# Adaptive Comfort: Passive Design for Active Occupants

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## Abstract

The adaptive model of thermal comfort shifts attention from engineered comfort solutions to architectural ones. As the concept of adaptive comfort displaces the old static model, architects are beginning to explore the opportunities to engage occupants in the provision of occupants' comfort, which in turn has re-awakened an interest in natural ventilation.
**Keywords:** adaptive model, thermal comfort, occupants.

## Introduction

After the 1970s oil crises, many countries started to look for ways of improving building energy efficiency. Since HVAC is the single largest energy end use in the built environment, it was inevitable that designers would start to question our dependence on air-conditioning. The spread of air-conditioned environments in the 20$^{th}$ century dramatically altered occupants' expectations of indoor environments.

Since the ultimate success or failure of a building project depends heavily upon the quality of the indoor environment delivered to the building occupants (Ürge-Vorsatz et al., 2007), it is imperative that buildings meet occupants' expectations. And with the advent of air conditioning, Ackerman (2002) argues, occupants' expectations changed.

There is fairly persuasive evidence that ice-cold air transported working and middle class customers to movie palaces, department stores, hotels, and railroad cars as part of the total entertainment experience. Air-conditioned environments offered an escape from a drab and hot workaday life and, at the same time, it became increasingly associated with luxury, comfort, and modernity.

As air-conditioning became embedded in the perceptions and expectations of occupants, technological innovation shifted design responsibility in comfort provision from the architect to mechanical engineer, and control responsibility from the occupant to technology (Roaf et al., 2010).

The engineering of comfort solutions gave architects the 'freedom' to design building envelopes without reference to thermal comfort or passive design. All their buildings needed was needed was an endless supply of cheap fossil fuel energy to run them.

Of course, this approach proved unsustainable. With the mainstreaming of green building places building performance back on the design agenda, architects are waking from the cheap oil era to find they've been deskilled by their reliance on engineered solutions.

To reassert the primacy of design in the post-carbon era, architects must take back responsibility for building performance and occupant comfort. For this to happen, they must come to understand how behaviour and design can be merged into a synergistic approach that contributes to both energy conservation and occupant satisfaction. Adaptive comfort shows the way, by promoting environments that are at once more sustainable and more stimulating than air-conditioned ones.

## Static vs. Adaptive Models of Thermal Comfort

Even though comfort has been defined as 'the state of mind that expresses satisfaction with the surrounding environment' (ASHRAE Standard 55, 2010), conventional design approaches assume that people have relatively constant biological comfort requirements, and that the environment is a set of variables which should be controlled to conform to that constant range. However people are *not* constant, and nor do they require constancy. Standardisation of indoor conditions can lead to sterile environments, because comfort depends not only on control of excesses in ambient conditions but also on stimulation through the senses from variations in conditions.

The tension between conventional, or 'static', and adaptive comfort theories has been played out in innumerable papers (Humphreys, 1978; Nicol, 2004), but it became especially prominent by the end of the 20th century when the oil and climate crises called into question the amount of energy required to air-condition indoor environments.

The static approach is based on Prof. Ole Fanger's 1960s climate chamber experiments. Fanger produced a comprehensive comfort index, Predicted Mean Vote, or PMV, which submits that it is possible to define a comfortable state in terms of the subject's *body* rather than the environment (Fanger, 1970). His book proposed three necessary conditions for thermal comfort: a steady-state heat balance; a mean skin temperature at a level appropriate for the metabolic rate; and a sweating rate at a level appropriate for the metabolic rate. Based on these conditions, the final equation comprises variables related to: the function of clothing (clothing insulation and ratio of clothed surface area to nude surface area); activity (metabolic heat production and work); and four environmental variables – air temperature, mean radiant temperature, relative air speed; and vapour pressure of water.

Fanger's thermal comfort model is as widely criticised as it is supported. In his dissertation, Fanger himself explained that the PMV index was derived in laboratory settings and should therefore be used with care for values below -2 and above +2 (Fanger, 1970). But beyond its reliability, probably the most important criticism of the PMV index is its concept of a universal neutral temperature. 'The cool, still air philosophy of thermal comfort, which requires significant energy consumption for mechanical cooling, appears to be over-restrictive and, as such, may not be appropriate criterion when decisions are being made whether or not to install HVAC systems' (de Dear and Brager, 1998). The 'adaptive comfort model' successfully challenged PMV and shifted the paradigm in favour of natural variability.

## Return of the Welcome Breeze

Even though the static approach is able to take some behavioural adaptation into account, for example clothing or air speed, it fails to account for psychological adaptation. But psychological adaptation can result in significant differences in occupant satisfaction with and acceptance of an environment (de Dear and Brager, 2002). This is particularly important in indoor environments where occupants are exposed to more dynamic conditions – such as naturally ventilated buildings. Understanding how behavioural adaptation operates can enable designers to enlarge the thermal spectrum to which occupants are exposed. This means designers can rely less on air-conditioning to provide acceptable thermal conditions, thereby lessening the environmental footprint of the building.

de Dear and Brager (1998) set out the rationale for adaptive comfort as follows:

Building occupants are not simply passive recipients of their thermal environment, like climate chamber experimental subjects, but rather they play an active role in creating their own thermal preferences. Contextual factors and past thermal history are believed to influence expectations and thermal preferences. Satisfaction with an indoor environment occurs through appropriate adaptation.'

Based on an analysis of over 20,000 row set of indoor microclimatic and simultaneous occupant comfort data from buildings around the world, the ASHRAE RP-884 database found that indoor temperatures eliciting a minimum number of requests for warmer or cooler conditions were linked to the outdoor temperature at the time of the survey. Buildings were separated into those that had centrally-controlled heating, ventilating, and air-conditioning systems (HVAC), and naturally ventilated buildings (NV). Since the ASHRAE RP-884 database comprised existing field experiments, the HVAC versus NV classification came largely from the original field researchers' descriptions of their buildings and their environmental control systems. The primary distinction between the building types was that NV buildings had no mechanical air-conditioning, and that natural ventilation occurred through operable windows that were directly controlled by the occupants. In contrast, occupants of the HVAC buildings had little or no control over their immediate thermal environment (de Dear and Brager, 2002).

The adaptive model of thermal comfort advocates the shift from statically controlled indoor environments to passively ventilated buildings occupied by active occupants. Its posterior implementation in ASHRAE 55 (2004), providing for higher air speed values and control, was a step towards mainstreaming naturally ventilated buildings. Natural ventilation had been redefined in the language of thermal comfort research from 'draft' to 'welcome breeze'.

## Summary

Behavioural change in buildings can deliver fast, low-cost improvements in energy efficiency and greenhouse gas emission reductions. In order to promote behavioural change, however, buildings must be designed to re-engage occupants in the achievement of comfort.

It is becoming clear that the idea of air-conditioning as a pathway to 'freedom' for architects is both illusory and unsustainable. A lack of understanding by building designers of building performance and occupant behaviour has led to engineered solutions supplanting architectural ones. Buildings that are disconnected from the outdoor climate and environment in which they are situated are increasingly being viewed as obsolete. With this in mind, designers are starting to consider how to widen the range of opportunities available in a building to provide comfort for occupants. This in turn has re-awakened an interest in the role of natural ventilation, returning the responsibility for occupant comfort to the architect.

Climate control requires a flexible approach, mediating relationships between the whole, sensory person and the environment. Achievement of satisfaction (not only comfort) requires the development of a more comprehensive brief, increased selectivity in the application of performance and design criteria, and a more flexible, humane set of response systems.

When designed carefully, naturally ventilated indoor environments need not compromise occupant comfort, wellbeing or productivity. Indeed, a naturally ventilated building can provide an indoor environment far more stimulating and pleasurable than the static indoor climate achieved by centralised air-conditioning.

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