OB-17 Joint IEA EBC Annex 66 and 69 Symposium on Occupant Behaviour and Adaptive Thermal Comfort

Danmarks Tekniske Universitet

DTU

How occupants' thermal/visual comfort and air-quality perception may be improved thanks to non-physical drivers in a working place

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UNIVERSITÀ DEGLI STUDI DI PERUGIA

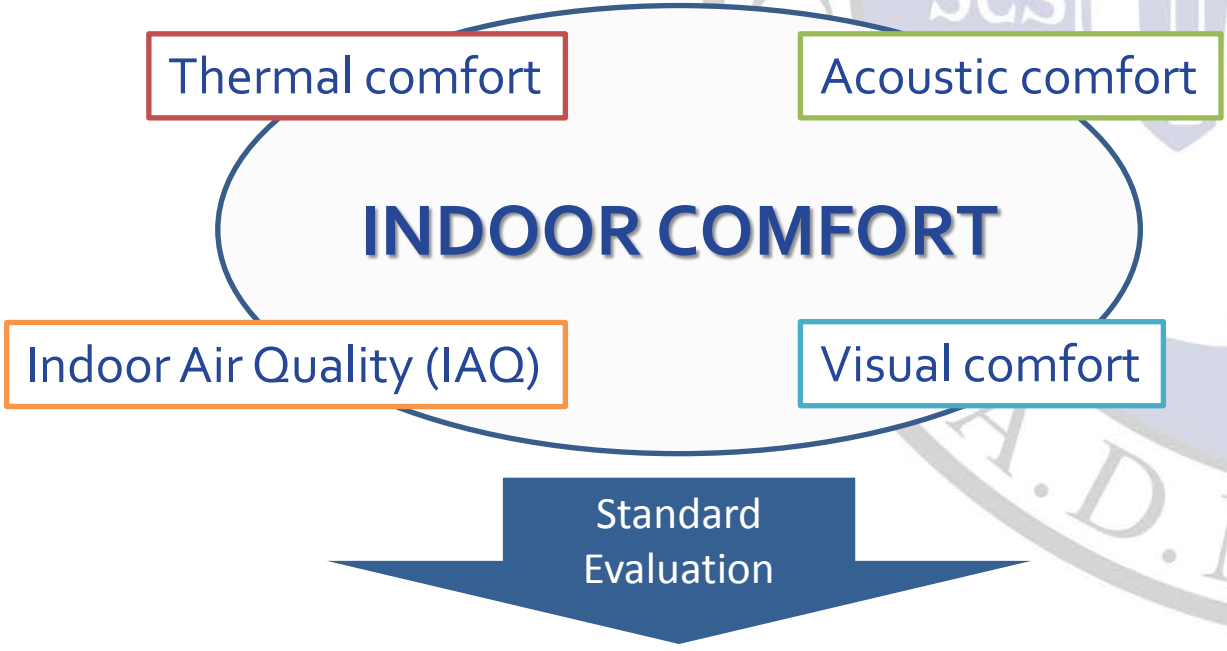
DTU - Copenaghen, May 17th 2017

OUTLINE

- Introduction: comfort evaluation
- Methodology
- Case study
- Results
- Conclusions and further developements

Intro - background

*Frontczak and Wargocki, 2011



Specific comfort ranges of measurable parameter

→ Consistent quantitative evaluation

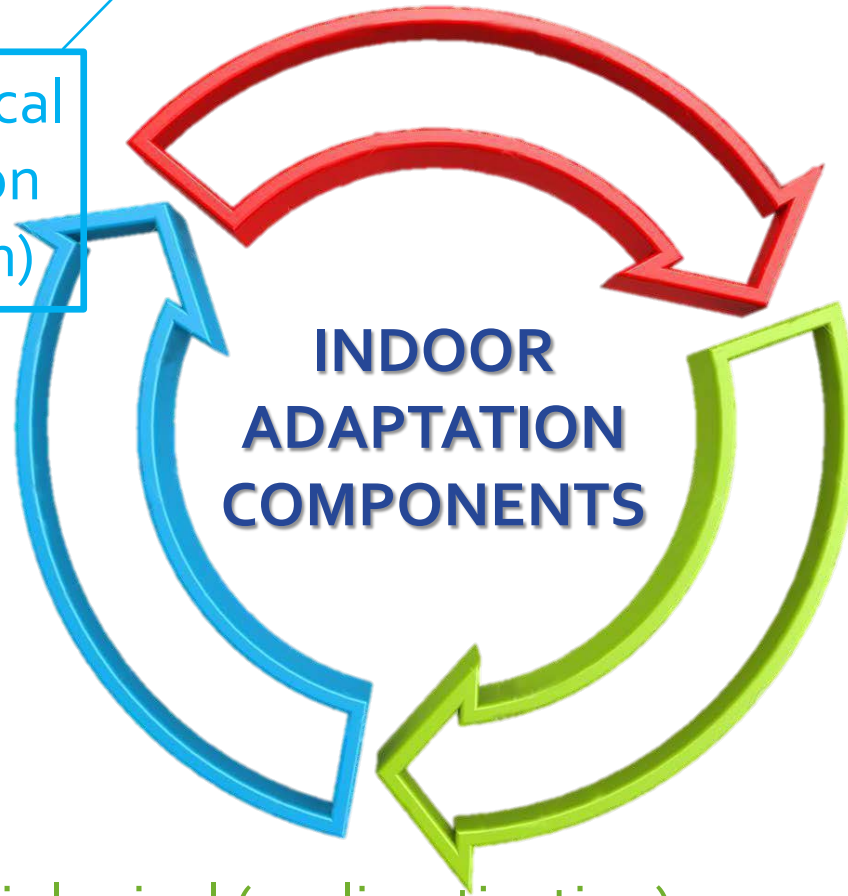
But: (i) Same indoor conditions may lead to **different subjective responses** (personal feedback)

(ii) Non-measurable drivers may (?) influence **indoor collective** environmental perceptions/satisfaction

Background

Positive influence of a pleasant quality of working life

Psychological (habituation expectation)



Behavioral (adjustment)

Physiological (acclimatization)

*De Dear, Brager, Cooper 1997

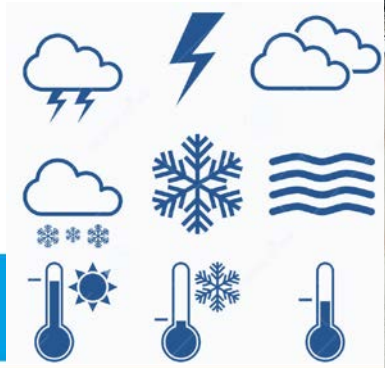
METHOD

i. Monitoring of In/out-doors
ii. Questionnaires submission
iii. Data analysis

Methodology

Monitoring of indoor/outdoor Parameters:

- Air temperature, aT [°C];
- Relative Humidity, RH [%];
- Mean Radiant Temperature, MRT [°C];
- Pavement Temperature, pT [°C];
- Ankle Temperature, ankT[°C];
- Radiant Asymmetry, ASYM [°C];
- Wind Speed, ws [m/s];
- Turbolence, TU [%];
- CO_2, CO and VOC concentation [ppm];
- Lighting level, E [lux].



Methodology

Questionnaires submission

- Personal information (i.e. Gender, age, clothing, health condition, ...);
- Working attitudes (i.e. working schedule, work enviroment control, ...);
- Thermal perception;
- Visual perception;
- General comfort condition and non-physical influences (i.e. work enviroment quality, domestic environemnt, health condition, personal mood);

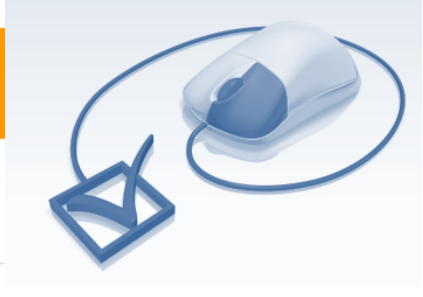
ISO 10551

Google Forms

Comfort termico e visivo in ambiente di lavoro

Informazioni generali

COMPILA MODULO



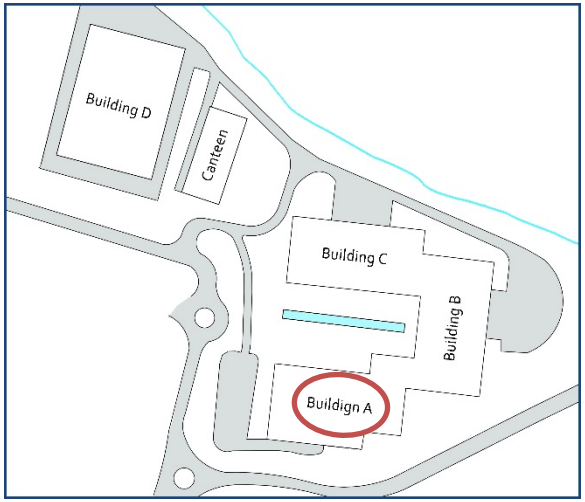
Case Study

Made-in-Italy luxury factory in central Italy fashion district

Case Study

4 working area buildings and one restaurant

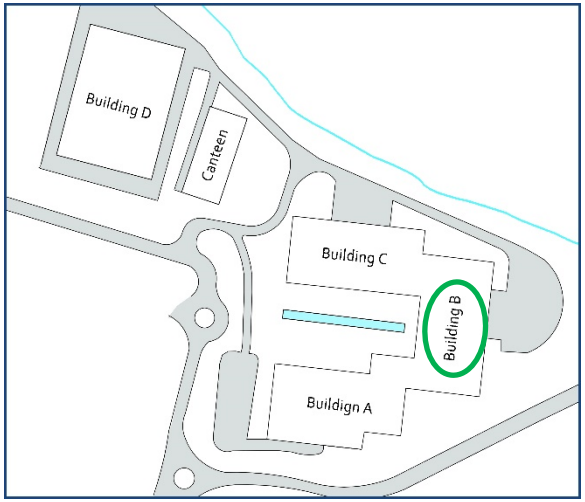
Building A Machinery area

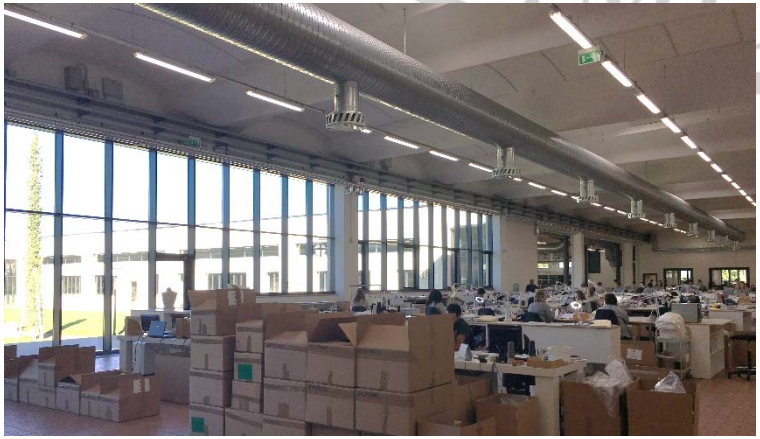


Case Study

4 working area buildings and one restaurant

Building B
Control area

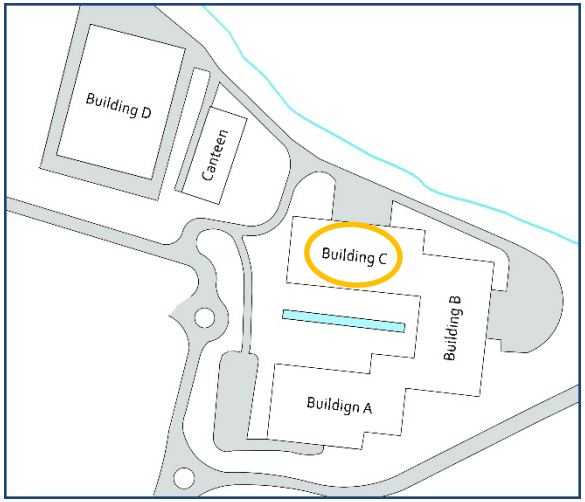




Case Study

4 working area buildings and one restaurant

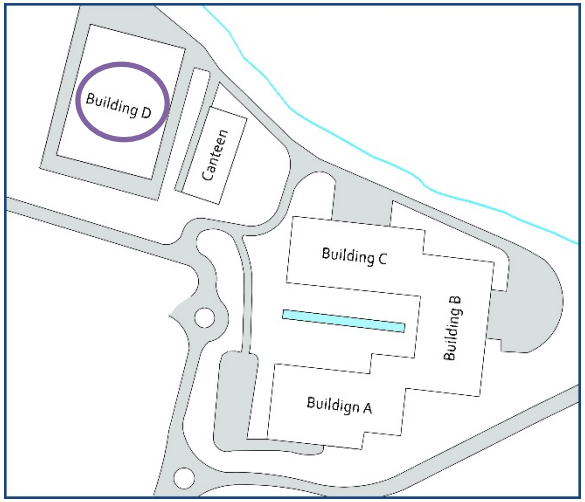
Building C
Administration area



Case Study

4 working area buildings and one restaurant

Building D Storage centre



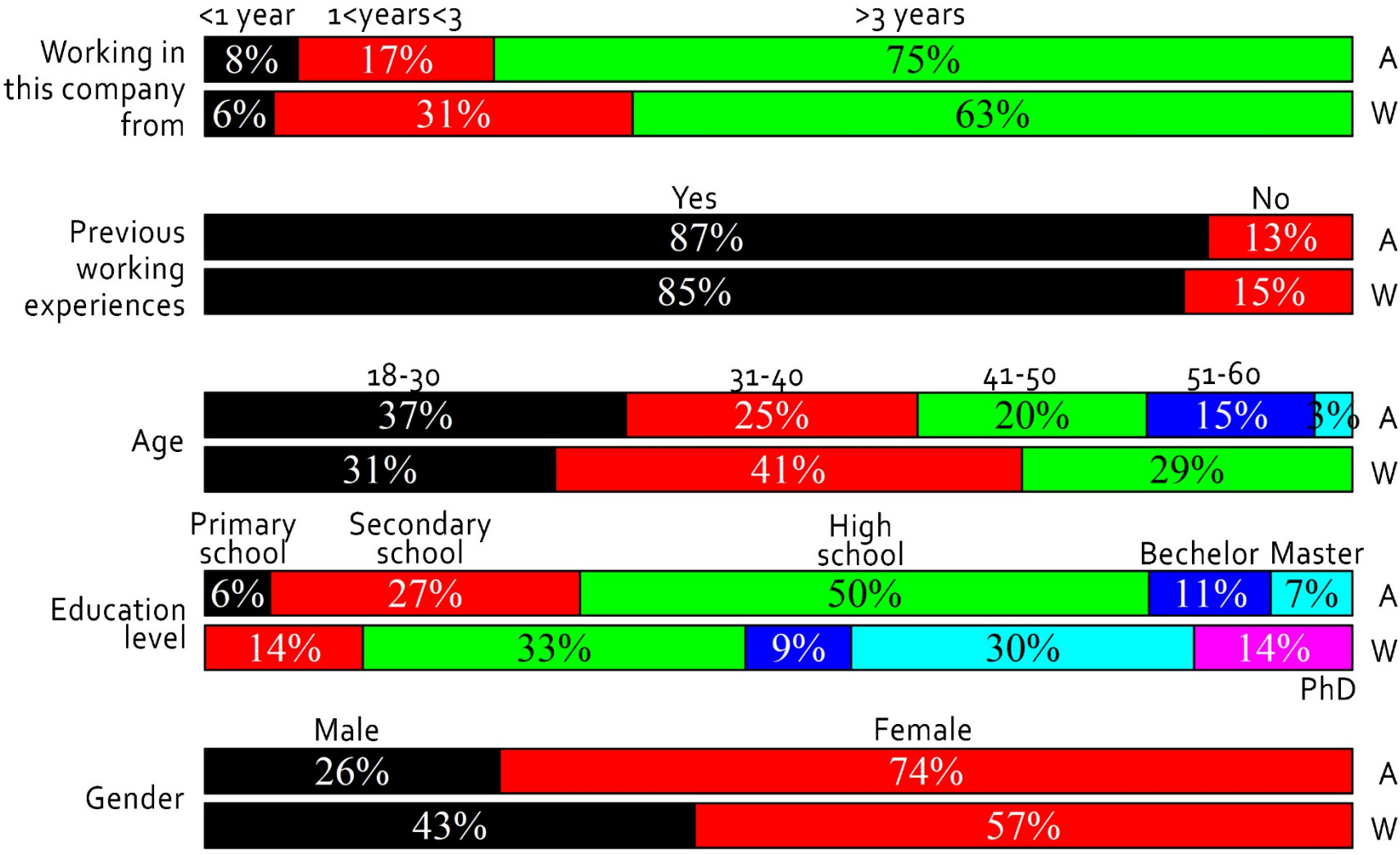
Case Study

Made-in-Italy luxury factory in central Italy fashion district

Sample composition

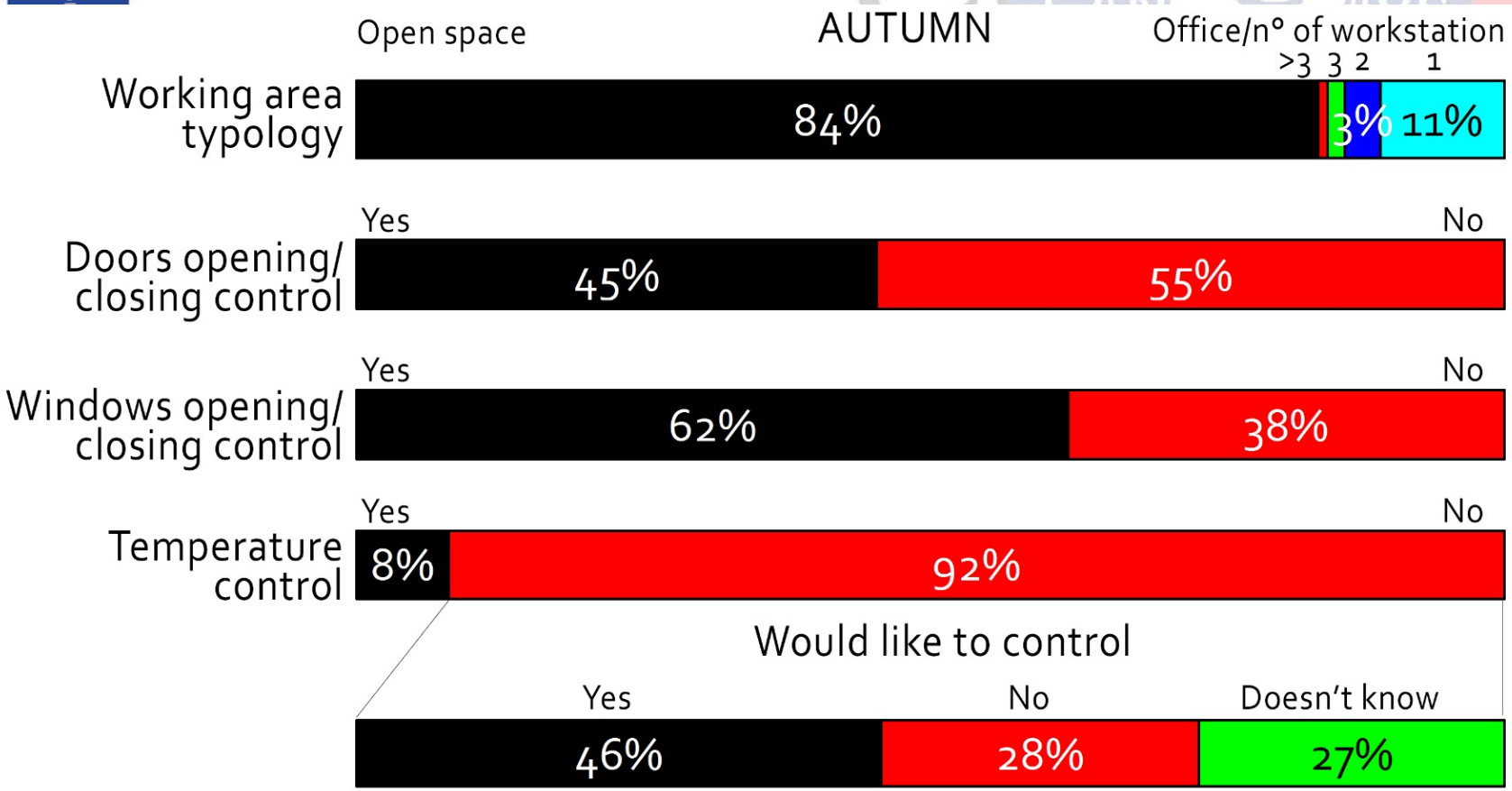
250 surveyed people per season → up to 1000

Autumn: 137, Winter: 75



Occupants' control capability

- Large majority of open-space employees
- Lack of local control of lighting, temperature, openings



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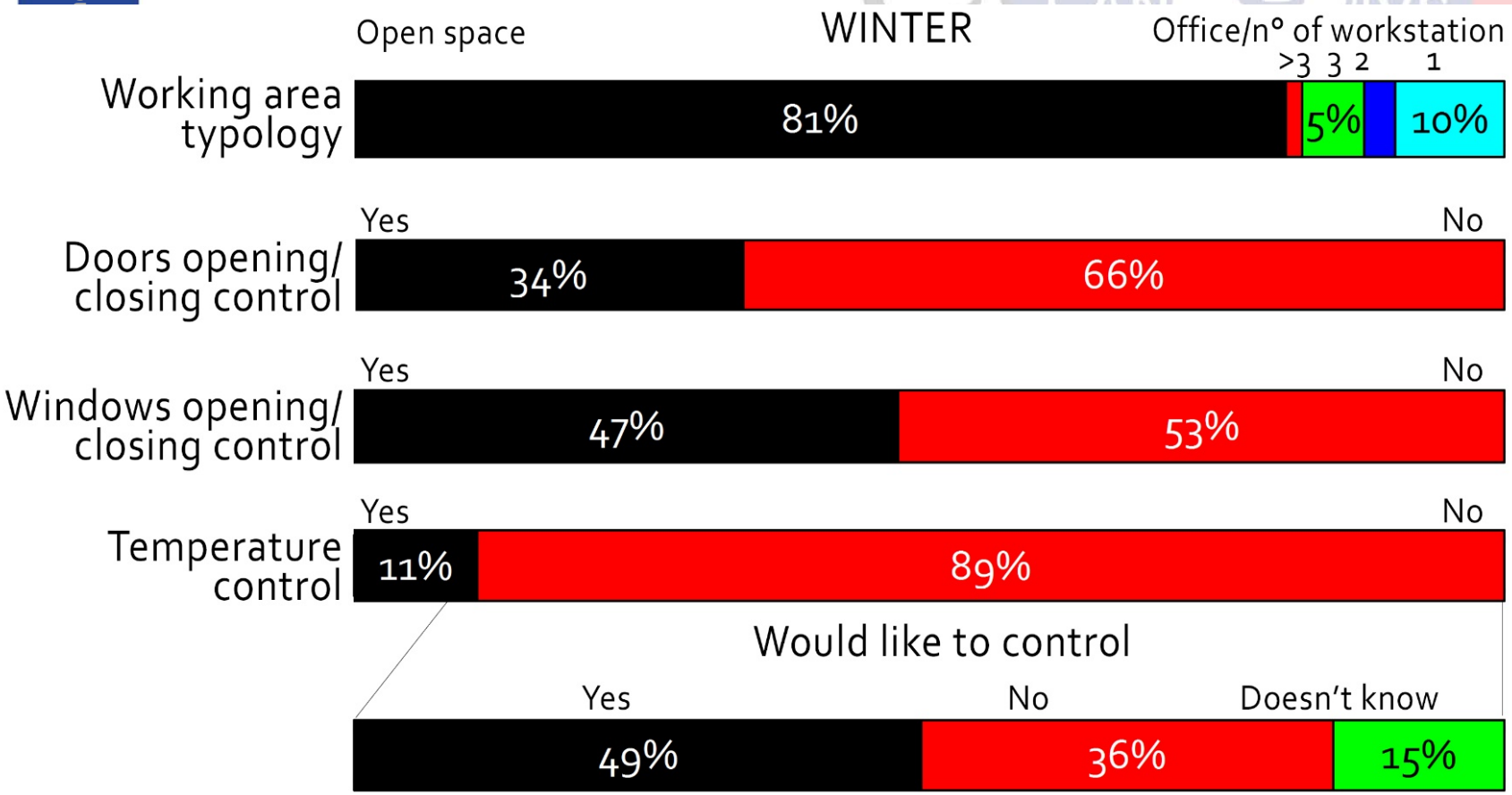
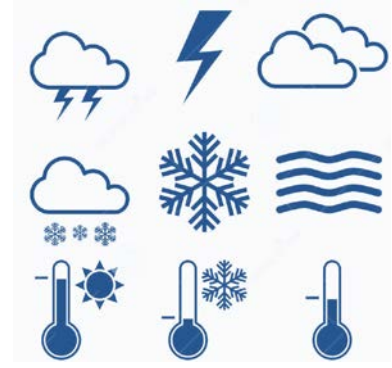


Results

1. Monitoring campaign, evaluation of:

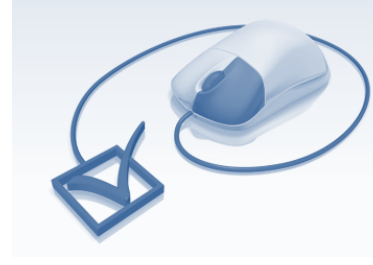
- Indoor Air Quality
- Lighting level
- Hygrothermal comfort condition
  - Fanger method
  - Adaptive method
- Local thermal discomfort



according to standars and literature (i.e. ASHRAE 62, EN 12464-1, ISO 15251, ISO 7730, ASHRAE55)

2. Questionnaires submission:

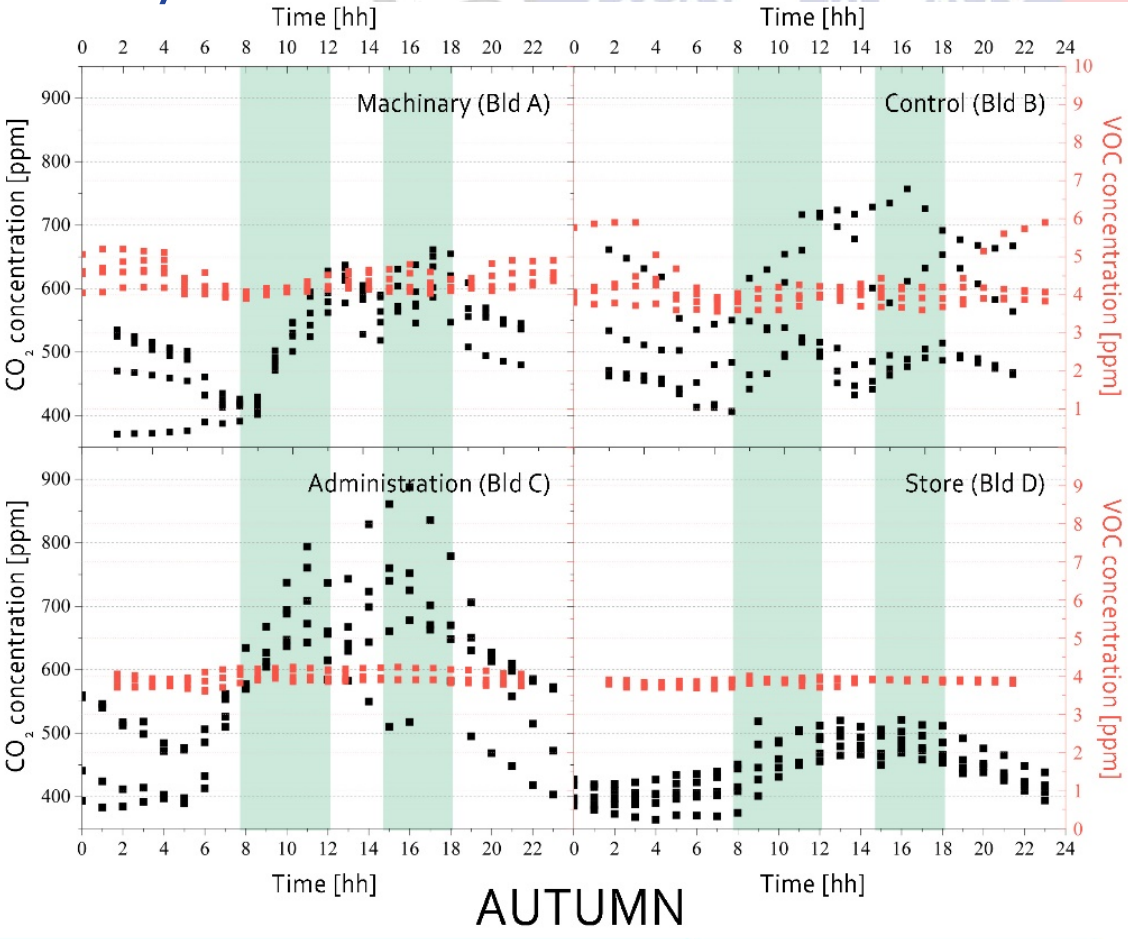
- Visual and Thermal perception



1. Monitoring campaign

Indoor Air Quality

- ASHRAE 62 – CO_2 concentration <1000 ppm
- VOC <10 ppm



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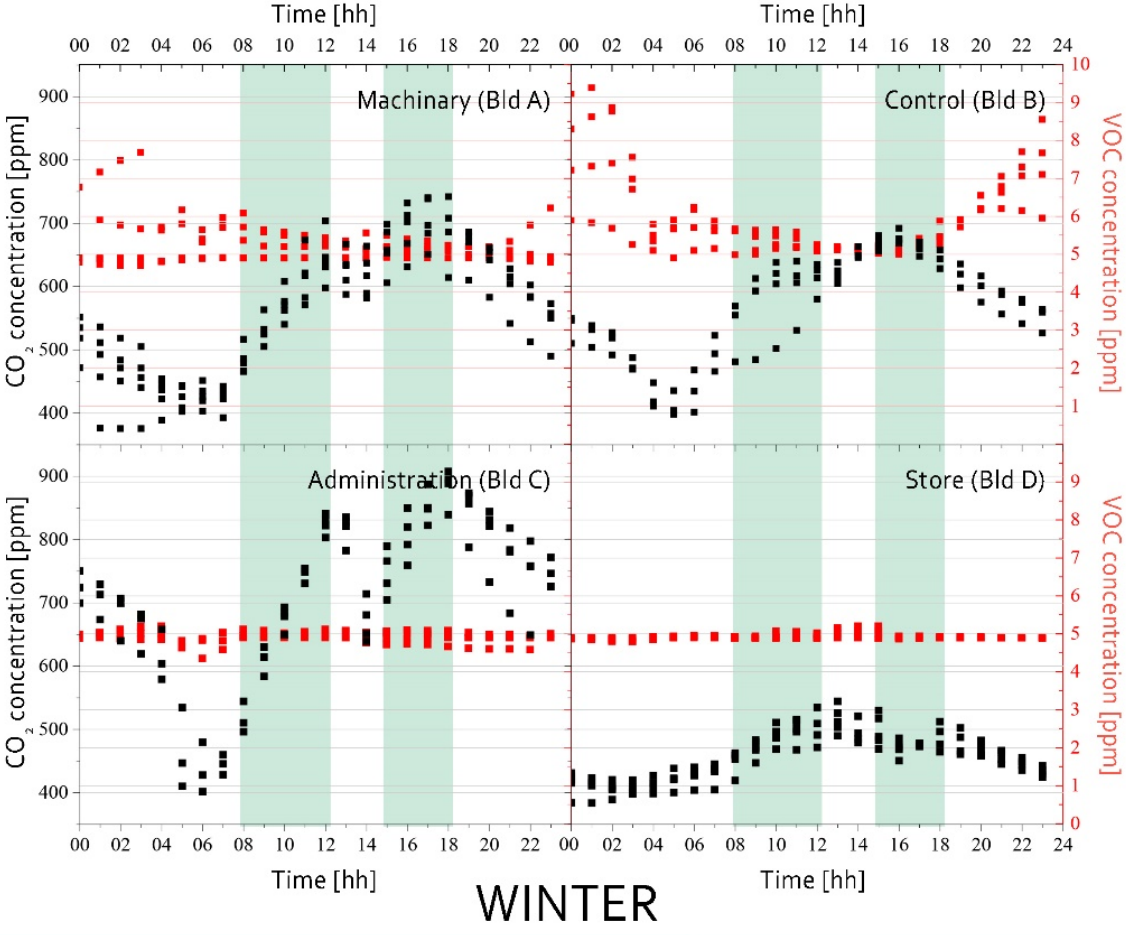


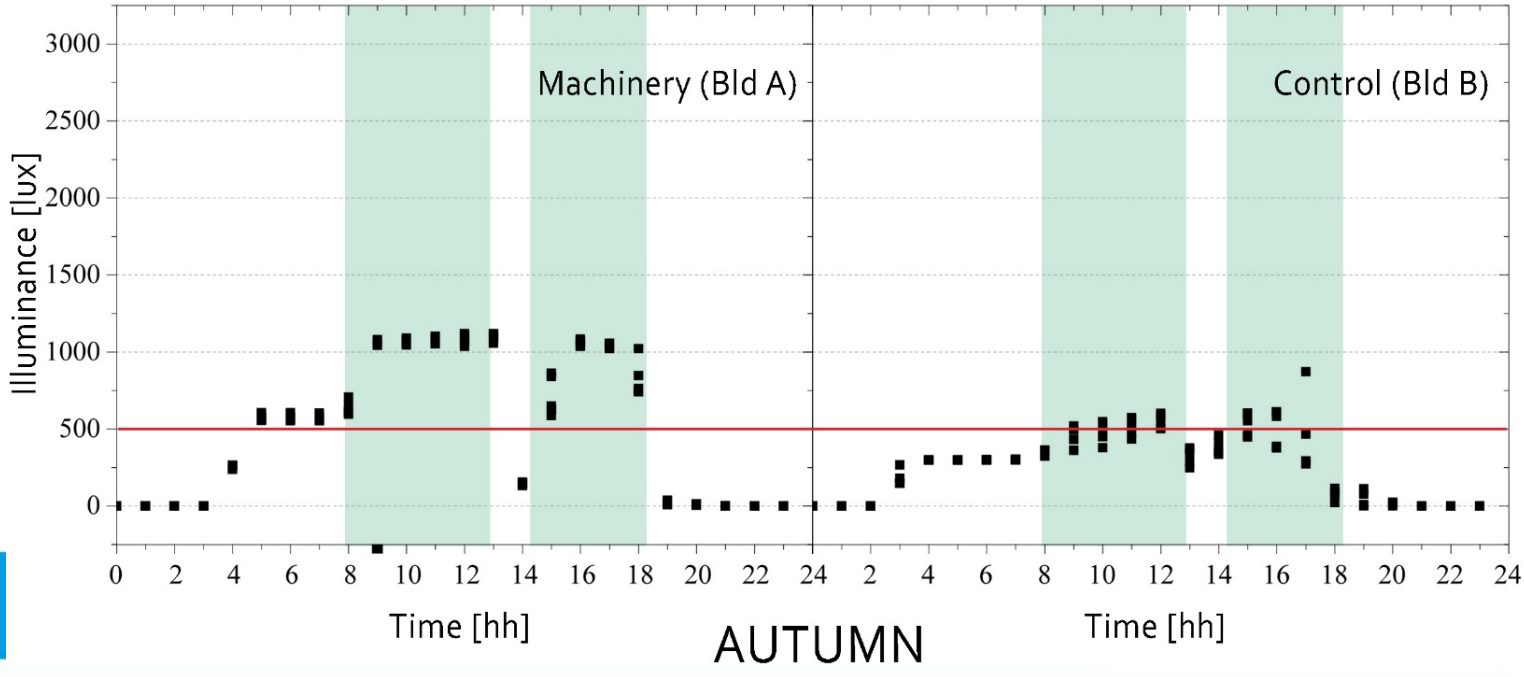
1. Monitoring campaign

Lighting level

- EN 12464-1

Seasonal Average day

	Lighting level [lux]
Globally working areas	200
Embroidery	750
To write/read	500
Store	300



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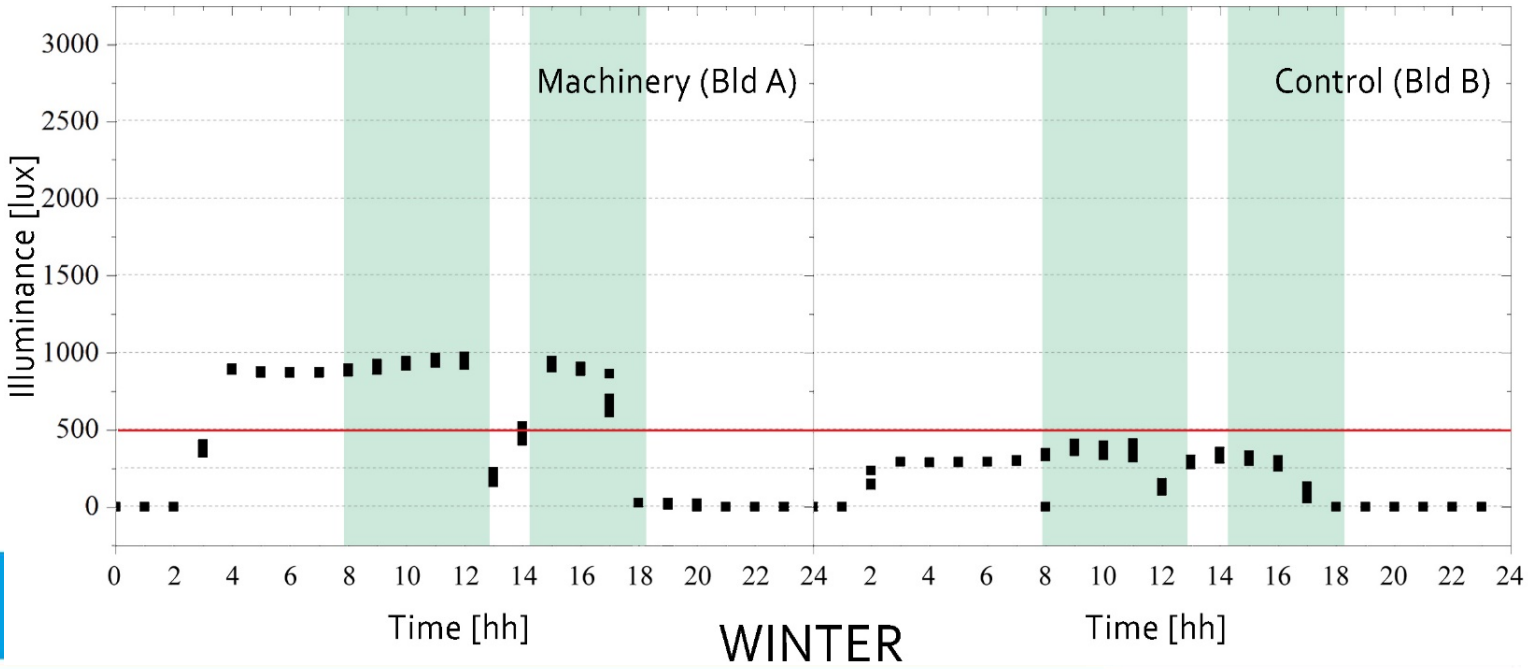
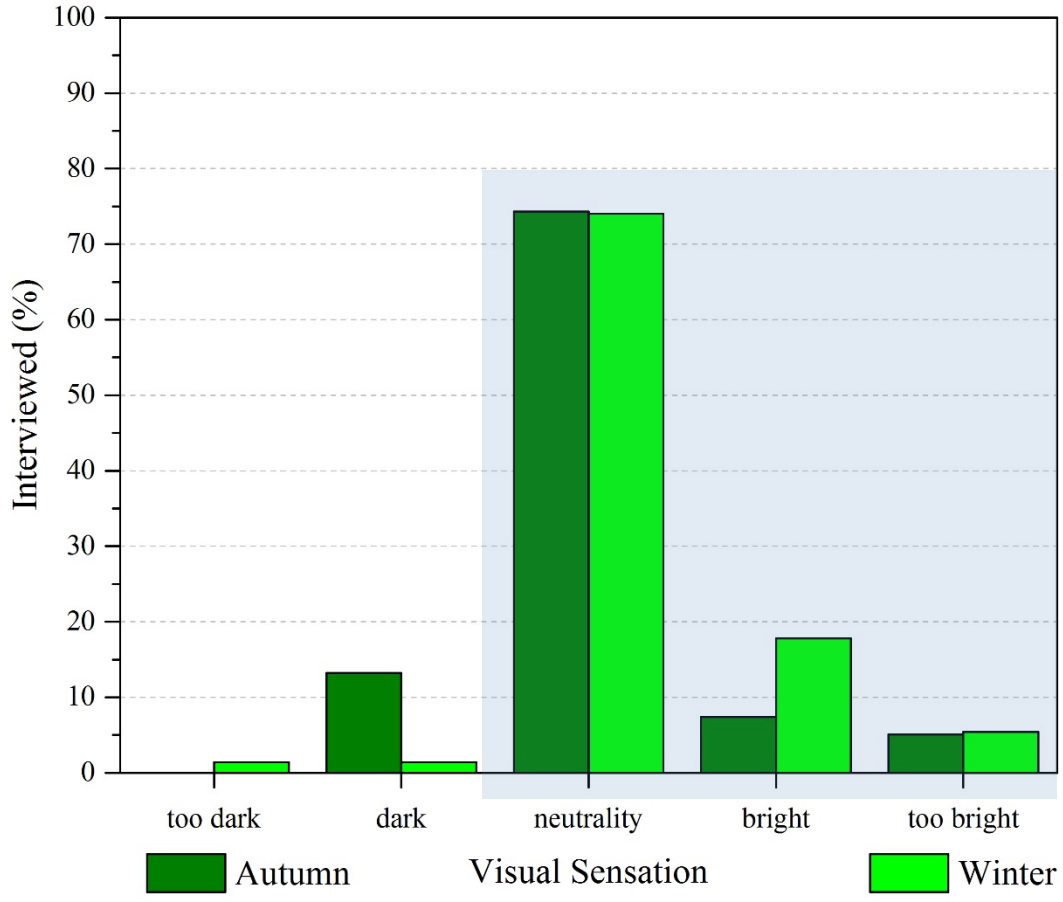


2. Questionnaires

Lighting level: autumn/winter

Response is influenced by non-physical (psycological?) agents

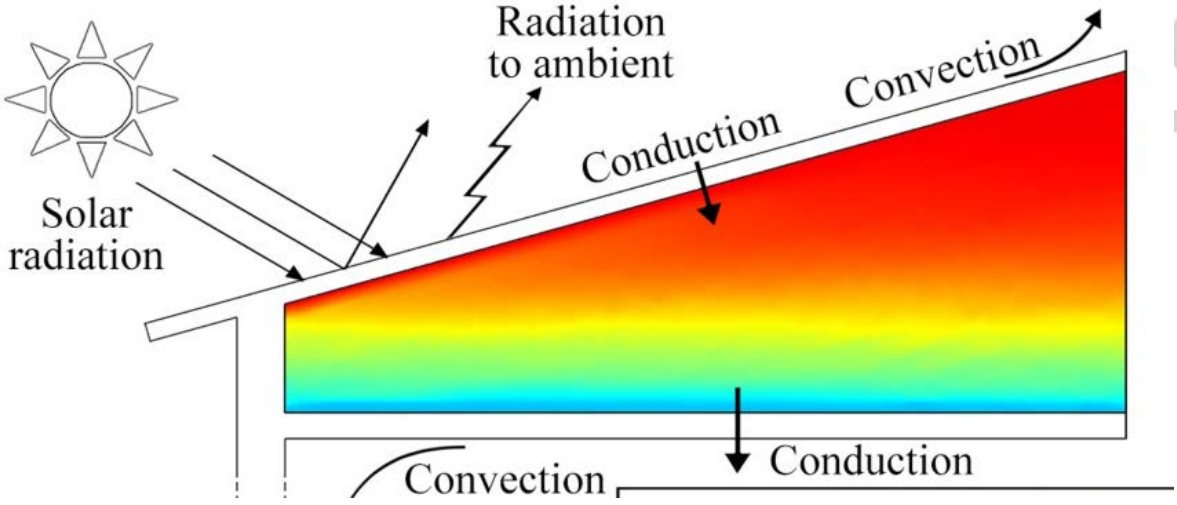


1. Monitoring campaign

Local thermal discomfort

ASHRAE 55 / ISO 7730

- Vertical temperature difference
- Pavement temperature
- Radiant asymmetry
- Predicted percentage if people dissatisfied due to draft (DR [%])



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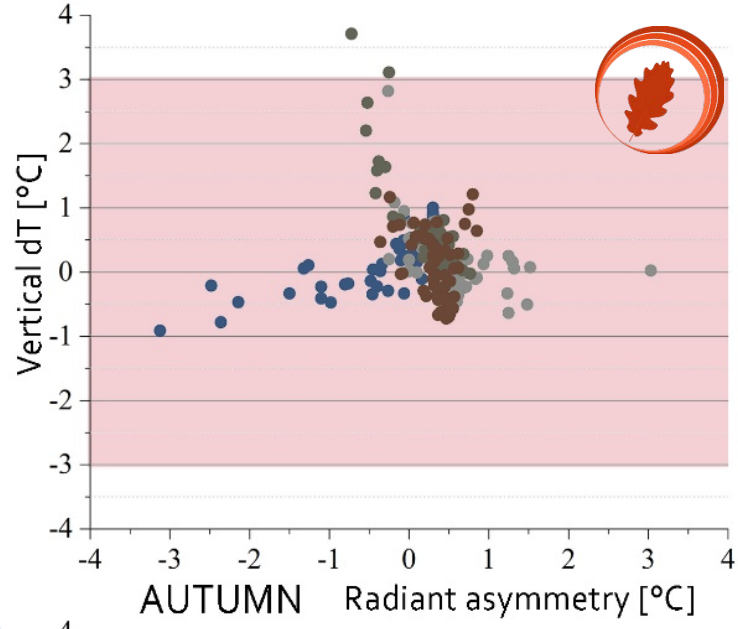

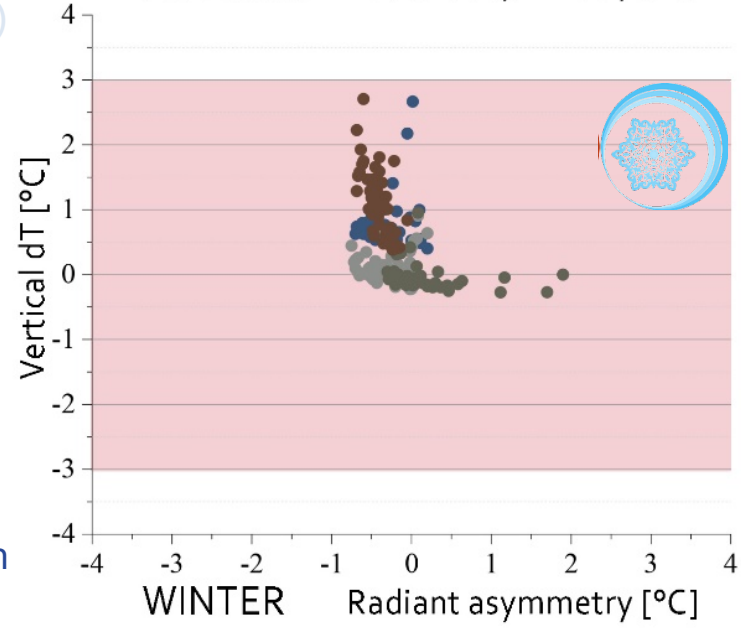

Radiant asymmetry< 10°C

Vertical dT< ±3°C – radiant paving system

• Machinery • Control • Administration • Store

1. Monitoring

Local thermal discomfort

ASHRAE 55 / ISO 7730

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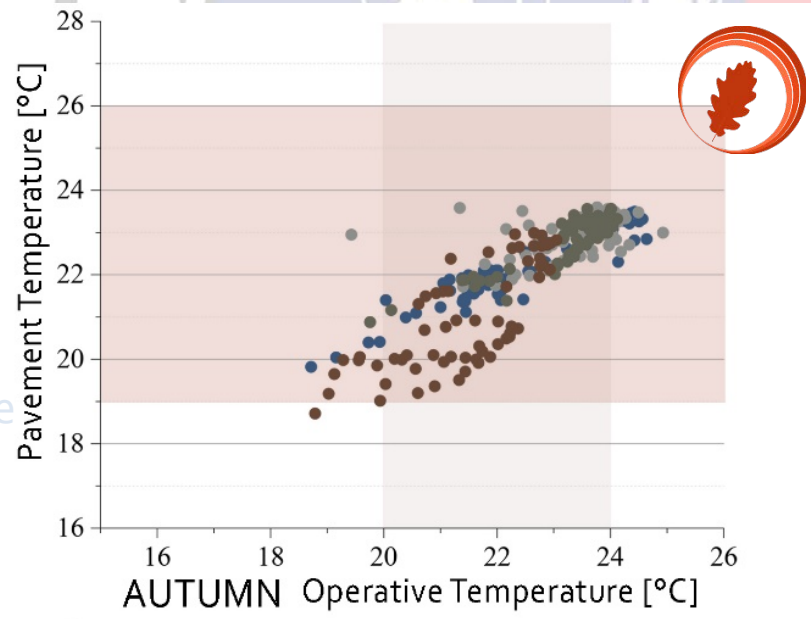

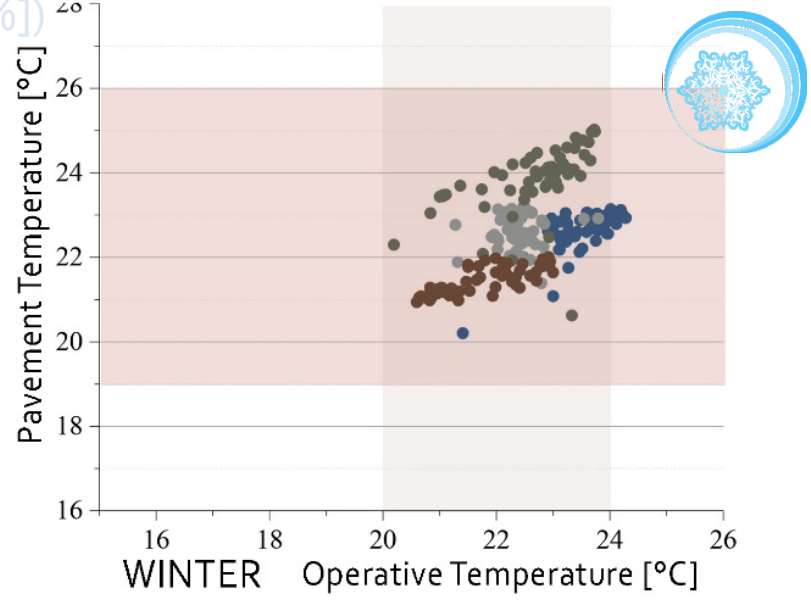

Machinery · Control · Administration · Store

1. Monitoring campaign

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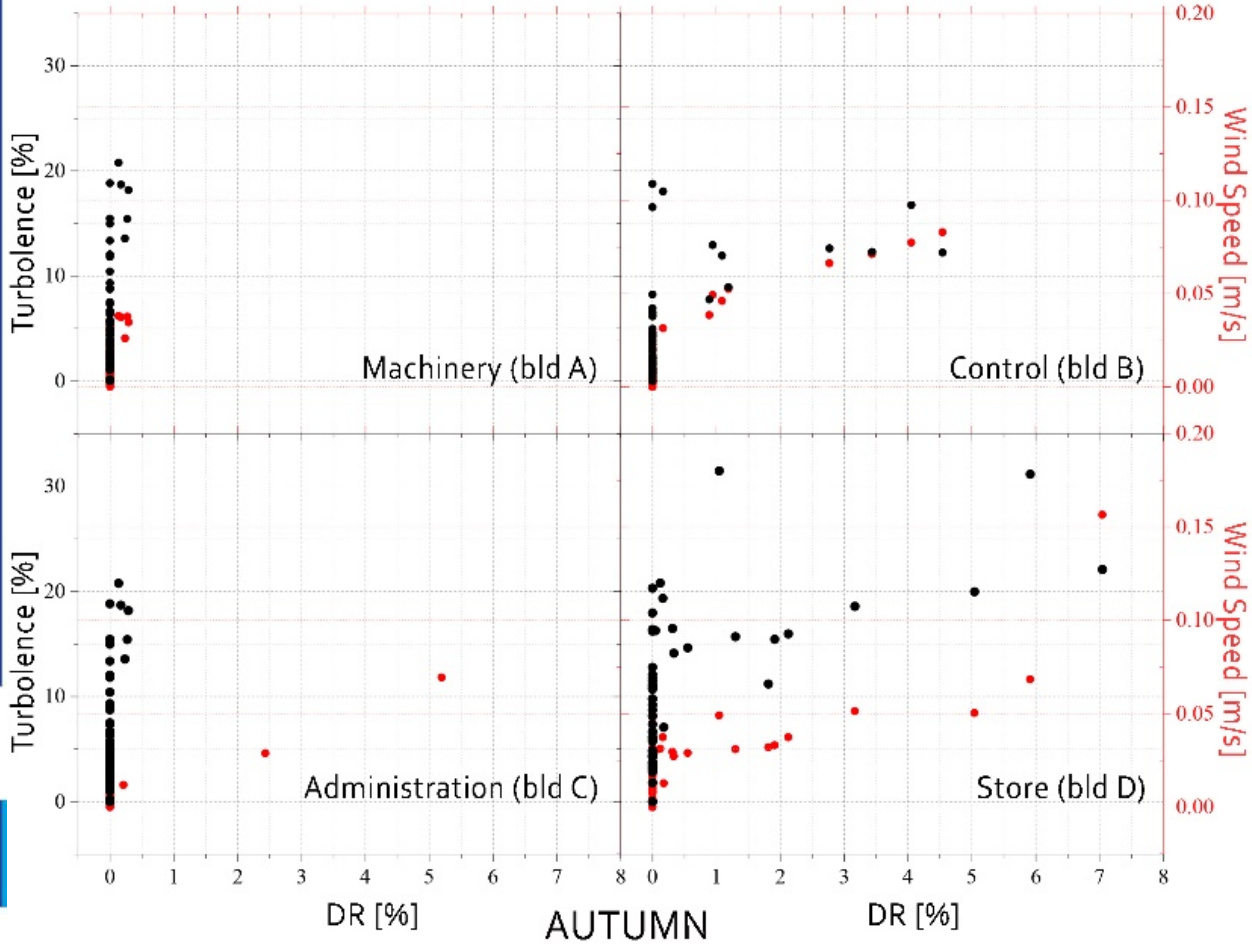
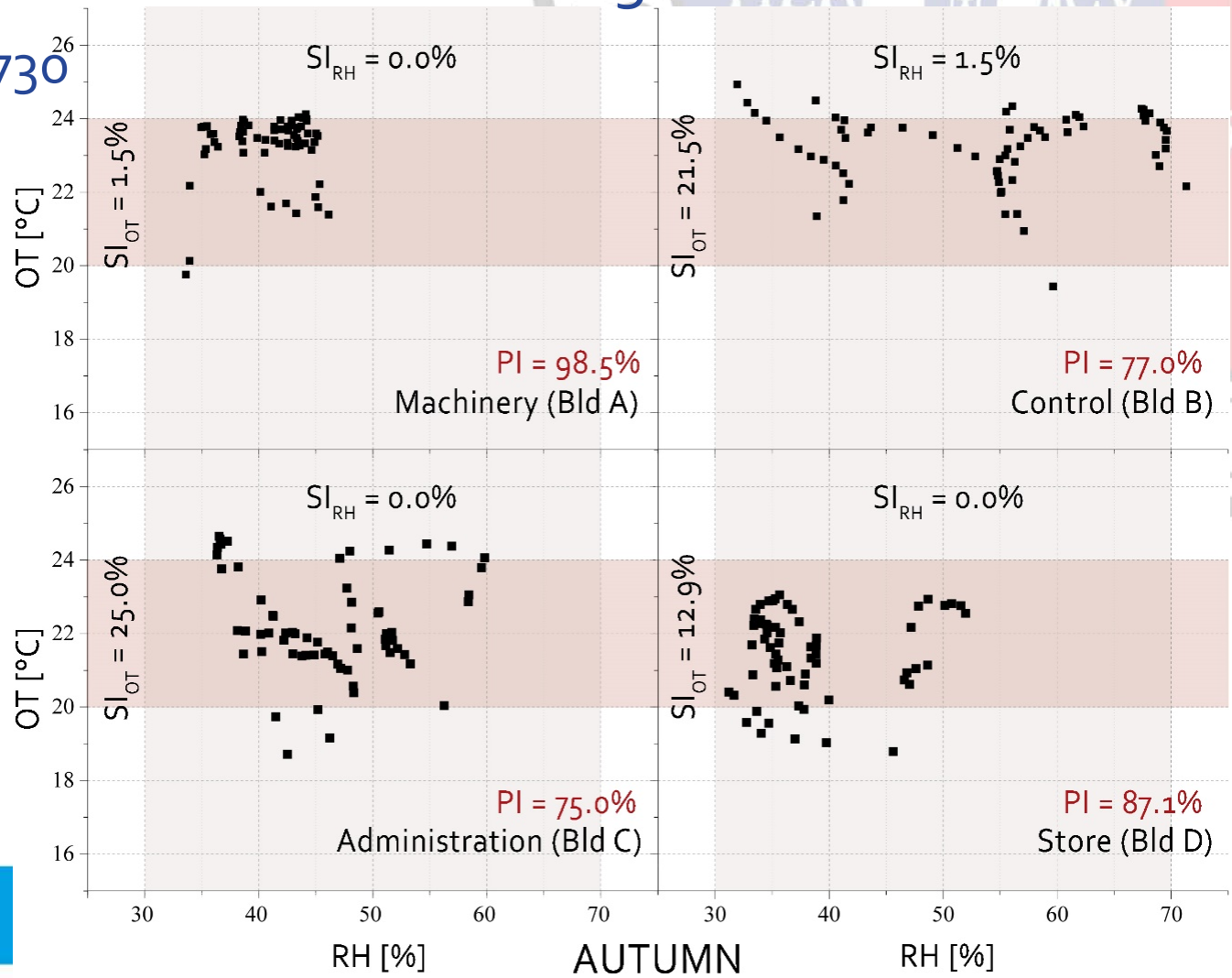


1. Monitoring campaign

Hygrothermal comfort ranges

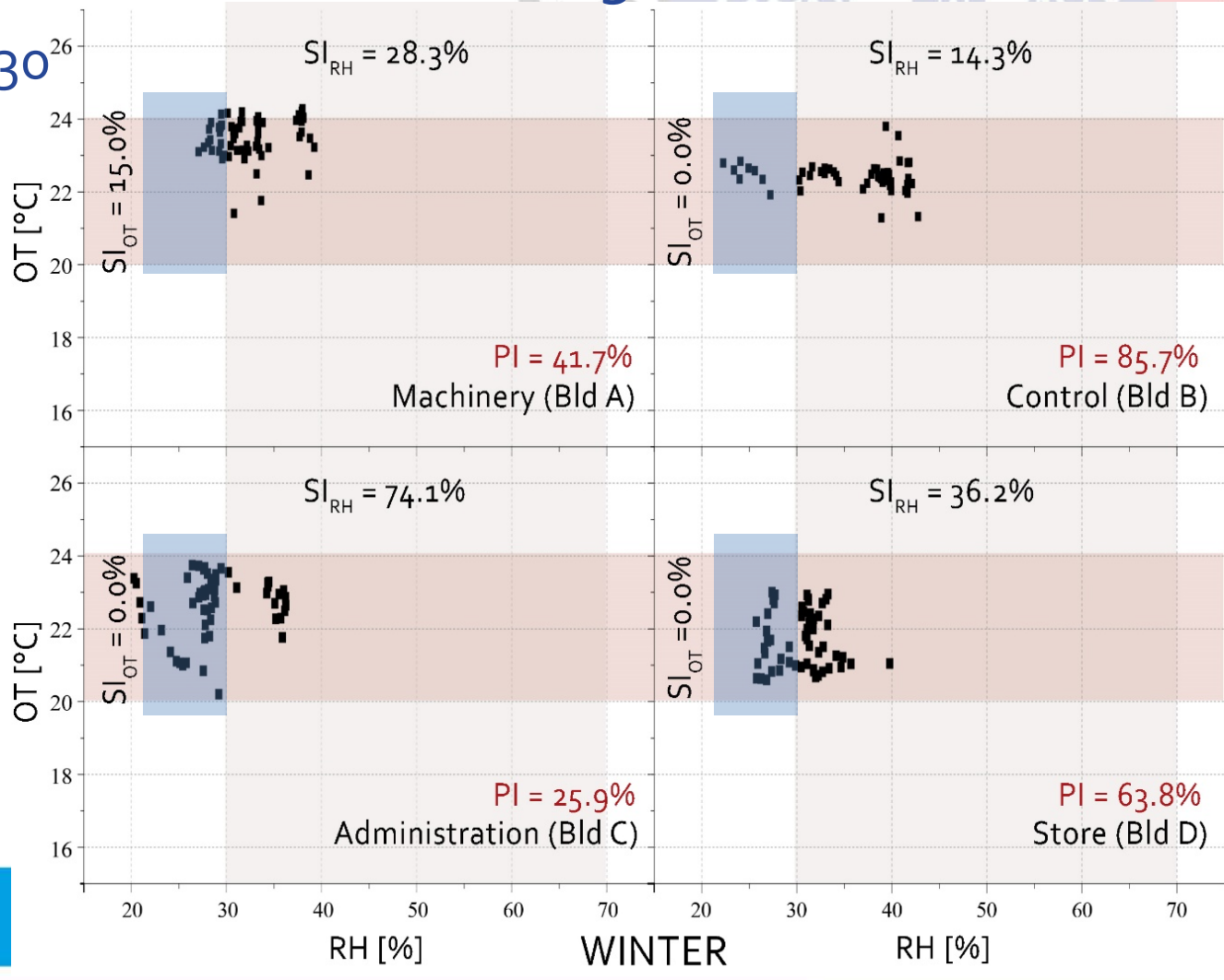
ISO 7730



1. Monitoring campaign

Hygrothermal comfort ranges

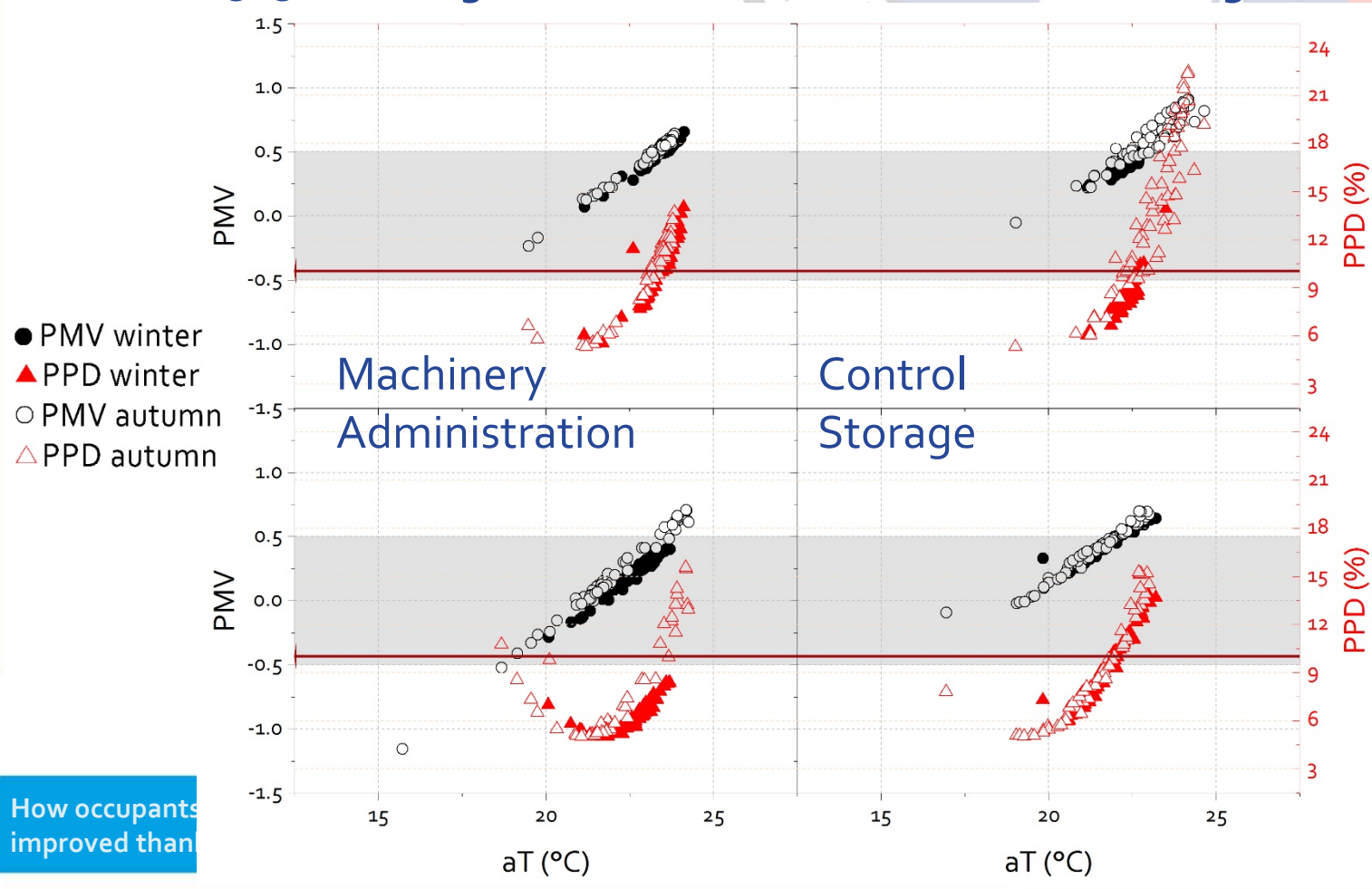
ISO 7730



1. Monitoring campaign

Thermal comfort evaluation

- ISO 15251 → Fanger method for air-conditioned buildings

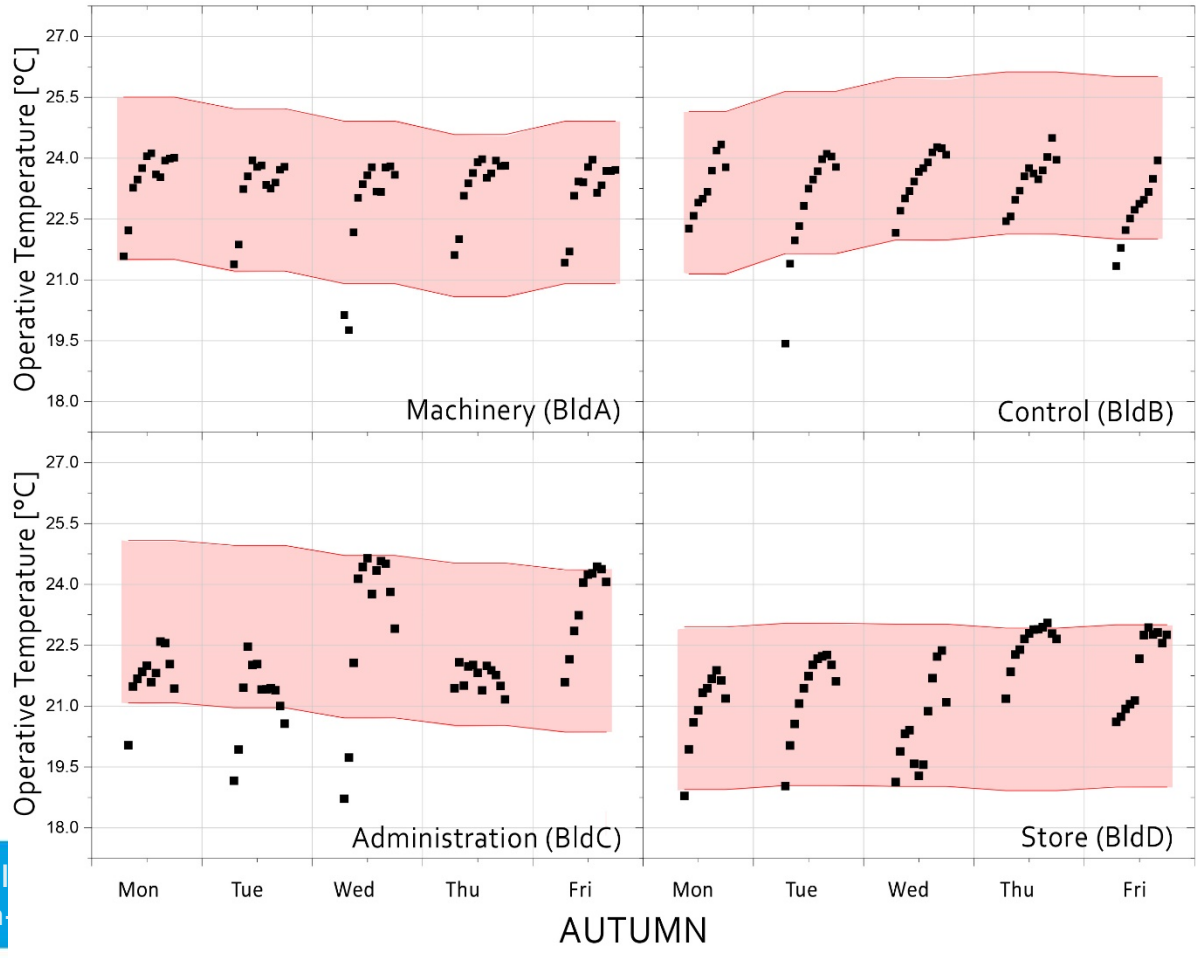


1. Monitoring campaign

Thermal comfort evaluation

- ISO 15251 → Adaptive model for naturally conditioned buildings

Category II

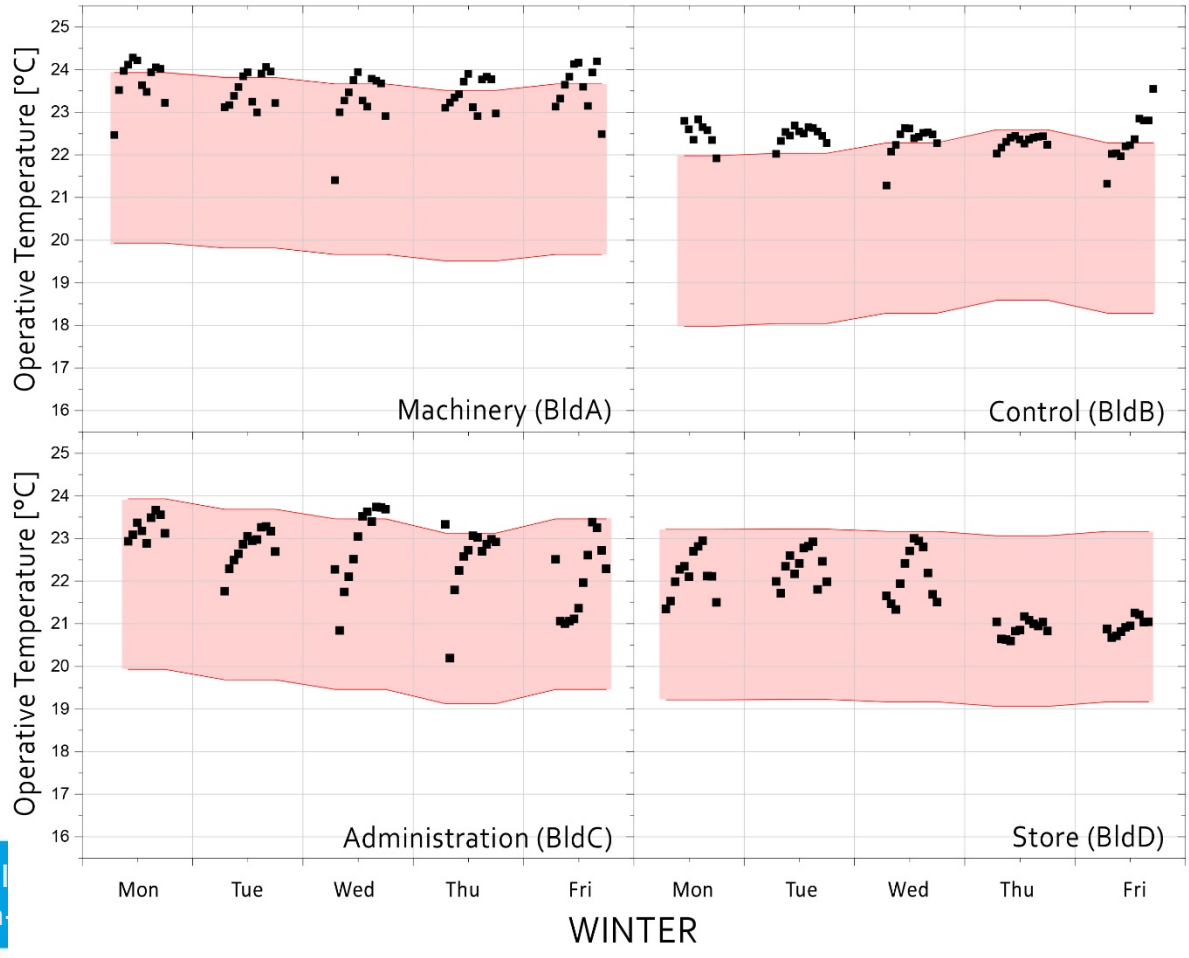


1. Monitoring campaign

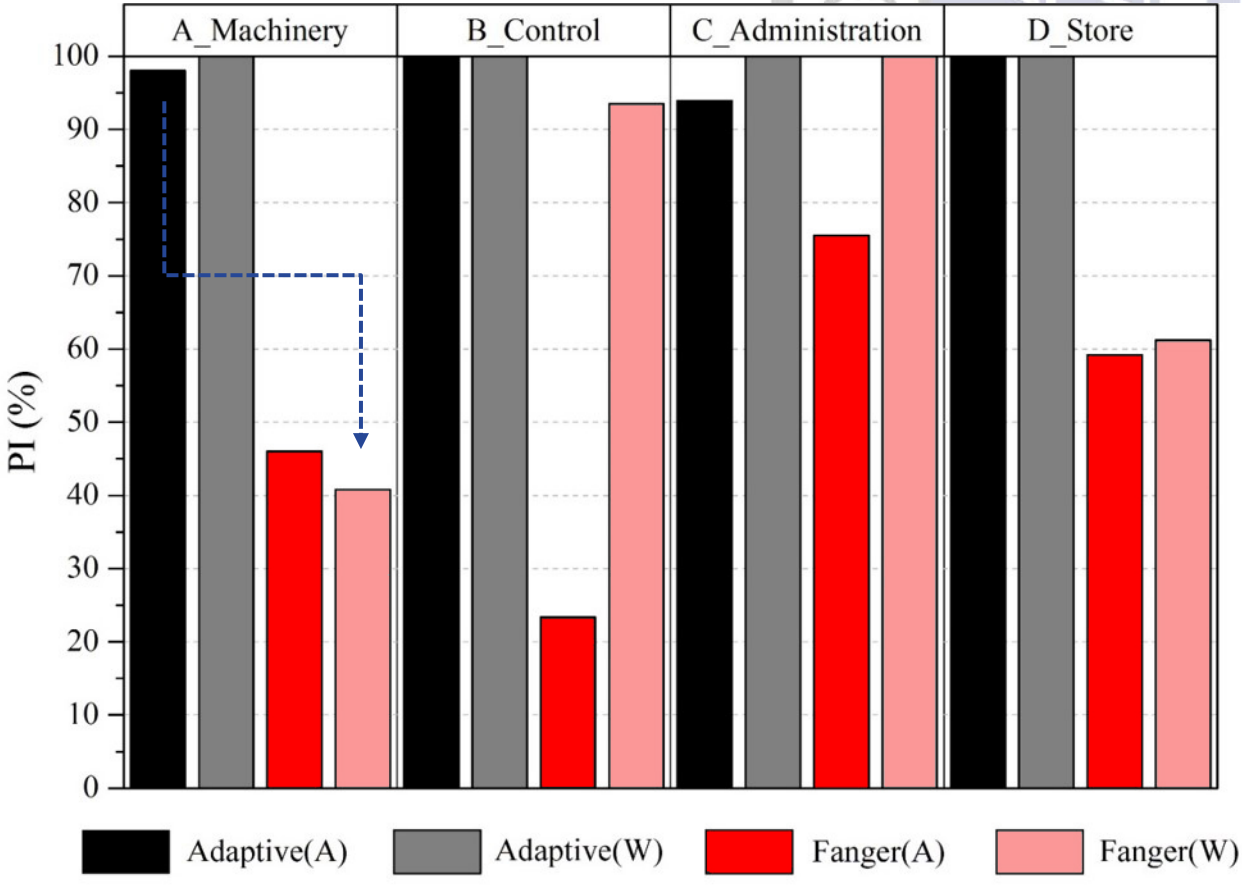
Thermal comfort evaluation

- ISO 15251 → Adaptive model for naturally conditioned buildings

Category II



1. Monitoring campaign



Performance Index (PI) : percentage in time when the parameter (PMV and OT) falls within the target range

1. Monitoring campaign

$$X_DI = \frac{\int_{P_h}[X - X_{M,s}]dt + \int_{P_c}[X_{m,s} - X]dt}{XDI_{BC,s}} \cdot \frac{t_s - t_{X,s}}{t_s}$$

Maximum and minimum seasonal limits of the parameter of interest according to regulations

Time periods when the parameter falls above (P_h) or below (P_c) the regulations limits

Entire monitoring period

Time period during which the comfort range is rispected

Sesonal deviation index of the parameter considered with rispect to a base case of reference

Deviation Index (DI) : index which quantify the distance of the X parameter considered from the target condition in terms of frequency and intensity of the gap

**Pisello et al., Build.Env. 2015*

1. Monitoring campaign

Monitored Workspace	PMV_DI		PPD_DI	
	Autumn	Winter	Autumn	Winter
Machinery	0.17	0.21	0.24	0.31
Control	1.19	0.00	1.72	0.00
Administration	0.07	0.00	0.10	0.00
Store	0.17	0.13	0.24	0.19

Fanger's model

$PMV_DI_{BC} = 0.1 \cdot t_s$ [h]

$PPD_DI_{BC} = 2 \cdot t_s$ [% · h]

Monitored Workspace	TO_DI (II category)		TO_DI (I category)	
	Autumn	Winter	Autumn	Winter
Machinery	0.00	0.00	0.00	0.25
Control	0.00	0.00	0.00	0.13
Administration	0.00	0.00	0.01	0.01
Store	0.00	0.00	0.00	0.00

Adaptive comfort model

$TO_DI_{BC} = 1 \cdot t_s$ [°C · h]

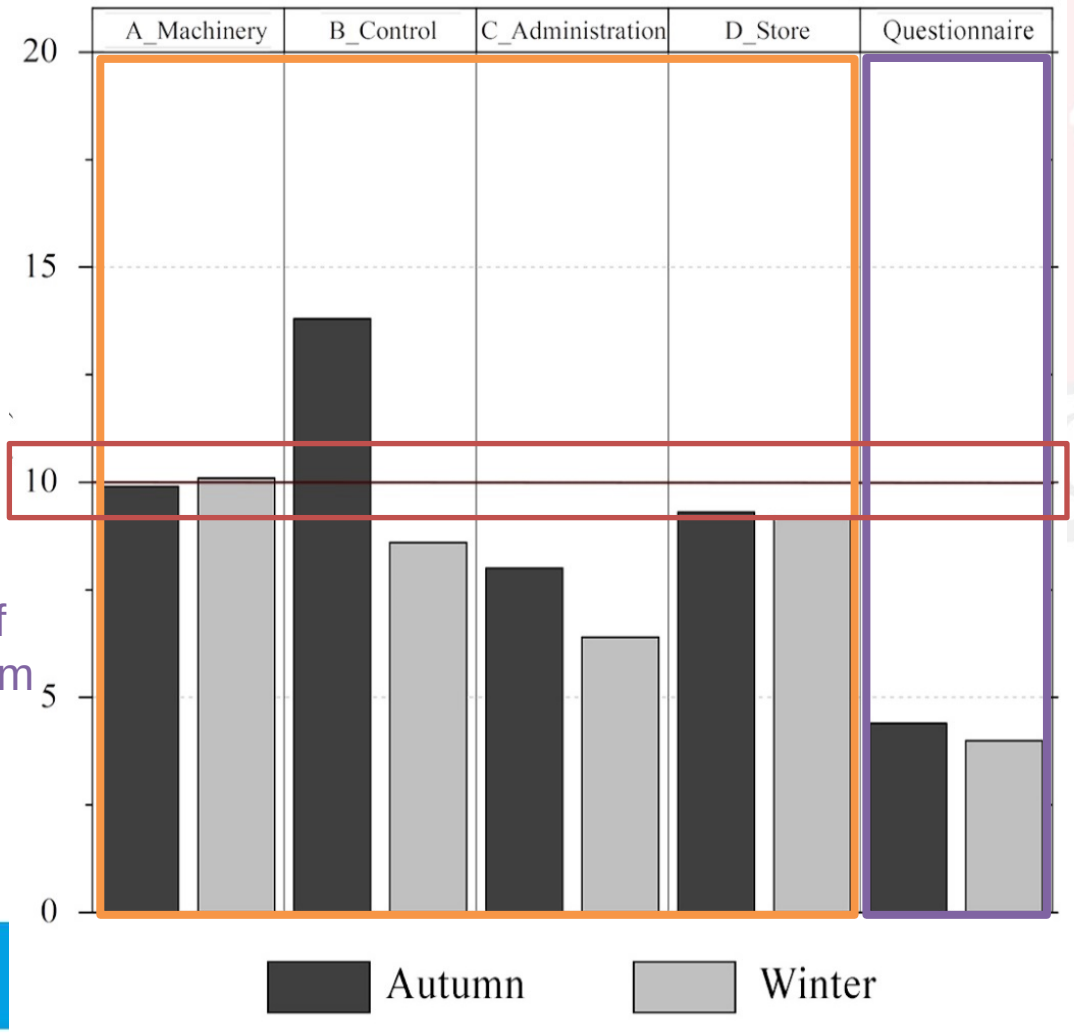
Monitoring campaign VS Questionnaires

Thermal comfort evaluation: minor and not depending on season

PPD (%)
Driven by measured physical data

Comfort threshold according to standards

PD (%), percentage of dissatisfied people from questionnaires



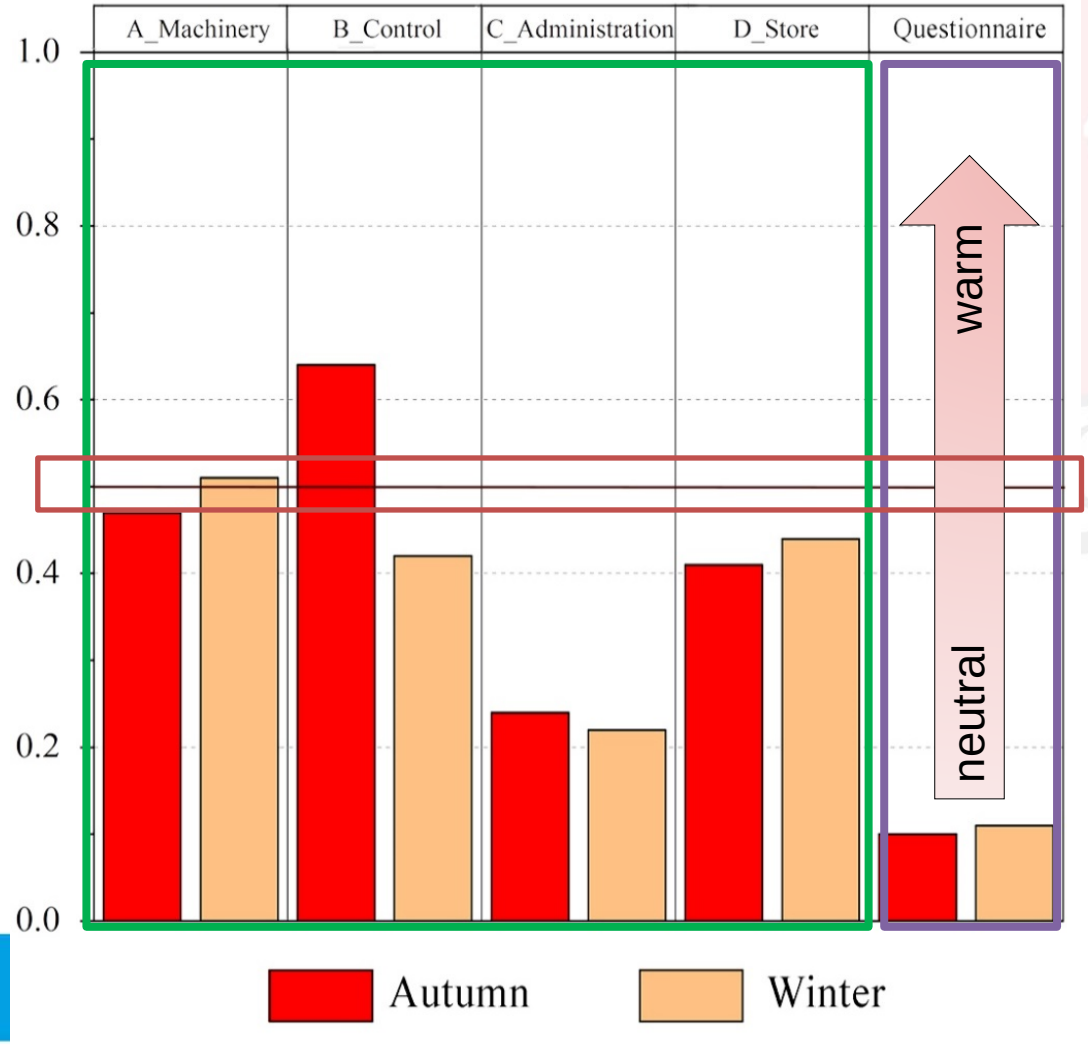
Monitoring campaign VS Questionnaires

Thermal comfort evaluation: minor and not depending on season

PMV
Driven by measured physical data

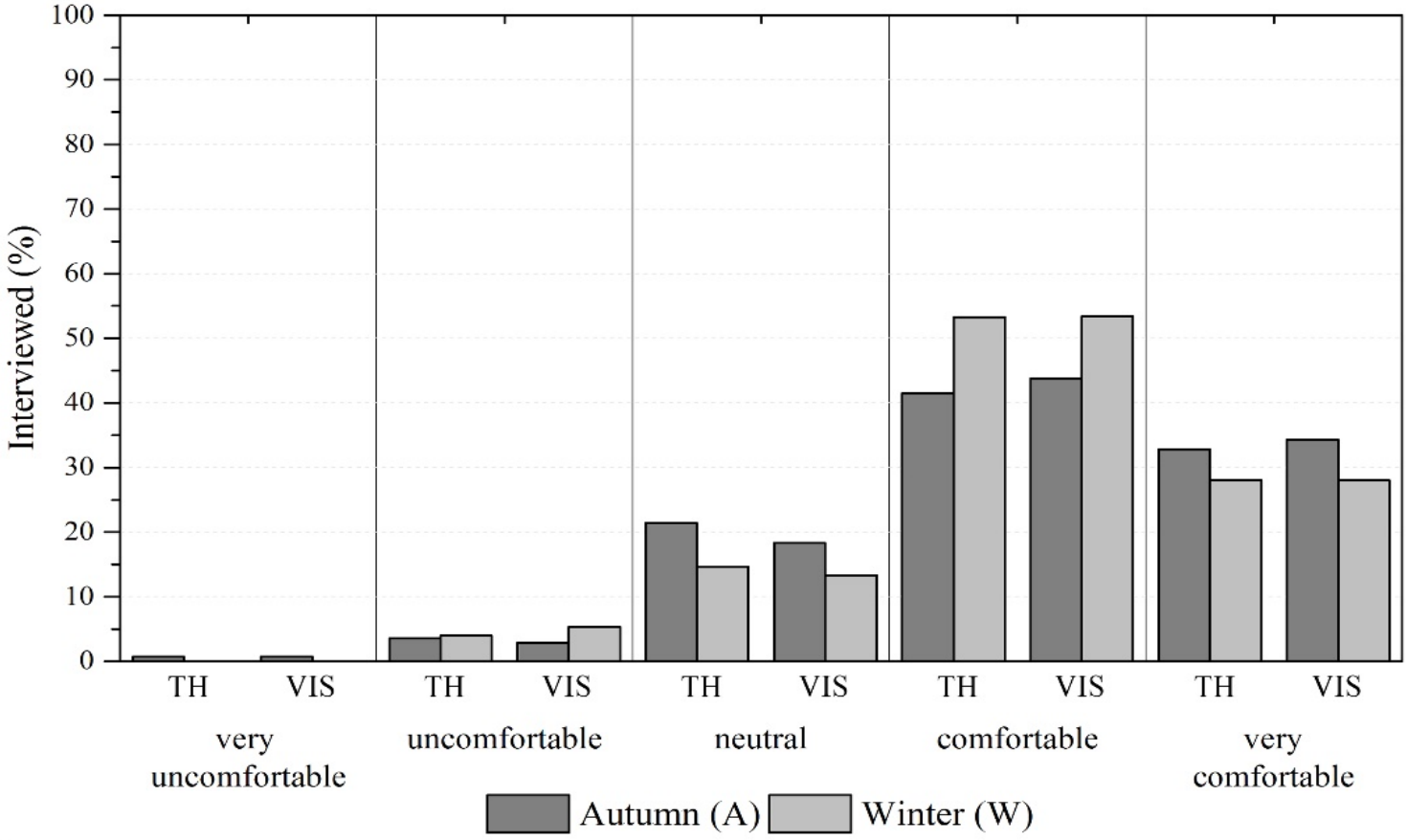
Comfort threshold according to standards

TSV , thermal sensation vote from questionnaires



2. Questionnaires

Consistent visual/thermal perception correlation

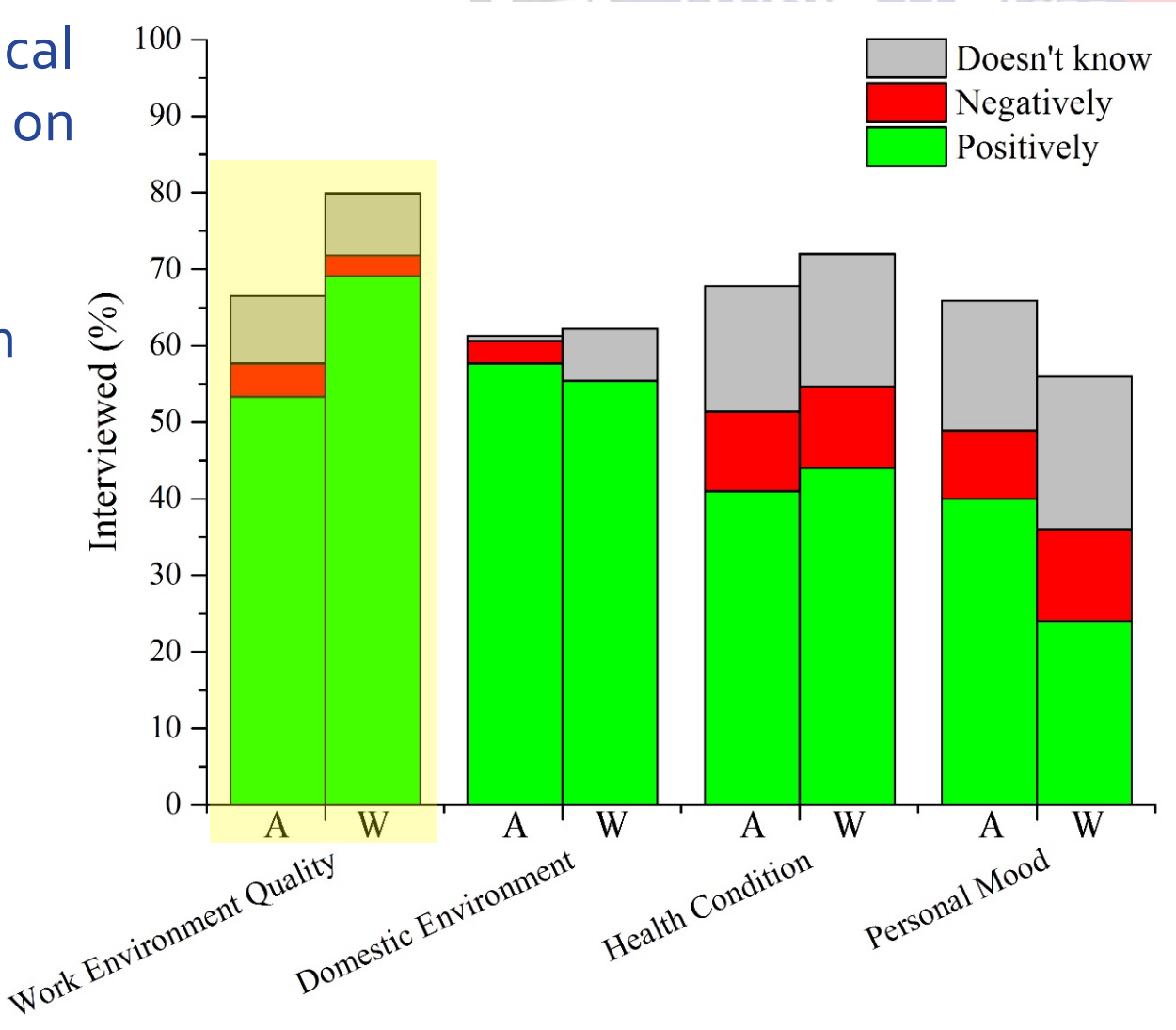


	R^2		Equation	
	Autumn	Winter	Autumn	Winter
Comfort	0.48	0.46	TH = 0.7VIS + 0.25	TH = 0.7VIS + 0.37
Acceptability	0.44	0.45	TH = 0.6VIS + 0.40	TH = 0.6VIS + 0.40
Tolerability	0.47	0.59	TH = 0.7VIS + 0.24	TH = 0.7VIS + 0.32

TH, thermal sensation VIS, visual sensation

2. Questionnaires

Non-physical influences on general comfort perception



Conclusions

1. **Consistent discrepances** in terms of comfort evaluation between (i) physical data analysis according to standards and (ii) workers' personal perception

2. **Adaptive model** (less strict than Fanger model) more suitable to describe real perception even if the case study is mechanically conditioned most of the time

3. **Positive influence (?)** of company policy strategies to improve the work life well-being on comfort perception: always better surveyed satisfaction and minor correlation to season

Further developments

1. Whole year assessment

2. Possible relationships between different typologies of perceived comfort (i.e. thermal-visual-acoustic) – develop first findings

3. Different benchmark case study: negative environment

4. Economic quantification of work-environment quality policy and its influence on employees' productivity

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Centro Interuniversitario
di Ricerca sull'Inquinamento
e sull'Ambiente - "Mauro Felli"

Special thanks to:

InPath TES

Grant number
657466

Dr. Francesco De Giorgio
medical doctor

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Thanks for your kind attention

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