

Thermal comfort comparison and evaluation in different climates

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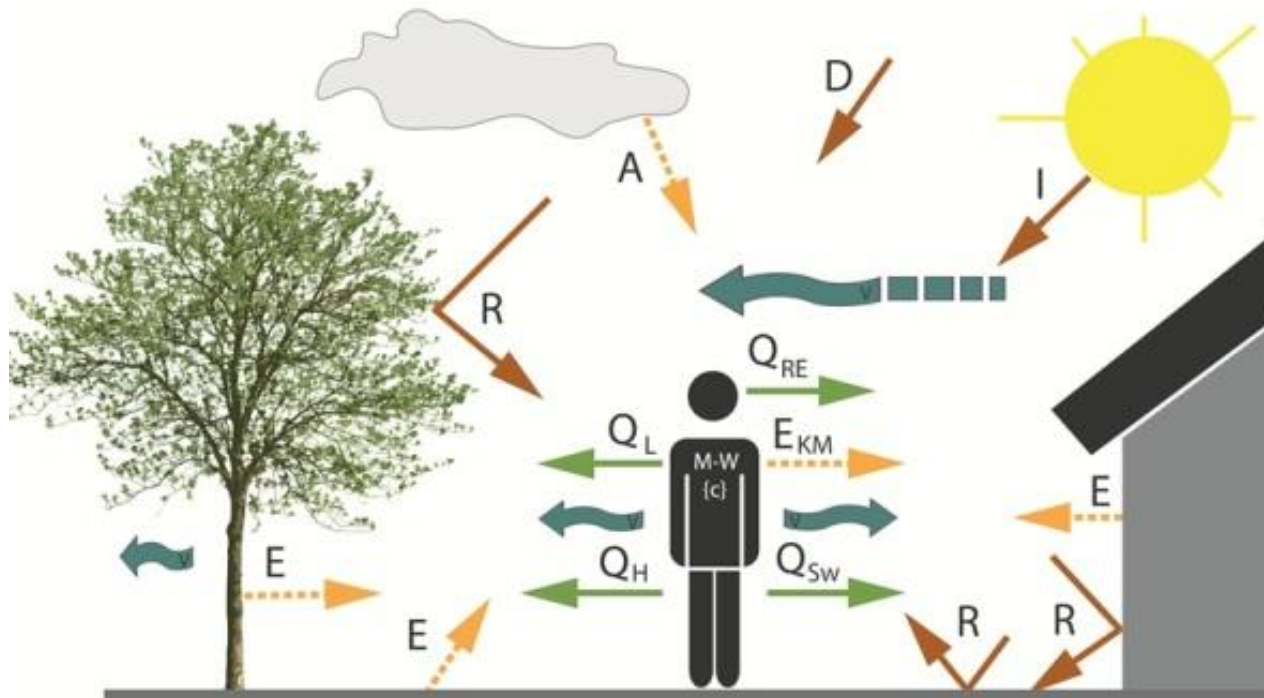
PET Comfort Index Calibration using Decision Trees

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Variables of the heat balance of man



M metabolic rate
 Q_H turbulent sensible heat fluxes
 Q_{SW} turbulent latent heat fluxes
 Q_L latent heat fluxes by water vapour diffusion
 Q_{RE} heat fluxes by respiration (sensible and latent)
 V wind speed
 $M-W$ heat production by energie metabolism

I direct solar radiation
 D diffuse solar radiation
 R reflecting solar radiation
 A atmospheric radiation
 E long-wave emission of the surrounding surface
 E_{KM} infrared radiation of human surface
 (c) thermal isolation of clothing

(nach VDI 3787 1998)

Verein Deutscher Ingenieure (1998): VDI-Richtlinie 3787
 Blatt 2, Umweltmeteorologie: Methoden zur human-
 biometeorologischen Bewertung von Klima und Lufthygie-
 ne für die Stadt- und Regionalplanung, Teil I: Klima, Berlin.

Introduction

- Biometeorological indices are applied to understand thermal comfort and its effects on human being

Physiological Equivalent Temperature index PET

“the physiological equivalent temperature at any given place (outdoors or indoors) is equivalent to the air temperature at which, in a typical indoor setting, the heat balance of the human body (work metabolism 80W of light activity, added to basic metabolism; heat resistance of clothing 0.9 clo) is maintained with core and skin temperatures equal to those under the conditions being assessed”
(Höppe, 1999 page 73)

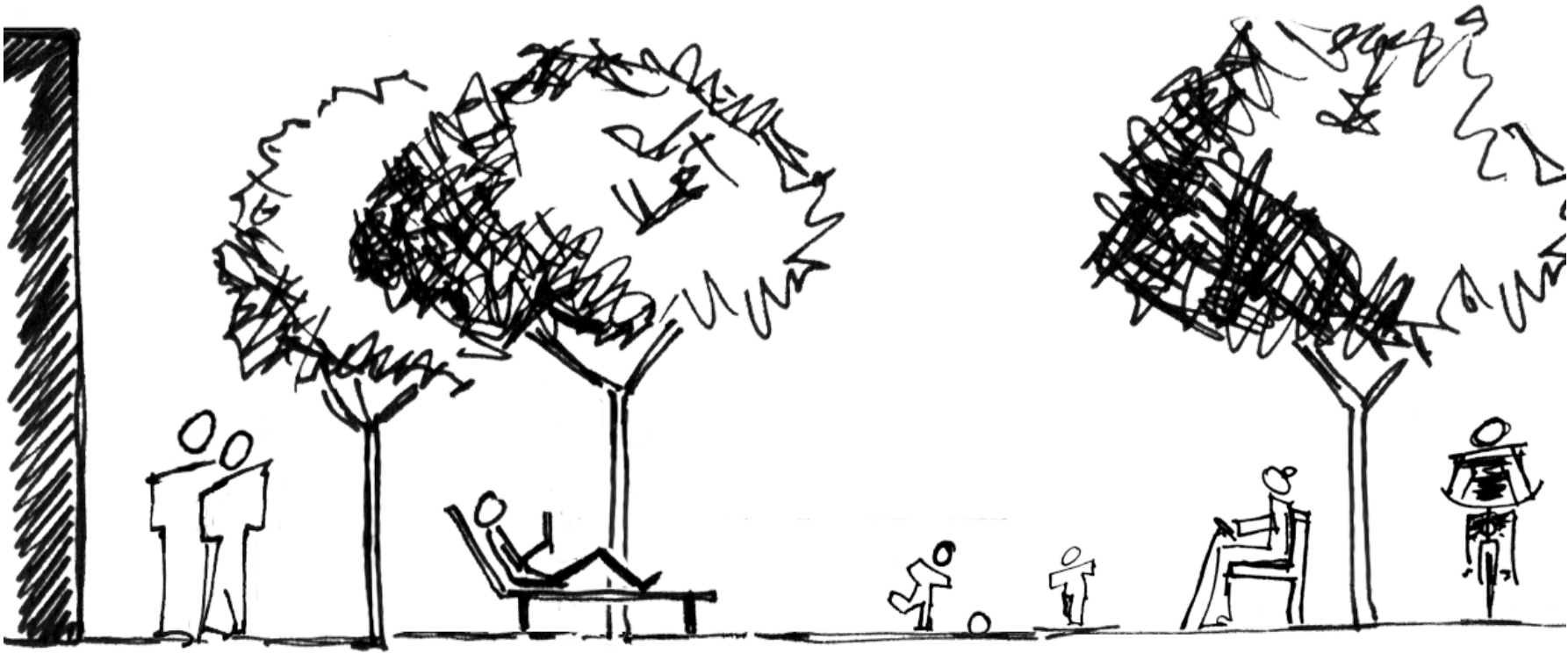
Introduction

- People with different cultures, and adapted to different climates, may react differently to the same thermal conditions, indicating that the thermal, emotional and perceptive evaluation of a physical place can be influenced by psychological and sociocultural processes (Knez; Thorsson, 2006).
- Thermal comfort indices may not be applicable in different cultural/climate areas without adaptations, if they do not consider psychological processes involved in the environmental evaluation (Knez; Thorsson, 2006).

Objectives

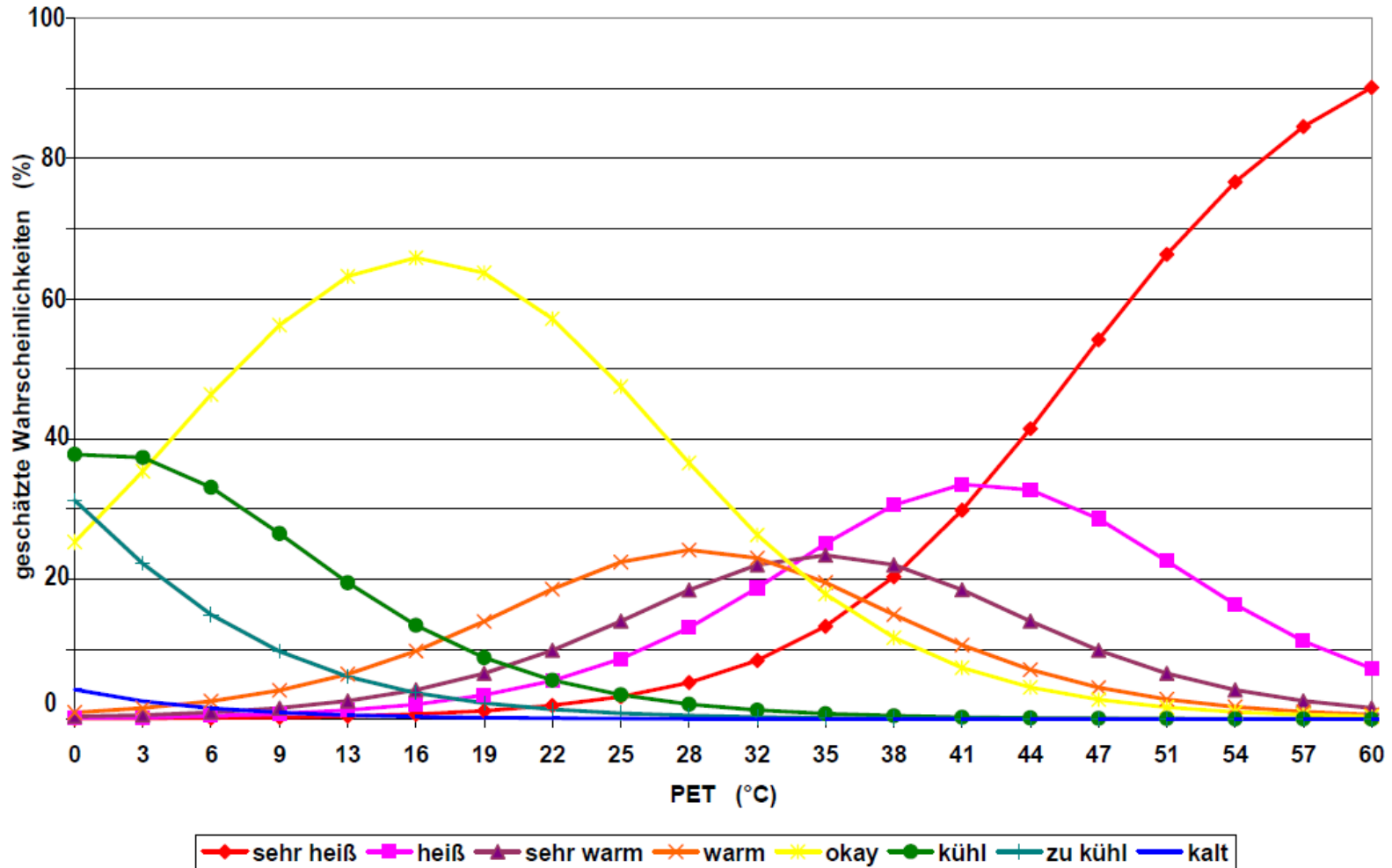
- Calibration of the PET index for cities located in different cultural/climate zones
 - Belo Horizonte (Brazil)
 - Salvador (Brazil)
 - Freiburg and Kassel (Germany)
- Comparison of the thermal comfort perception of subjects living in these cities, within the same PET intervals





Cuting Points Freiburg / Kassel Germany

Source: KLIMES project



Deutscher Wetterdienst; Umweltbundesamt (German Weatherservice; Environmental Administration Germany)

perceived temperature heat stress ° C:

strong > 32 with some days of duration
extreme > 38 low nocturnal cooling

Gefühlte Temperatur <i>GT</i> in °C	Thermisches Empfinden	Thermophysiologische Beanspruchung
$GT \geq 38$	sehr heiß	extreme Wärmebelastung
$32 \leq GT < 38$	heiß	starke Wärmebelastung
$26 \leq GT < 32$	warm	mäßige Wärmebelastung
$20 \leq GT < 26$	leicht warm	schwache Wärmebelastung
$0 < GT < 20$	behaglich	Komfort möglich
$-13 < GT \leq 0$	leicht kühl	schwacher Kältestress
$-26 < GT \leq -13$	kühl	mäßiger Kältestress
$-39 < GT \leq -26$	kalt	starker Kältestress
$GT \leq -39$	sehr kalt	extremer Kältestress

Study areas



Thermal comfort comparison and evaluation in different climates

Study areas



Liberdade Square



Sete de Setembro Square

Belo Horizonte



Germany

Freiburg Vauban



Opernplatz Kassel

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SALVADOR CITY, Latitud -13°





Areas in Freiburg

Wiehre

Vauban

Rieselfeld

Methods

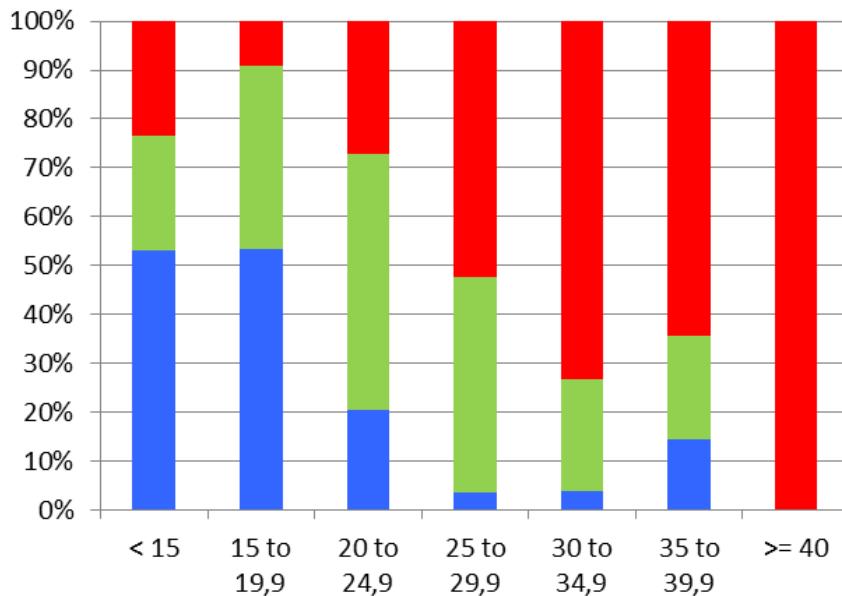
- Microclimatic data
 - Air temperature, relative humidity, mean radiant temperature (globe temperature, 40mm-diameter gray globe) and wind speed, all of them at 1.10m (ISO 7726, 1998), collected on sunny and shaded places
- Interviews with people on site about their thermal perceptions
 - Adults between 20 and 59 years old
 - Questionnaire including individual (weight, height, age, gender, acclimation to the environment, physical activities and clothing) and subjective variables (perception of thermal sensation)
- Valid questionnaires Belo Horizonte: 1182
- Kassel and Freiburg: 776



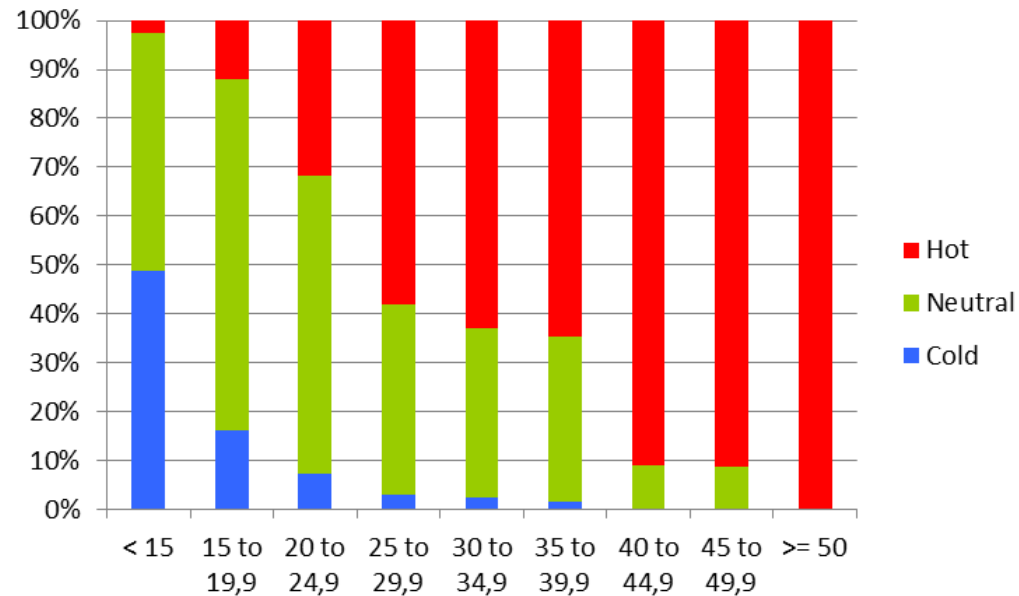
Results

Graph of perception of thermal sensation for each range of PET values (° C)

Belo Horizonte



Kassel / Freiburg



Results

Calibration of the PET index for Belo Horizonte and Kassel / Freiburg

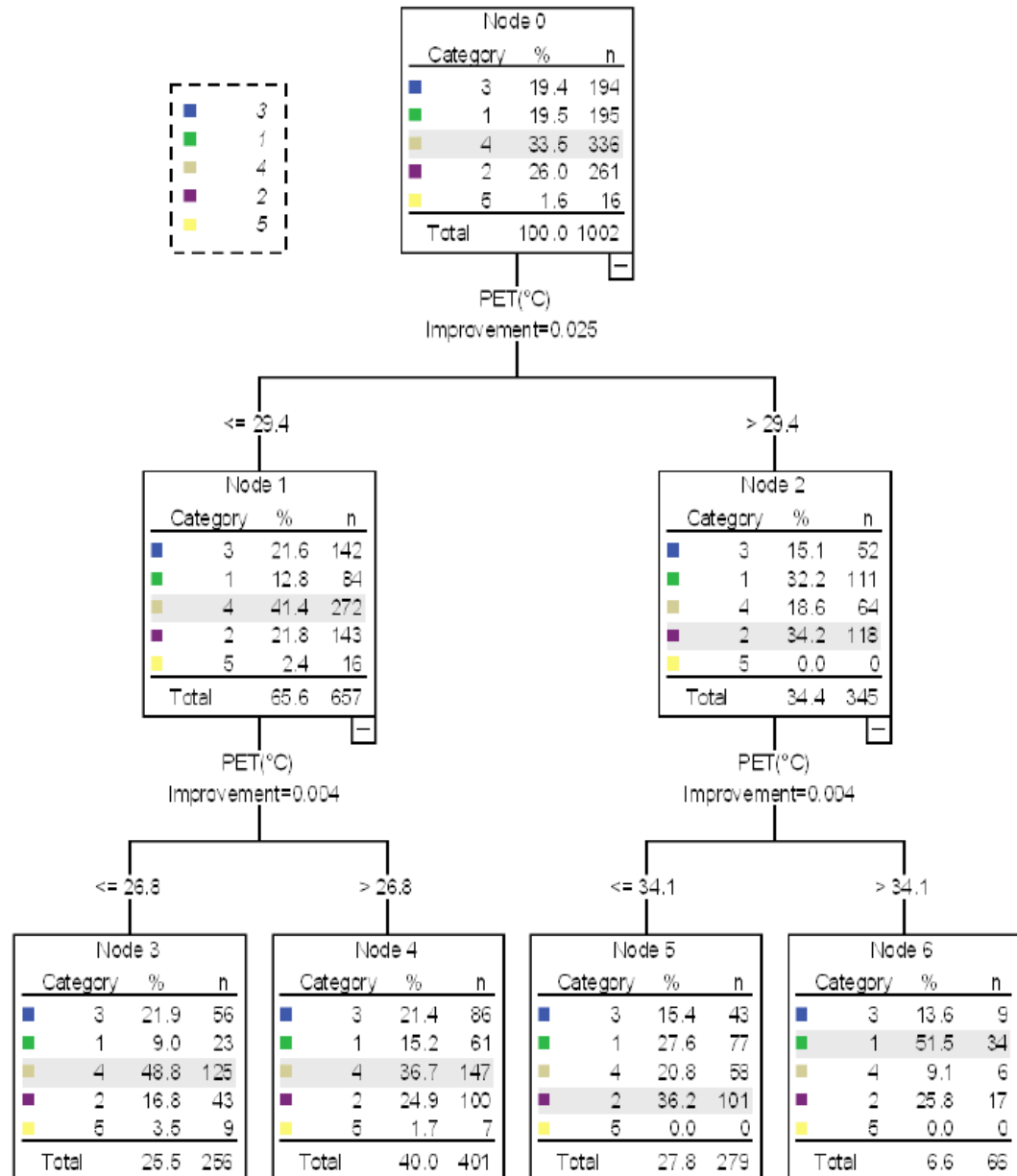
Thermal Perception	PET (°C)	
	Belo Horizonte	Kassel / Freiburg
Very Cold	-	below 8
Cold	below 12	8 to 12
Cool	13 to 15	13 to 17
Neutral	16 to 30	18 to 28
Warm	31	29 to 34
Hot	32 to 35	35 to 38
Very Hot	over 36	over 38

Methods Salvador

Legend for Categories:

- 1= "Hot"
- 2= "Warm"
- 3= "Slightly warm"
- 4= "Comfortable or Neutral"
- 5= "Slightly cool"
- 6= "Cool"
- 7= "Cold"

Thermal Perception



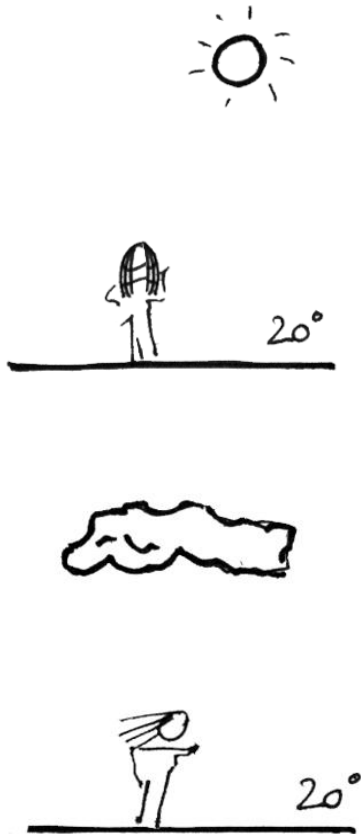
Decision Tree results (%) in relation to PET (° C) intervals

	Category	1	2	3	4	5
PET (°C)	→	Hot	Warm	Slightly Warm	Comfortable	Slightly Cool
↓	Node ↓	(%)				
≤ 26.8	3	9.0	16.8	21.9	48.8	3.5
26.8 - 29.4	4	15.2	24.9	21.4	36.7	1.7
29.4 - 34.1	5	27.6	36.2	15.4	20.8	0.0
≥ 34.1	6	51.5	25.8	13.6	9.1	0.0

Conclusions

- The response to thermal stress in cities in moderate and tropical climates can be quite different.
- An understanding of the sociocultural and psychological factors that influence the perception of thermal environments is essential for proper evaluation of comfort conditions and to make decisions in open space design.
- For city design of open spaces in colder climates some warm places should be kept as long they do not lead to heat storage, for hot climates, as expected, shadow is important at any case.

more conclusions



Thank you!