Solar shading and ventilation patterns: to what extent are they accurate to comfort expectations?

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ABSTRACT

In temperate continental climates, the reduction of the solar radiation influence in summer season, over the comfort conditions of internal spaces, can only be achieved by natural means in two ways: one possibility is through occupants' adjustments of themselves (clothing, activity, metabolism) and the second possibility is through occupants' control of the energy flows (heat, light, sound) in-out the building (management of the envelope). The failure of one, or both strategies, can result in the compromise of internal comfort and as a consequence, the abuse of active non-renewable energy consuming devises. This paper assesses two main passive techniques for overheating prevention: solar shading and ventilation by analysing window opening and blind usage patterns of typical family houses. The study is conducted during working days and on weekends to address the "home alone" situation and the "full house" scenario. In each case internal gains by occupation and hourly management of the envelope can be opposed variables. Integral comfort perception (including thermal, visual and auditive comfort) does not always match internal temperature measurements. Criteria of how to address this problem are discussed, focusing on how to support intuitive management of the envelope and the correct selection of energy flow in-out the building.

1. INTRODUCTION

Solar shading and ventilation patterns: to what extent are they accurate to comfort expectations? This question will lead the development of this paper. There are two main parts in it:

On one hand, *solar shading and ventilation*, that is: two passive strategies for summer season and these related to the word *patterns*, meaning the way they are being used, and, by whom? By occupants, of course! On the other hand, the problem is set (not related to a physical response of the building) but to a psychological space perception by the mentioned occupants and their *comfort expectations*.

It is not hard to see that the possibility of comfort (and with that the responsibility to meet own expectations) lays on occupants (in summer, given a building with adequate thermal mass, solar shadings and openings for ventilation in a continental temperate climate).

Are occupants conscious of what they have in hands? Are architects and designers aware that the actual performance of what they project and build "to meed comfort requirenments" will be constantly (or not) modify by occupants? Do they give main guidance on how to manage the building? Are all buildings the same? Are all users the same?

2. WHAT DO WE MEAN BY COMFORT?

There are many definitions of comfort. It is important to identify the variables that come into play for its achievement. Let's review some of the most significant answers to this matter:

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 characteris-tics also come into play. (Goulding et al., 1992).

Thermal comfort for an individual is also famously described by ASHRAE Standard 55-2004 as 'that condition of mind which expresses satisfaction with the thermal environment'. Quantitative units for local discomfort, under steady-state conditions, are given in ISO 7730 (ISO, 1984).

Classic comfort standards are based on the heat balance model of the human body, which assumes that thermal sensation is influenced by four environmental factors (temperature, thermal radiation, humidity and air speed), and three personal factors (metabolism, activity and clothing). New theories state that thermal sensations, satisfaction, and acceptability are all influenced by the correspondence between what really exist and occupant's expectations.

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 ºC from the comfort temperature generally give only a minimal rise in discomfort (Nicol and Humphreys, 2005).

People who live and work in naturally ventilated free running buildings, where they can adjust the envelope of the space by opening windows and moving blinds, become used to thermal diversity that reflects local patterns of daily and seasonal climate variability.

That is: building occupants will make themselves comfortable, first if they are given the opportunity and secondly if they are willing to do so. Such a description is inherently more sustainable as it does not seek to specify answers, but only to provide the necessary character and context for a successful building. As a result, the relationship occupant-building will be looser, the building more flexible and the occupant more responsible. In this line of design often significantly less energy will be required to achieve 'comfort'.

3. OCCUPANTS' PARTICIPATION

The way in which comfort is achieved is particularly important in passive solar buildings as it can have a profound effect on occupant's perception of well-being.

In temperate continental climates, the reduction of the solar radiation influence in summer season, over the comfort conditions of internal spaces, can only be achieved by natural means in two ways: one possibility is through occupants' adjustments of themselves (clothing, activity, metabolism) and the second possibility is through occupants' control of the energy flows (heat, light, sound) in-out the building (management of the envelope). This second group is directly dependent on the design of the building and its cooling systems. The failure of one, or both strategies, can result in the compromise of internal comfort and as a consequence, the misuse of active non-renewable energy consuming devises.

3.1 Occupants' adjustments of themselves

For constant clothing levels, the temperature ranges for comfort are relatively small (+/- 2ºC). However, if people are willing to modify their clothing during the day, then a much wider temperature range is acceptable (+/- 4ºC). This is a first step toward personal adaptation specially in daily very variable climates such as temperate continental climates.

Givoni suggests that the comfort temperature range in acceptable still air conditions, for people that inhabit developed countries, is 20°C-26°C for the 80% of persons in comfort with 1 cló and 1 met of activity. (Givoni, 1991). For countries in development the author suggests the flexibility of 2ºC of the limit temperatures, that is 18ºC-25ºC in winter, and 22ºC-28ºC in summer. The author refers as developed countries, to habitats with central conditioning. Inhabitants of spaces without this type of thermal conditioning tolerate higher thermal variations. In relation with the level of activity we can affirm that sedentary people are particularly sensitive to local discomfort whereas those with a higher level of activity are less likely to complain. The type of activity that will be developed in the building will increase or decrease design temperature ranges.

To give a parameter towards the adaptive goal it is possible to state that during progressive increasing or decreasing temperatures with changes up to 5ºC an hour people sense the actual thermal environment in the same way that they do in steady-state conditions.

But above all this, beyond fundamental physics and physiology, occupants' expectations and thermal preferences play an important psychological role. Occupants of free running natural ventilated buildings need to accept variability and to take action in their thermal environment by participating in the adaptation towards comfort. Otherwise, their expectations will hardly be fulfilled.

3.2 Occupants' control of the energy flows in-out the building

The role of controls in comfort has been observed in the past, but with the interest in adaptive comfort, there has been an increasing interest in the way building controls effect comfort and adaptability. POE-type surveys have demonstrated the importance of control on the satisfaction felt by building occupants (Leaman and Bordass, 1999). The study about what controls are most effective/useful/important, about how and why they are used by building occupants, and about how they might be made more effective must also become a concern of thermal comfort research. (Nicol and Roaf, 2005)

Most houses are provided with the following means of passive control of their envelope:

(1) open or close a window,
(2) open or close a door,
(3) adjust internal curtains,
(4) adjust an external blind (horizontal or vertical depending on façade orientation)

And also occupant may adjust mechanical conditioning by:

(5) adjust a thermostat,
(6) turn a local heater/radiator on or off,
(7) turn local lighting on or off,
(8) turn general lighting on or off,
(9) adjust air-conditioning and
(10) adjust a local fan/air outlet.

Nowadays buildings present more possibilities of mechanical control than passive adaptation of their envelope. How and why controls are used? Passive controls need anticipation and their effect are not immediate. To prevent or allow energy flows in-out the building first it is needed to know what to do and when to do it. This is time and mind demanding. On the contrary mechanical conditioning adjustment usually provides an immediate response and therefore there is no need of anticipation. These characteristics make mechanical conditioning more and more "popular" than natural envelope management since industrial revolution. We need to review these habits towards the achievement of local and global sustainability.

It is presented here one of the main keys that structures occupant-building relationships: physical, physiological and psychological self-adjustment variables in one hand and on the other hand the possibility of in-out energy flows passive management. The first set of variables depends on occupants themselves (and their willingness to adapt) and the second one depends mostly on the time occupants spend in their house (and actually perform the envelope management).

This analysis will be completed by studying two main passive techniques for overheating prevention that are (giving a house with thermal mass): solar shading and ventilation patterns in two common situations: "home alone" and "full house scenarios".

4. MAIN PASSIVE TECHNIQUES FOR OVERHEATING PREVENTION

This paper assesses two main passive techniques for overheating prevention: solar shading and ventilation by analysing window opening and blind usage patterns of typical family houses.

According to the Bio-climatic chart, Ventilation and Thermal Inertia are suggested as adequate passive strategies to regain internal comfort in temperate continental climates. It is important to know wind's characteristics (direction and frequency) to analyse how to best profit from this natural resource.

There are two ways in which Ventilation can improve comfort: One is by a direct effect providing a higher indoor air speed by opening the windows to let the wind in, thus enhancing the cooling sensation of the inhabitants. This strategy is termed Comfort Ventilation. The other way is to ventilate the building only at night and thus cool the interior mass of the building. During the following day the cooled mass reduces the rate of indoor temperature rise. This strategy is termed Nocturnal Ventilative Cooling (Givoni, 1998)

As for solar shading, barriers and filters are usually combined with the transparent elements of the envelope to protect or to diminish the incidence of exterior energy fluxes. They can be movable or fixed; this choice must be hand on hand with the possibilities of having an active occupant.

Solar shading must respond geometrically with the orientation (vertical to protect east and west façades and horizontal to protect the surfaces facing the Equator). They may be made with a great variety of expressions, materials and colours to wider its possiblities of architectural integration and user acceptance.

In relation to solar radiation, opaque elements in solar shadings will be barriers and translucid elements will only act as filters. It is clear that in theory they are highly recomended for temperate continental climates. In pactice possibilities to prevent overheating with the exposed passive techniques must be analysed related to occupants' use patterns. With that objective two houses will be compared and analysed as a case study in Mendoza, Argentina (32.88º south latitude, 68.85º west longitude and 827 m.a.s.l.).

4.1 Solar shading and ventilation patterns: "home alone" and "full house" scenarios. A case study.

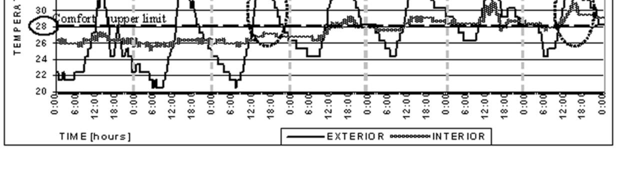
The study is conducted during working days and on weekends to address the "home alone" situation and the "full house" scenario.

Figure 1 shows a series of measurements of two cases: Case A and Case B. Interior and exterior measurements were performed *in situ* with HOBO data loggers every 15 minutes. There were measured two equal rooms within two exact houses, one next to the other, oriented towards the equator in the city of Mendoza, Argentina.

In Case A there is a difference in the management of the envelope on week days "home alone" situation and on weekends "full house" scenario.

On week days the house remains most of the time closed day and night avoiding in and out energy flow exchanges. This situation leads to avoid non desired energy flows in, such as those during the hottest hours from 11 am to 18 pm. But also avoids the entrance of desired energy flows at night time such as winds for convective cooling. (See as an example Wednesday)

On weekends, as the family stays in the house, they open the envelope during daytime without taking into account that they are letting in non desired energy flows that rise interior temperatures, and as a consequence these are higher than the established upper comfort limit. During night time the house is closed again and this action prevents the entrance of desired energy flows. (See as an example Sunday)



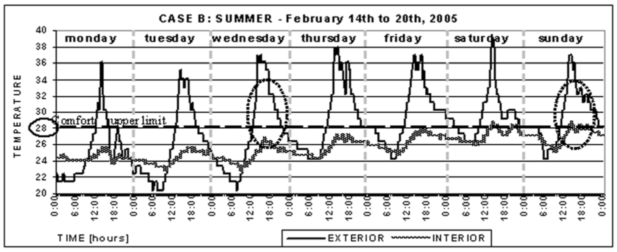


Figure 1. Case A and Case B. In situ interior and exterior temperature measurements. Compare “Home alone” situation (see Wednesday as an example) and “Full house” scenario (see Sunday as an example).

Occupants' perception is that the house is “too warm” and they tend to turn on the conditioner unit within the space they are staying. They are used to the immediate response by pressing a button to their temperature they desire.

In Case B everyday of the week the envelope tends to be managed in the same way: most of it closed (windows and blinds) during day time to avoid the entrance of hot non desired energy flows and open at night time to allow in cool desired energy flows. Ventilative cooling works perfectly combined with the thermal inertia and solar protection that the house already has. The “full house” scenario that occurs on weekends can rise the interior temperature due to an increment of internal gains. (Compare Wednesday and Sunday with their equivalents in Case A).

Occupants' perception is that the house is “very comfortable”. They are very self-conscious that the achieved well-being is partly a result of their active use of the controls in their house's envelope.

6. CONCLUSIONS

In relation with the question about comfort it was concluded that the way in which occupants evaluate the indoor thermal environment is context dependent and varies with time. Therefore, thermal comfort is a goal of building occupants and not merely a product of the building services, although the building services may provide part of the means by which the goal is achieved. Buildings and their occupants interact continually and the relationship between them is dynamic.

By studying the particularities of the case study in which two exact houses were compared, the answer to the initial question: Solar shading and ventilation patterns: to what extent are they accurate to comfort expectations? Answers differ significantly.

In each case internal gains by occupation and hourly management of the envelope can be opposed variables. That is whenever there is occupation in the house, there will be internal gains, but at the same time, this opens the possibility of hourly adjustment of protections and openings. As we observe in Case B, occupant' actions are of great benefit.

Nevertheless, these possibilities will have a high profit with active users that intuitively manage the envelope in a successful manner (Case B), and could also have inverse consequences when users do not know when and how to use the natural controls provided in the architecture. (Case A on weekends). The third possibility is the house free-running without any intervention of the occupant, that remains closed to desired and non desired energy fluxed (Case A on week days). This last option is preferable to the case of an incorrect use pattern.

It is then important to enthusiast occupants to participate in the management of their living spaces, and in this is crucial to focus on how to support intuitive management of the envelope and the correct selection of energy flows in-out the building. But, if users will not participate at all, the option is to design a free-running building focusing on fixed solar shadings to ensure a neutral relationship with the environment, neither profiting, nor benefiting from it. Another possibility is to add seasonal timer controls for openings for a standard behaviour.

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