to the way occupants usually adapt to variations and how are their comfort expectations. With all of these in mind, the main issue that is addressed in this paper is to know how occupants feel in their homes. The case experience has been conducted through winter and summer surveys in the city of Mendoza, Argentina and presents interesting results related to architectural performance (previous measurements) and the sensitivity occupants have towards their own living environment. It is discovered the need to study the effect of variables such as indoor air movement and radiative temperature to understand even better how occupants feel in their homes and why. Only from there it is possible to propose sustainable solutions.

**Keywords:** existent buildings, passive adaptive comfort , climate-sensitive architecture.

## 1. INTRODUCTION

Temperate continental climates present considerable daily and seasonal temperature variations in a range that goes from 0-15°C in winter and can reach up to 18-36°C in summer with a low relative humidity (30-50%).

Climate characteristics sometimes compromise architectural solutions but also, if climatic features are taken as design opportunities, architecture can advantage of its richness.

Unluckily, most of existent buildings were only designed to protect from the exterior environment often with the help of auxiliary energy, and not to work with it in an environment friendly way.

As the rate of replacement of old buildings with new buildings is very slow, the existing building stock in cities will eventually be refurbished in order to reach certain desired "up grading" levels of comfort and modernity to create the necessary conditions to put the dwelling back into the market with an economic redevelopment.

This modernization, however, usually leads to increased energy needs, which are usually covered

by conventional, non renewable, energy resources, with the consequent contribution to the pollution of the city environment and thus, to global warming.

Comfort may be defined as the sensation of complete physical and mental well-being. Thus defined, it is only to a limited extent within the control of the designer. The occupants' biological, emotional and physical characteristics also come into play. [1].

Thermal comfort for an individual is famously described by ASHRAE Standard 55-2004 (non air conditioned buildings) [2] as 'that condition of mind which expresses satisfaction with the thermal environment'. Sedentary people are particularly sensitive to local discomfort whereas those with a higher level of activity are less likely to complain. Quantitative units for local discomfort are given in ISO 7730 [3].

It is important to take into account that the way in which occupants evaluate the indoor thermal environment is context dependent and varies with time. That is directly related to the way occupants usually adapt to variations and how are their comfort expectations. With all of these in mind, the main issue that is addressed in this paper is to know how occupants feel in their homes.

The post-occupancy evaluation (POE) is an increasingly important tool for the improvement of buildings and the evaluation of what makes energy-efficient and sustainable buildings. [4] In the POE, the occupant provides a subjective measure of a building and acts effectively as "its" memory. [5]

The answer of these questions will provide knowledge to nourish a climate-sensitive architecture that will give occupants the necessary tools (the ones each of them will be comfortable with) in order to enable passive adaptive comfort.

The main objectives of this work are:

- To work with most common single housing typologies in Mendoza, Argentina. (90% of existent urban tissue. [6])
- To know thermal comfort perception of occupants.
- To identify unsatisfied comfort needs and transformations that occupants have performed or wish to carry out to better their homes.
- To recognize envelope flexibility opportunities feasible to be used in houses' adaptation to occupants needs of comfort and image desires.

## 2. METHODOLOGY

The case experience has been conducted through winter and summer surveys in the city of Mendoza, Argentina and presents interesting results related to the role of the envelope and the sensitivity occupants have towards their own living environment. The characteristics of Mendoza's climate are shown in Figure 1 through its Bioclimatic Chart.

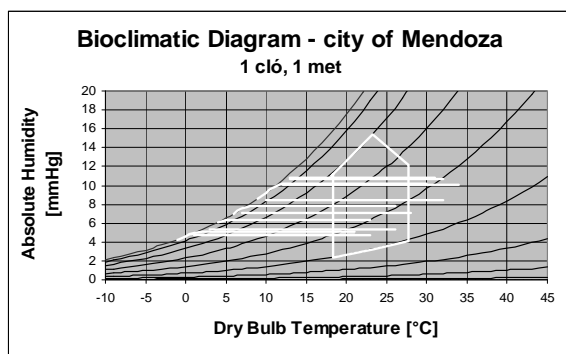


Figure 1. Bioclimatic chart. Mendoza, Argentina.

According to the Bio-climatic chart, Thermal Inertia is suggested as adequate to couple with the high thermal amplitude. Passive strategies such as Direct / Indirect Passive Gain and energy conservation in winter and Sun Protection and Nocturnal Ventilation in summer are adequate strategies to regain internal comfort. [7]

There were identified three main typologies (See Table 1). Each case presents a different level of compactness:

- a- OPEN: Half-patio Mediterranean House
- b- COMPACT: Rational Movement House
- c- SEMI-COMPACT Neocolonial Chalet

TYPOLOGY	OPEN Mediterranean half-patio	COMPACT Rational Movement	SEMI-COMPACT Neocolonial Chalet
External Envelope/ Floor Area Factor [8]	3.18 m2 of envelope in m2 of floor	1.95 m2 of envelope in m2 of floor	2.62 m2 of envelope in m2 of floor
External Envelope/ Included Volume	0.79 m2 of envelope in m3 volume.	0.54 m2 of envelope in m3 volume.	0.65 m2 of envelope in m3 volume.
Compactness Coefficient = c [9]	0.60 -0.75 open typology	0.90-100 compact typology	0.75-0.90 semi-compact typology

Table 1. Characterization of three studied typologies. [10]

The qualitative evaluation method was based in comfort perception enquiries performed in the same cases in two different seasons: winter and summer. Results were complemented with information drawn from direct observation. Qualitative results were finally compared with quantitative information already obtained, analysed and published. [11] [12] [13].

Field studies of thermal comfort have shown that the way in which occupants evaluate the indoor thermal environment is context-dependent and varies with time. In using occupants as part of the means of measuring buildings, post-occupancy evaluation should be understood as reflecting the changing nature of relationship between people, the climate and buildings. Surveys are therefore measuring a moving target, and close comparisons based on such surveys need to take this in to account.[4]

## 3. CASE STUDIES

Selection of sixty representative cases, twenty per typology. Some examples can be seen in Fig. 2 to 4.



Fig. 2 OPEN. Half-patio Mediterranean House



Fig. 3 COMPACT. Rational Movement House



Fig. 4 SEMI-COMPACT. Neocolonial Chalet

Orientation plays an important role related to comfort perception. Because of this, there were considered five houses in each one of the four orientations to be found in the squared reticule of the city of Mendoza: North, South, East and West. Therefore it is possible to obtain global answers responding to a particular typology and not influenced by a particular orientation. And also, by reorganizing the obtained data to identify responses influenced by orientation with or without the typology variable.

General data such as: time of the day (from 4 pm to 6 pm) and season the enquiry was performed (winter/summer), amount of inhabitants per home (usually 4 or 5), years occupants' have lived in their homes (between 10 and 30), consent to control the homogeneity of selected cases and to restrict variables that could create noise in the obtained results.

#### 4. THERMAL COMFORT PERCEPTION

To evaluate the obtained responses to enquiry questions related to comfort it is important to take in to account adaptive opportunities occupants' have had at their hand. This is why it is worked at the same time with direct observation performed by a professional to identify changes that do not belong to the original architecture but to occupants spontaneously modifying their homes trying to make them more comfortable.

Also is important to keep in mind that : Over time the temperature that people find comfortable (the "comfort temperature") is close to the mean temperature they have experienced. This implies that the conditions that occupants find comfortable are influenced by their thermal experience and that they can adapt to a wide range of conditions. Temperatures up to 2°C from the comfort temperature generally give only a minimal rise in discomfort. [14]

Therefore, the reference to comfort perception in enquiries must be taken from the adaptation to climate point of view and, in this line of thought, lack of comfort or the use of mechanical air conditioning, must be taken as examples of the incapacity of occupants to adapt to indoor climate in their homes. It must be kept in mind that most of inhabitants (62%) inhabit their homes for more than 20 years.

##### 4.1 Summer comfort

68% of occupants perceive their homes as comfortable in summer. Even though not every house

has air conditioning equipment, every year there are more houses that do. It is a matter of time before every house that presents lack of comfort will restore comfort by mechanical means and therefore by using non-renewable energy. Understanding reasons of discomfort will lead architects in the path of providing adjusted passive solutions.

In open typology, 70% of the occupants feel comfortable in their homes while the other 30% perceive their houses hot. Only 15%, that is half the occupants without comfort, use air conditioning (AC) to restore comfort. See Figure 5.

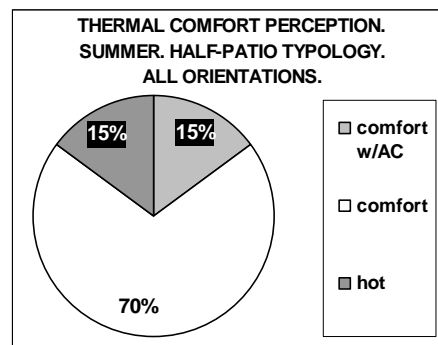


Figure 5. Summer: 70% of occupants feel comfortable in open typology houses.

In the case of the houses that were oriented North (towards the Equator in the South Hemisphere), the percentage of occupants in comfort rises to 80%, been only the 20% of cases above expected temperatures.

As we are evaluating an open typology, this is the effect of a poor response of the protection resources. That is, usually windows are protected by horizontal galleries with an excellent result in providing an intermediate space between indoors and outdoors, moderating the incident radiation on windows. In some cases (the ones overheated) this galleries have been glazed and whenever they remain closed, spaces indoor raise their temperatures. It is necessary to provide new protections to deal with incident radiation before it reaches the glazed galleries. See Figure 6.

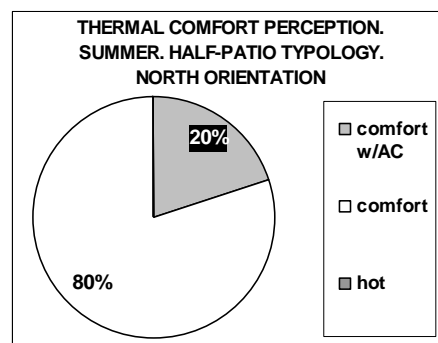


Figure 6. Summer: 80% of occupants feel comfortable in north open typology houses.

In the case of compact houses, the perception of comfort diminish to 60%, while only 30% of uncomfortable occupants use air conditioning to deal with the unpleasant overheating. See Figure 7.

In the case of North (Equator oriented) houses, all of them are perceived as hot. To understand this situation we have to use the direct observation resource. This is a typology that was conceived without any blind or sun protection. Its windows are about the 20% of the façade surface and therefore the house is overheated.

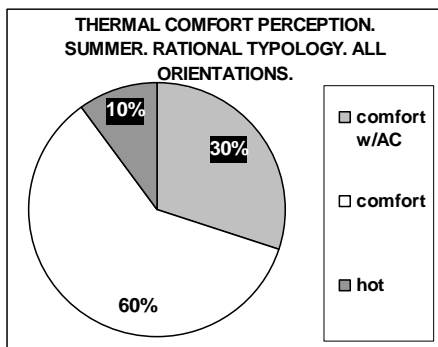


Figure 7. Summer: 60% of occupants feel comfortable in compact typology houses.

Occupants solve this problem by adding internal blinds or curtains that do not completely solve the overheating problem and also diminish considerably natural day lighting and sight. See Figure 8.

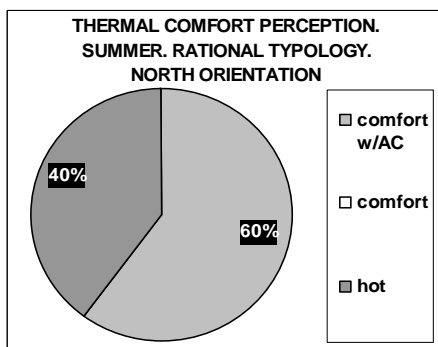


Figure 8. Summer: There is a clear problem of overheating in compact typology houses.

In the case of the semi-compact typology, perception of comfort increases to 80% (see Figure 9) and in the case of houses oriented towards the Equator (North) the total of occupants enquired feel comfortable. This can be understood by analyzing big tilt roofs that shadow windows and by the presence of external blinds in every window. Truth is that they are always vertical, even though this is not the best way to protect spaces when they are oriented North (because of the lack of daylight and sight that can result from their use), occupants feel good. Main problems are registered with West orientations.

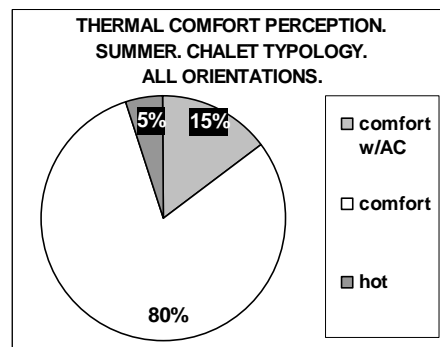


Figure 9. Summer: 80% of occupants feel comfortable in Chalet houses.

#### 4.2 Winter comfort

In all typologies it is used auxiliary heating in winter. Even though this fact and the great non-renewable energy use (usually natural gas), 54% of occupants perceive their houses as cold in winter.

In open typology houses, 60% of occupants feel their homes comfortable in winter. (See Figure 10) In the case of houses oriented North (towards the Equator) the total of people enquired perceived their houses comfortable in winter. This is because houses present intermediate spaces such as glazed galleries (greenhouse effect) and double door porches that act as buffer spaces between the outdoor climate and indoor spaces. The main problem are houses oriented South because energy conservation strategies materialized in buffer spaces and thick masonry walls are not enough to maintain spaces comfortable.

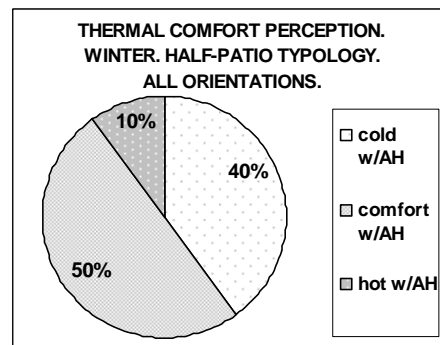


Figure 10. Winter: 60% of occupants feel comfortable (of hot) in open typology houses.

The difference of perception when radiation is coming into a space is due to mean radiant temperature that makes us feel comfortable even if air temperatures are not as high as we think they are.

In the case of compact typology houses, 50% of occupants perceived them as comfortable or hot, while the other half feel them cold. This houses have mainly two orientations each along an axis that can be N-S or E-W. This is because they are usually attached one to another and only leave two façades: one towards the street and the other towards the patio.

Houses with North and South façades free have a better response. See Figure 11.

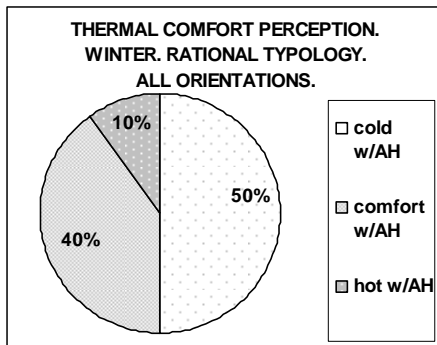


Figure 11. Summer: Half the occupants feel comfortable (or hot) in compact typology houses.

Semi-compact houses present 40% of occupants that perceive them comfortable. (See Figure 12)

These houses are difficult to classify in orientations because they are detached and their morphology usually articulates volumes, therefore they are not open, nor compact. These lead to situations in which there are almost the same amount of exposed surface in all orientations. Mere over their tilt roofs also present a variety of orientations and, their surface, is important in the heat balance because the more they are tilt the more incidence they have over the overall house behaviour. This is the reason we take this results as representative of all orientations.

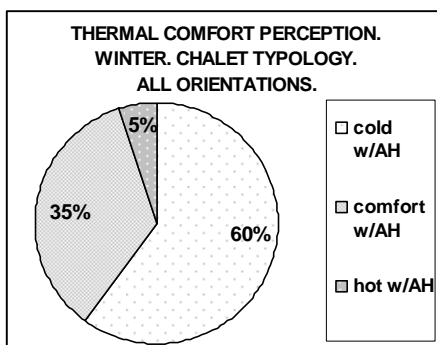


Figure 12. Summer: 40% of the occupants feel comfortable (or hot) in semi-compact houses.

## 5. COMPARED RESULTS AND CONCLUSIONS

In table 2, results from enquiries to occupants are compared with mean air temperature measurements. This information incorporates results from enquiries addressed in this paper and data obtained in previous works that were focused in site measurements. These measurements were performed with ONSET H8 data loggers every 15 minutes and in periods of twenty days in each season.

See table 2 for a summary of referred measured data compared with inhabitants' perception of comfort.

	OPEN Mediterranean half-patio	COMPACT Rational Movement	SEMI-COMPACT Chalet
SUMMER – All orientations			
Mean exterior Air Temp.	18-36°C		
Mean interior Air Temp.	25-29°C	27-29 °C	27-28 °C
Occupant Comfort Perception	70%	60%	80%
WINTER – All orientations			
Mean exterior Air Temp.	0-15°C		
Mean interior Air Temp.	16-20 °C	15-20 °C	15-18 °C
Occupant Comfort Perception	60%	50%	40%

Table 2. Measurements. Years 2004 and 2005 [15]

Some comparisons are very interesting to analyze, for example: in the summer case, even though internal temperatures seem equivalent between compact and semi-compact houses, occupants perceive them in a very different way (60% of occupants are comfortable in compact houses against 80% in semi-compact.) This can be understood probably because of air movement comfort or radiative temperatures.

This also happens in the winter comparison between open typology houses and the compact one. This can be once more related to indoor air movement, specially at night. The possibilities of an open envelope to exchange energy are more probable than in compact one.

It is clear that measurements must be complemented with POEs because of two main reasons: In one hand, occupants are the ones that finally feel their homes. On the other hand, differences between perceptions when there are none significant ones in air temperature measurements relate to new data that must be collected in order to stand closer to the whole picture.

Therefore, a further study is expected to follow the one presented on this paper not only with new enquiries and air temperature measurements but also including radiative temperature measurements and indoor air movement to add new variables of analyses.

The more the variables analyzed, the closer we will be to fully understand how occupants feel in their homes and why. Only from there it is possible to propose sustainable solutions.

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