THERMAL COMFORT
INTRODUCTION
Research Brief

PARTNERSHIP INITIATIVE
INTEGRATED DESIGN LAB
at the Center for Integrated Design

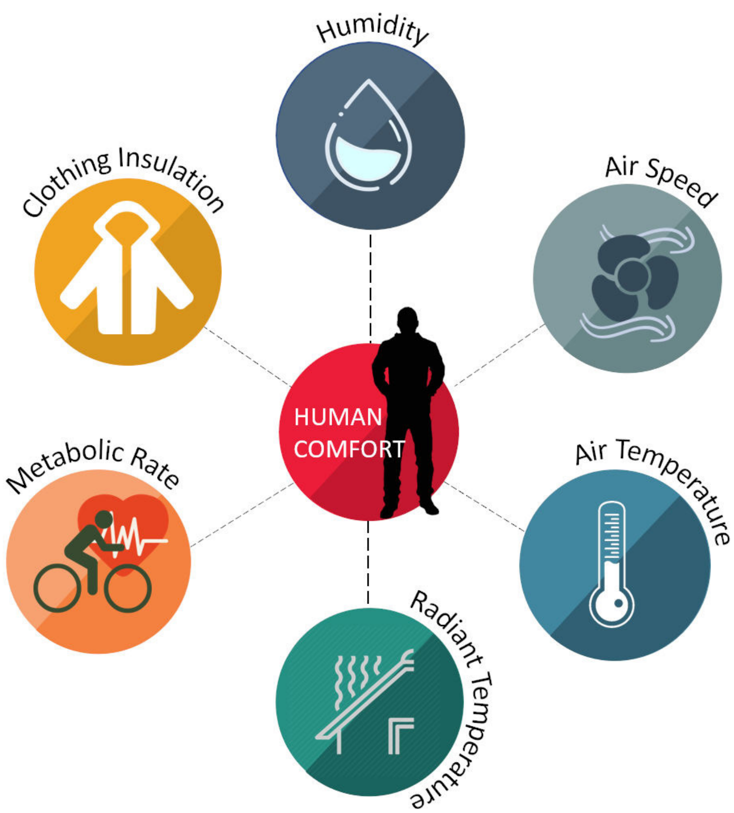

Figure 1:
Factors Affecting Human Thermal Comfort

Source: https://www.pae-engineers.com/news/articles/a-holistic-approach-to-thermal-comfort

Keywords:
Thermal Comfort, Adaptive, Static, Environmental Factors, Personal Factors

CONTENT OVERVIEW

THERMAL COMFORT INTRODUCTION SUMMARY

Thermal comfort is the state of satisfaction with one's thermal perception. Thermal comfort is affected by both environmental factors and personal factors such as humidity, air speed, air temperature, radiant temperature, metabolic rate, and clothing insulation.

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I. Introduction

Thermal sensation is the subjective expression of one's thermal perception of the environment (ASHRAE-55 2017). A subset of thermal sensation is thermal comfort which is a state of satisfaction with one's thermal perception. Both environmental and personal factors affect thermal comfort. These factors can be optimized to provide the greatest number of individuals with a thermally comfortable environment. Two primary models exist within current research to understand thermal comfort: the static model and the adaptive model. The static model relies solely on the environmental factors of an interior space and personal factors of the occupants. The adaptive model utilizes outdoor climate to modify acceptable thermal comfort ranges. Both models can be superimposed on a psychrometric chart to gather specific comfort ranges.

II. Environmental Factors:

Factors that occur within an architect's or building manager's purview fall under environmental factors. These factors are air temperature, radiant temperature, air speed and humidity. What exactly do each of these factors contribute to the thermal environment?

1. Air temperature- This factor is straight forward. Air temperature is the temperature of the air within a space. General comfort range: 68F in winter to 78F in summer (Lechner 2014).
2. Radiant temperature- Mean radiant temperature (MRT) is based on the surrounding surfaces temperatures and their emissivity. Together mean radiant temperature, air speed, and air temperature form the operative temperature of a location within a space. Suggested radiant temperature is to be as close to ambient air temperature as possible (Lechner 2014).
3. Air speed- This is the rate of air movement at a point. Air movement is relevant to thermal comfort because it promotes heat loss by convection and evaporation. Air movement is the basis of ventilation strategies. General air speed suggested: 20-60 feet/minute comfortable. 60-200 feet/minute air movement noticeable but acceptable dependent on activity (Lechner 2014).
4. Humidity- Humidity is the moisture content in the air. Relative humidity is recorded as percentages and represents the minimum and maximum moisture content possible for air at a given temperature. General comfort range: above 20% all year, below 60% in summer, below 80% in winter (Lechner 2014).

III. Personal Factors:

Some factors lie outside of the architect's scope and fall solely on the occupants. Think of that time you had to walk a few blocks to get to a meeting and once there you could not seem to cool off. Two personal factors most likely influenced your thermal state: metabolic rate and clothing insulation levels. How do these personal factors affect thermal perception?

1. Metabolic Rate- Energy transfer occurs constantly within the human body. This is relevant to the thermal environment because these energy transfers result in heat at varying rates, based on an occupant's metabolic rate. The given metabolic rate for someone at rest is 1 met (58.2W/m2) (Lechner 2014). Different physical activities result in elevated metabolic rates. If occupants of a space will likely have higher metabolic rates (gym or sports facility), then the thermal comfort range should be adjusted.

Personal Factors Cont...

2. Clothing Insulation- Insulation in a building provides thermal resistance for heat transfer. Clothing serves a similar function for the human body. Clothing insulation is defined as “the resistance to sensible heat transfer provided by a clothing ensemble” (ASHRAE 2017). Clothing insulation is measured using the CLO metric where 1 CLO is equal to 0.155 m¬2 oC/W or 0.15 CLO/lb of clothing weight. Average summer (warm) clothing is 0.5 CLO and winter (cold) is 1.0 CLO (Grondzik et. al. 2019).

IV. Static Thermal Comfort Model:

Several different thermal comfort models exist. The static thermal comfort model is the most pervasive model for understanding human comfort in buildings. This approach overlays a combination of comfortable temperature and relative humidity ranges on a psychrometric chart to depict a comfort zone (Figure 1). This model was based on the predicted mean vote (PMV) model of thermal comfort that was created by Fanger in the late 1960s. The PMV is based on young adults performing a set of activities within a temperate climate zone. The results are reflected in the ASHRAE thermal sensation index, a 7-point scale that assesses an individual’s thermal sensation (van Hoof 2007). “The PMV model includes all the major variables influencing thermal sensation and quantifies the absolute and relative impact of six factors of which air temperature, mean radiant temperature, air velocity and relative humidity are measured, and activity level and clothing insulation are estimated with the use of tables” (van Hoof et al. 2010). This model assumes a mean radiant temperature near air temperature, and that air movement is modest (Lechner 2014). Both mean radiant temperature and air movement are held constant in each iteration of the psychometric chart.

The static model is meant to inform spaces that are kept “static” by mechanical conditioning mechanisms.

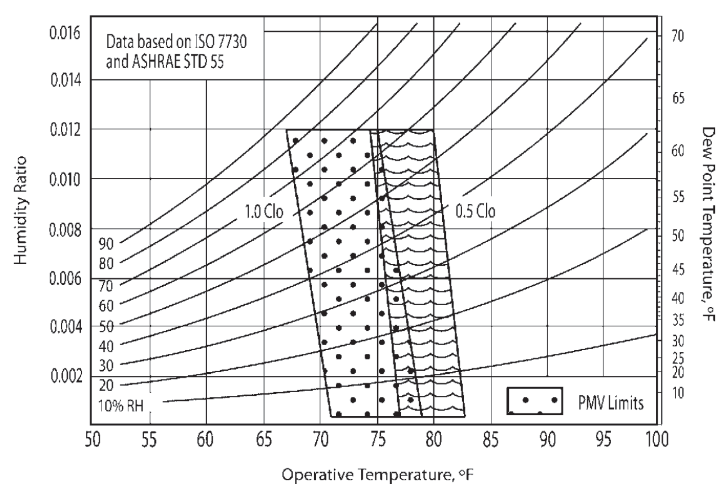

Figure 1. Static Model Psychrometric Chart displaying two zones of comfort that account for clothing worn in both warm and cold outdoor air temperatures from “Mechanical and Electrical Equipment for Buildings” (Grondzik et. al. 2019)

V. Adaptive Thermal Comfort Model:

The adaptive thermal comfort model is a more recent model for thermal comfort that advocates for a wider temperature range than the static model. Under certain conditions people can feel comfortable outside of the prescribed thermal comfort range. The static model above does not take into account that thermal conditions can be changed by inhabitants, such as with natural ventilation, adjustable shades, and variable clothing. The adaptive model "links indoor temperatures to the climatic context of the building and accounts for past thermal experiences and current thermal expectations of their occupants" (de Dear and Brager 1998). Rather than a temperature/humidity standard being static, this adaptive model accommodates for environmental and personal influences. The adaptive comfort model is shown in Figure 2, and shows a range of comfortable indoor temperatures for 80% and 90% of building occupants for a given outdoor temperature. This model delivers improved comfort while reducing reliance on mechanical cooling systems and energy consumption. This model should be applied to naturally ventilated buildings because occupants have more control over their comfort and environments

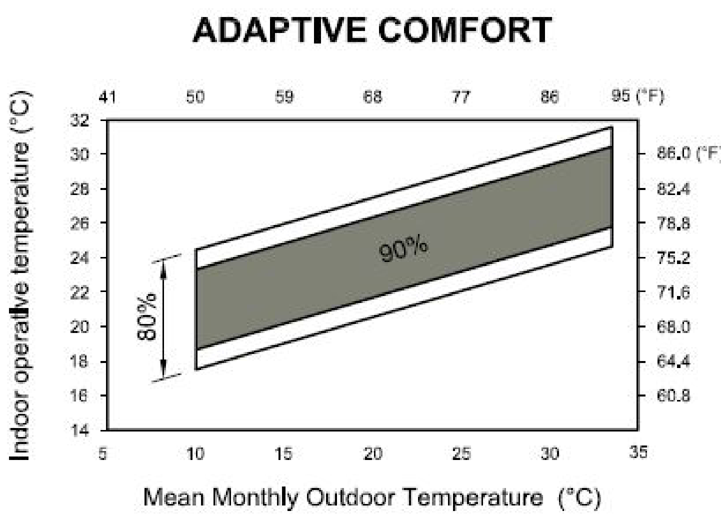

Figure 2. Adaptive Comfort Model (Lechner 2014)

VI. KEY REFERENCES

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