Adaptive Thermal Comfort Actions

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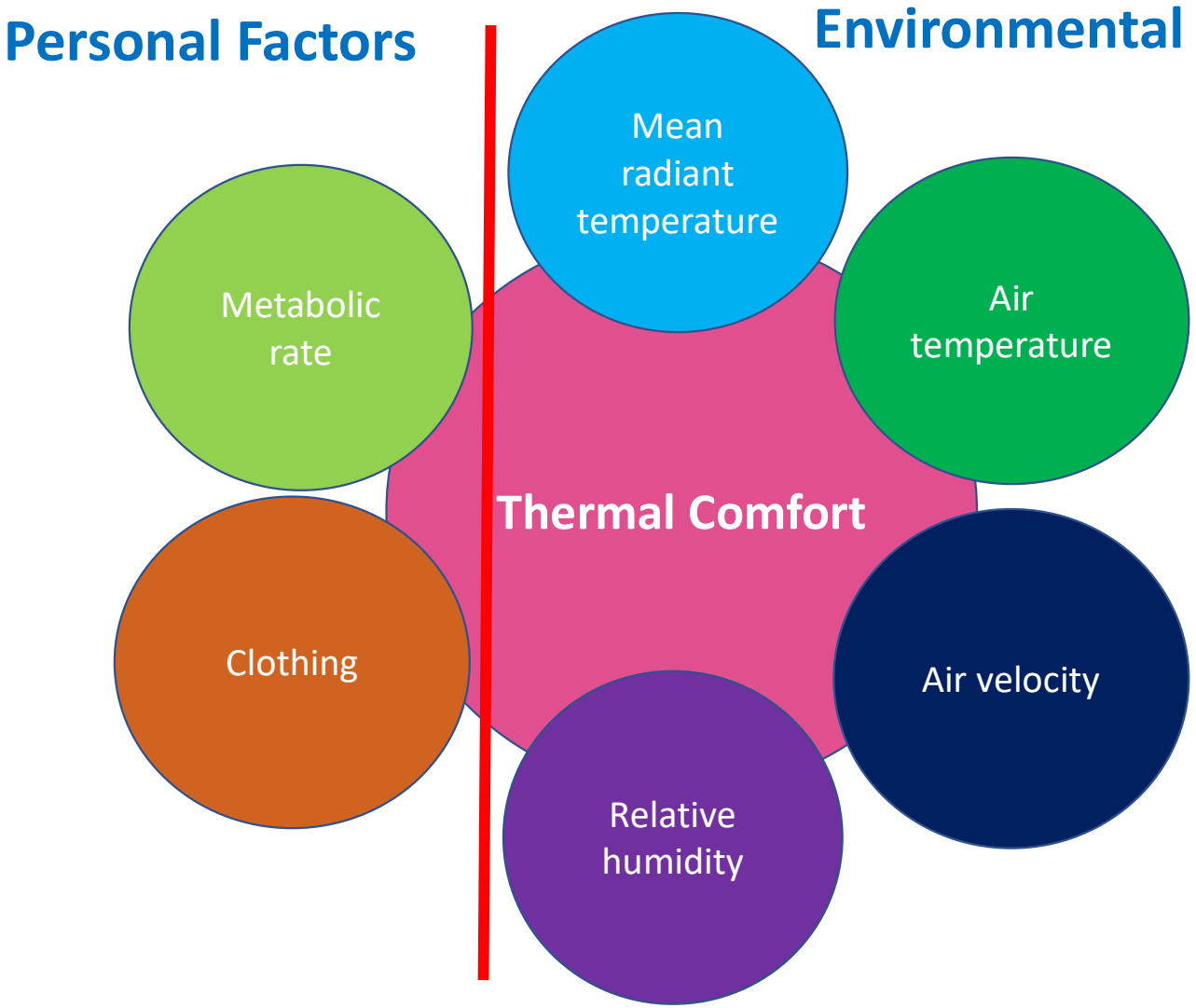
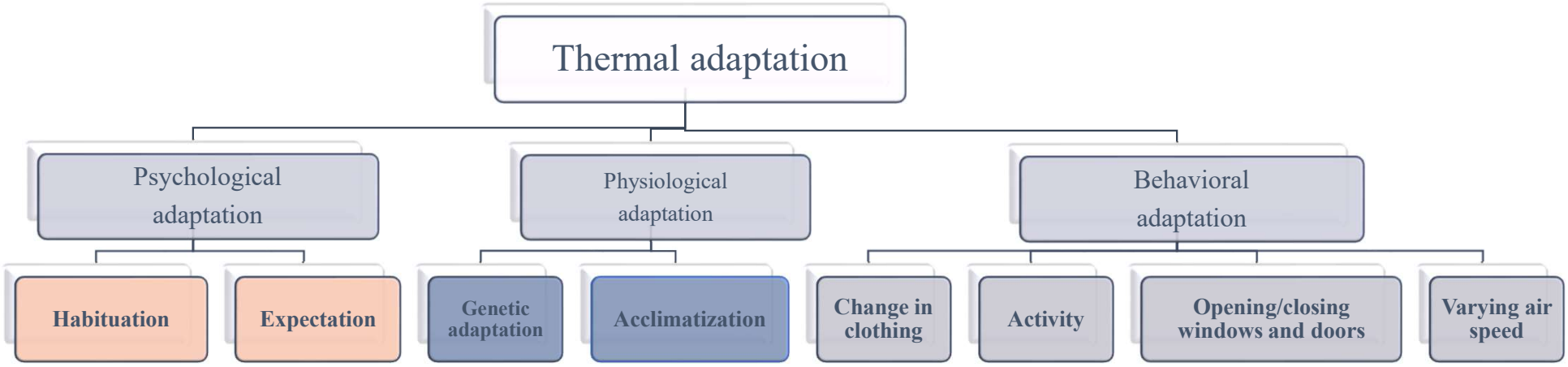
Factors influencing thermal comfort

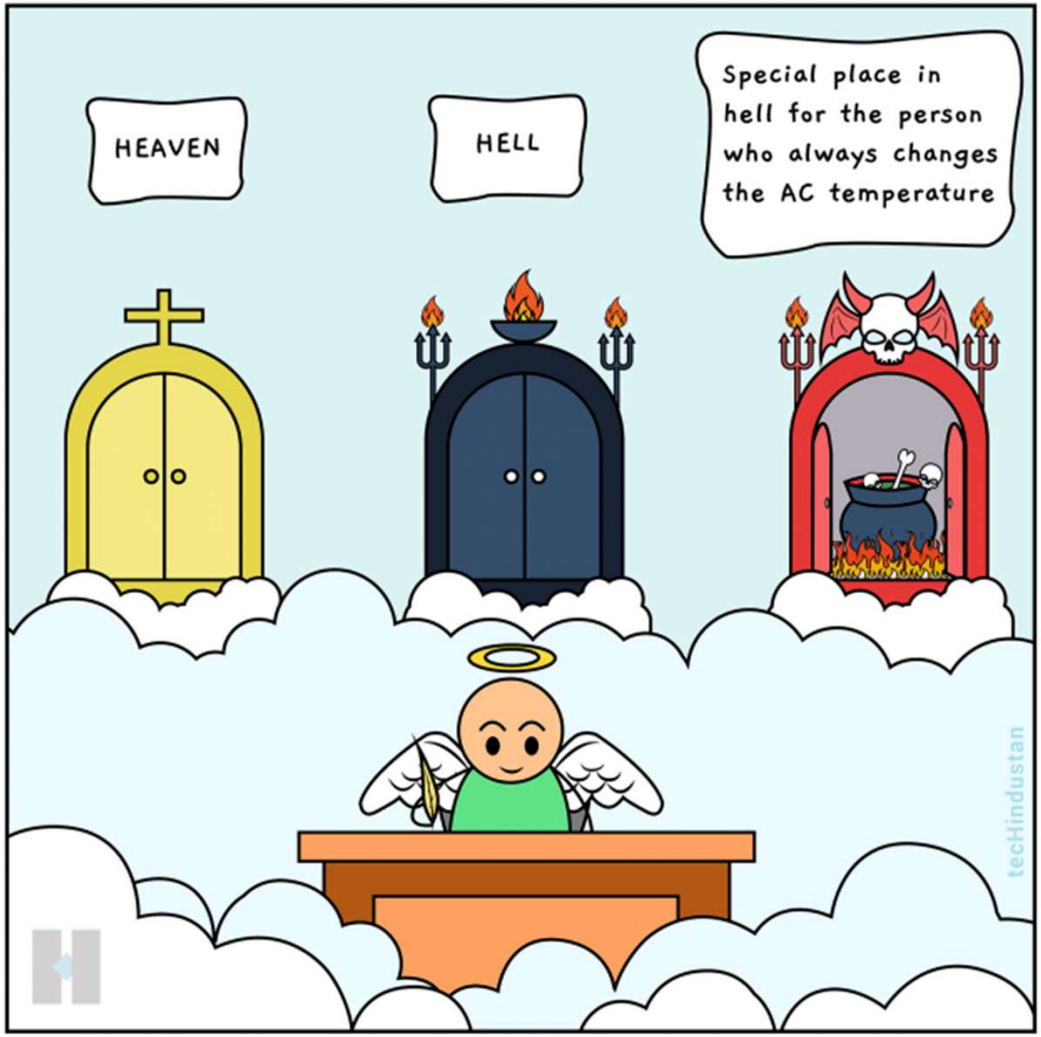


Thermal adaptation

If a change occurs such as to produce discomfort, people react in ways that tend to restore their comfort *(Humphreys and Nicol, 1973)*



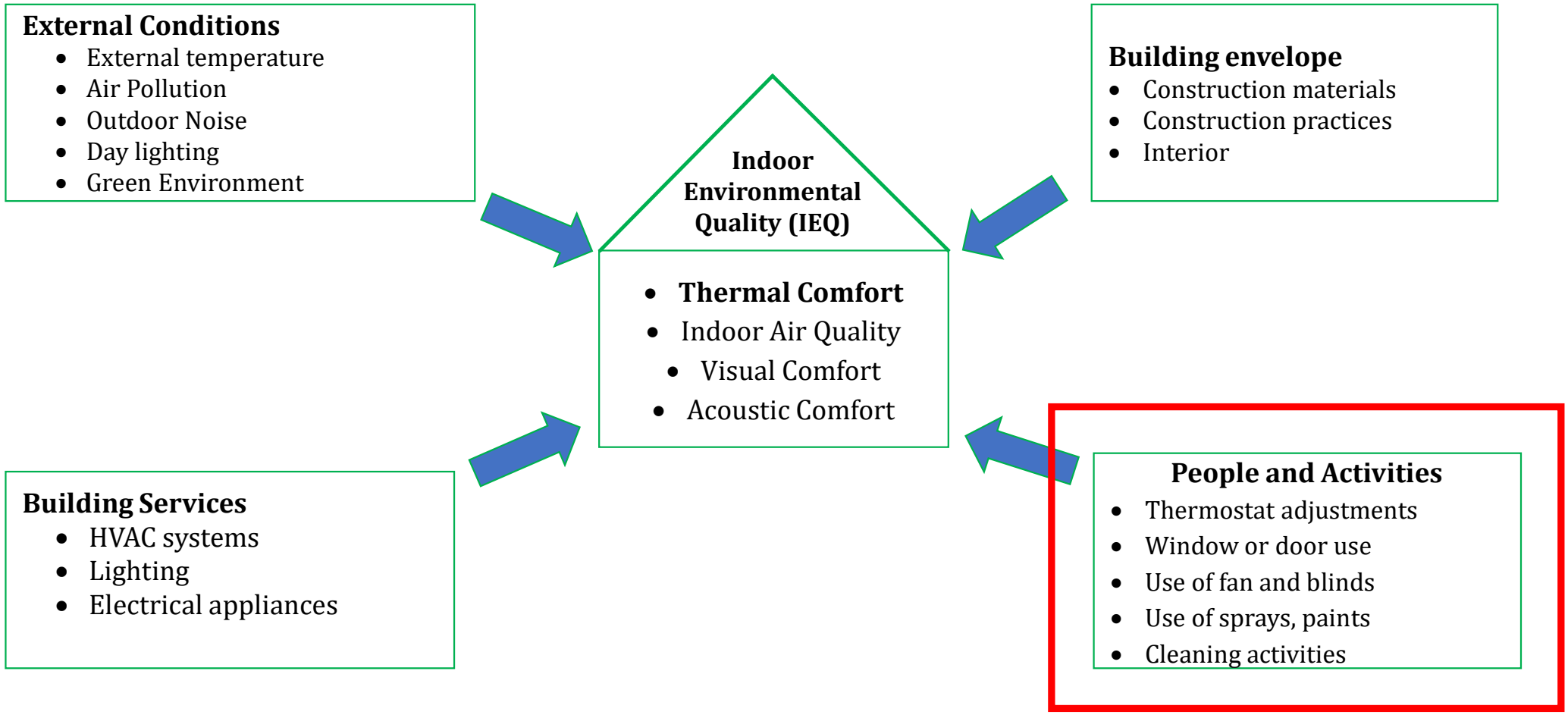
What people think about the person with remote in hand ……..



Occupant's adaptive behaviour

- Tolerate as it is (non voluntary action)
- Window opening/closing
- Blind opening/closing
- Fan on/off
- Light on/off
- Thermostat adjustments
- Clothing adjustment
- Activity adjustment

Thermal Comfort as One of Four Basic Comforts



Common adaptive actions in residential environment

Conditioned

- Adjust temperature
- Use blanket if feeling cold
- Adjust fan speed
- Adjust blinds/curtains

Un-conditioned

- Adjust fan speed
- Adjust window opening
- Adjust clothing
- Adjust blinds/curtains
- Tolerate if nothing works

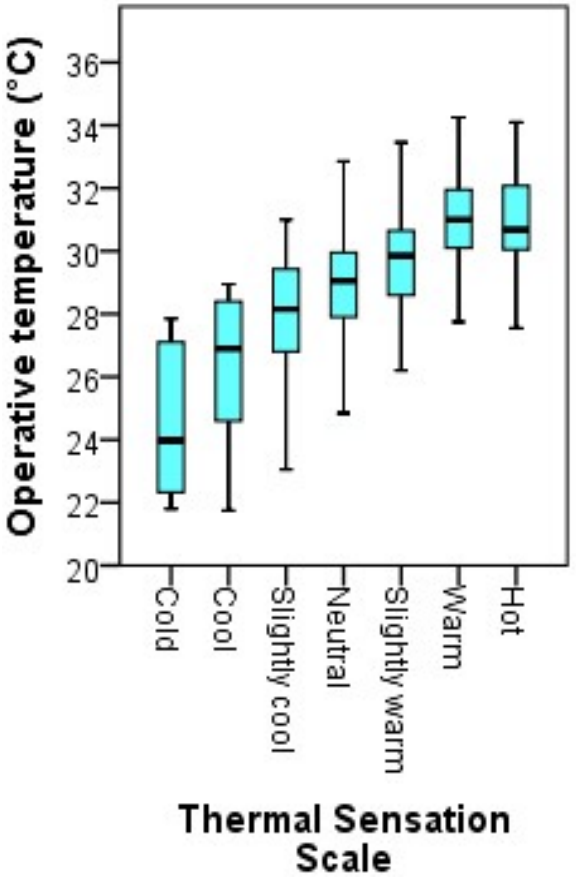
Is temperature the main driver for window operation?

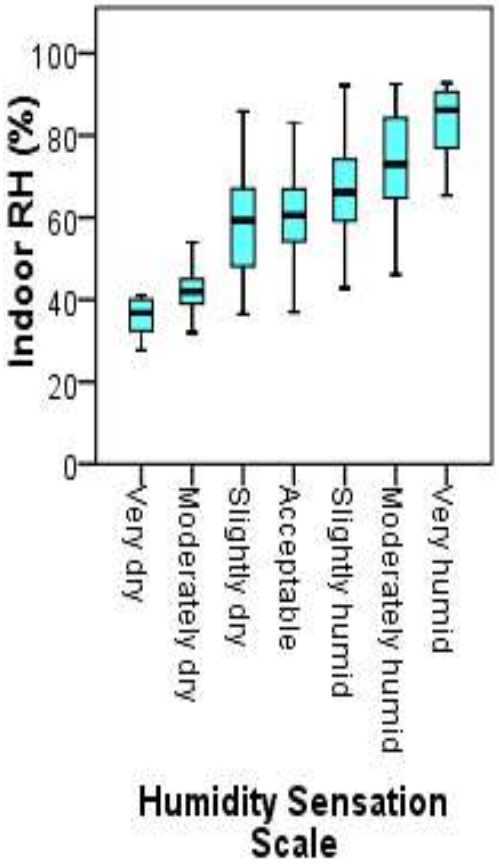
Situation	Adaptive action
What do you do when you feel low?	Open the window, put off the curtains
What do you do when there is too much noise coming from outside?	Close the window
What do you do when there is too much pollution outside?	Close the window
What do you do when feeling suffocated?	Open the window
What do you do when there are too many mosquitoes outside?	Close the window
What do you do if there is a safety/theft issue:	Close the window
What do you do when there is glare in room?	Pull the curtains/blinds
What do you do when mosquitoes are more	Close the window

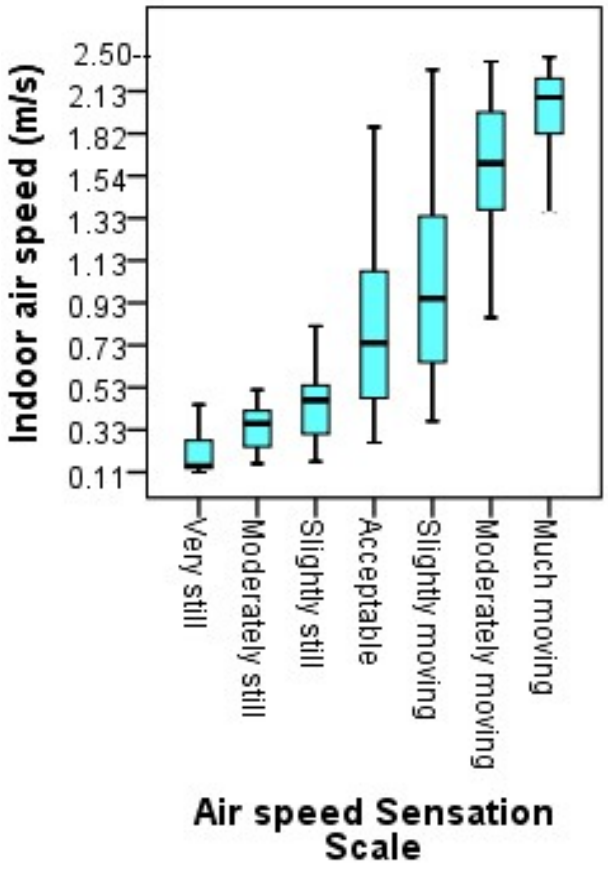
Key issue in study of adaptive actions

- Most adaptive actions are taken not only due to one single cause
- Multiple adaptive actions are taken together in **AC homes**: temperature, clothing, fan in very few cases
- More multiple adaptive actions are taken together in **non-AC homes**: windows, curtains, fan, clothing, expectation
- Making multi-variate analysis a necessity for truly reflecting adaptive model

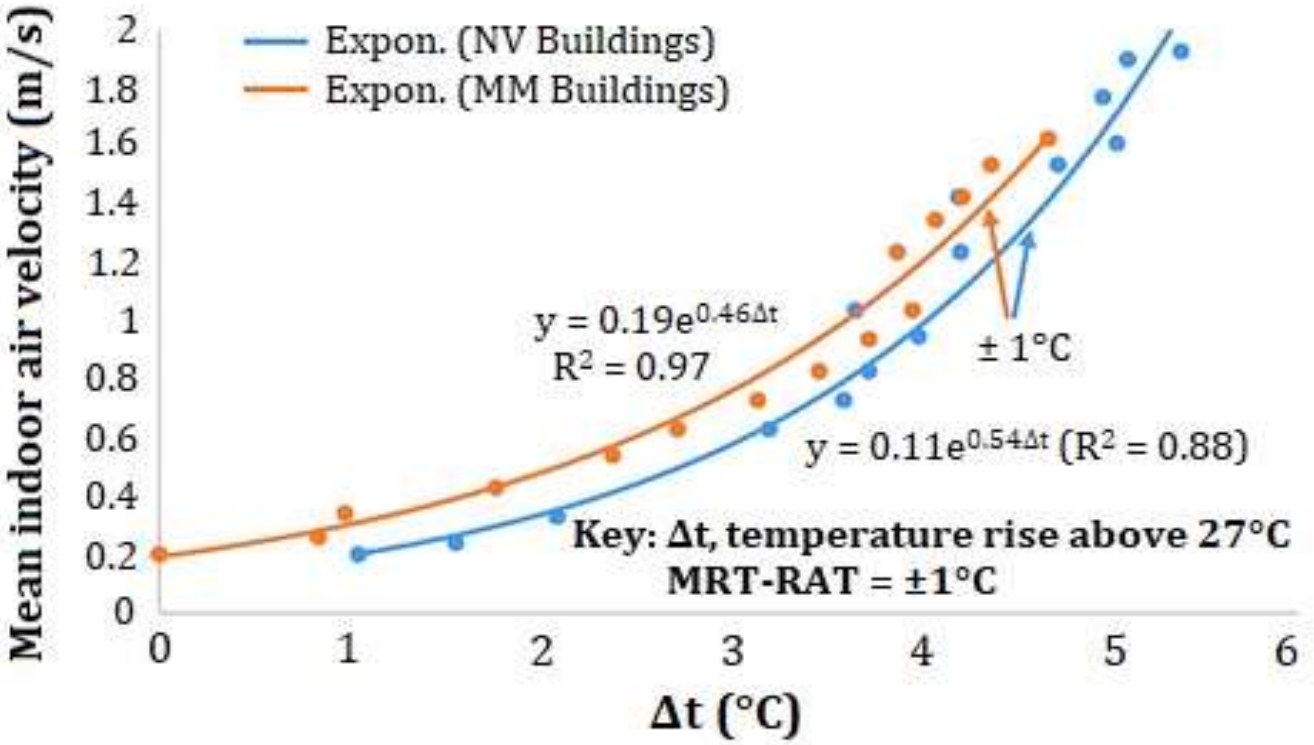
Wide variation in thermal comfort data (4658 samples)







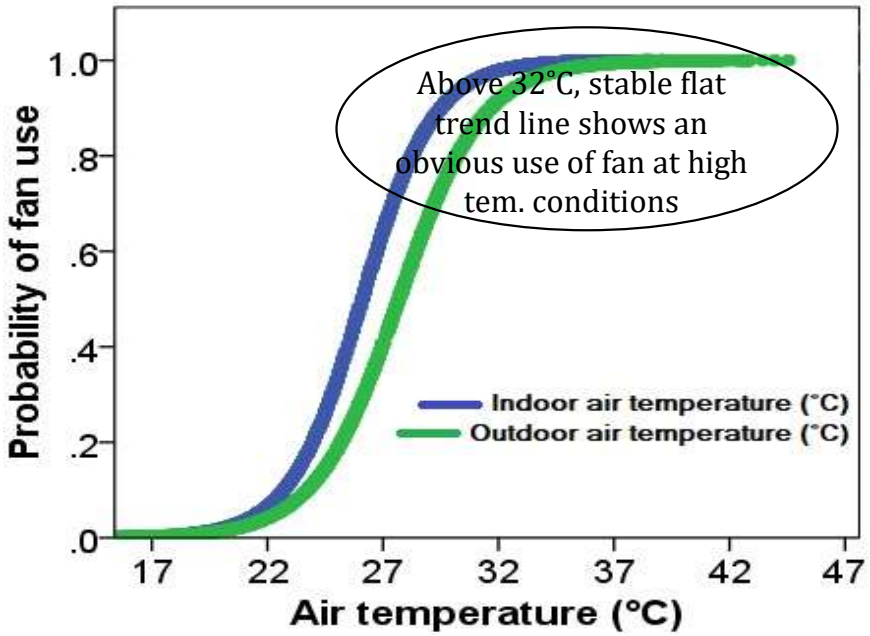
Air velocity significantly influences comfort temperature

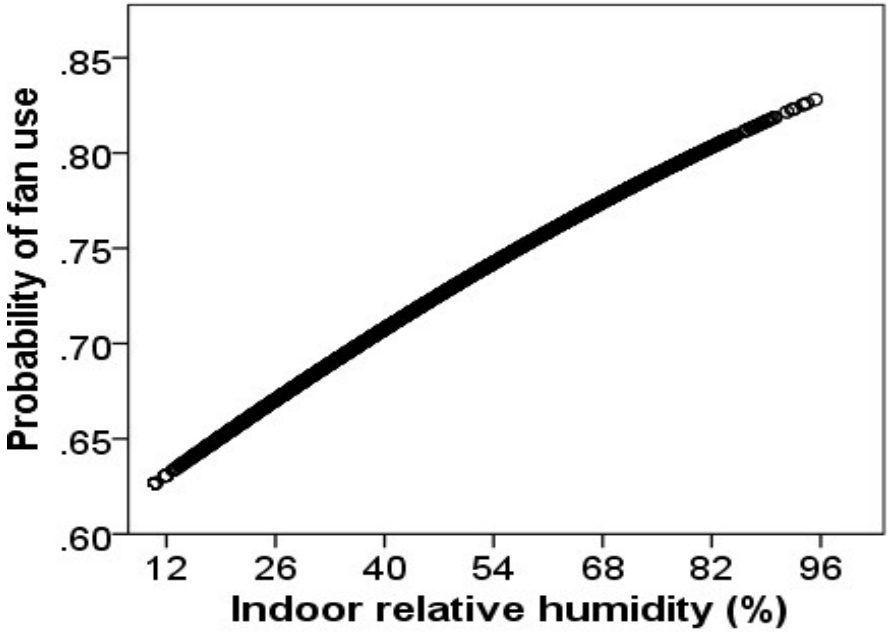


Side effects of higher air velocity

- Noise
- Fluttering/flying of objects like papers
- Additional energy consumption of fan
- Non-uniform distribution in space
- Flicker due to improper installation of light and fan

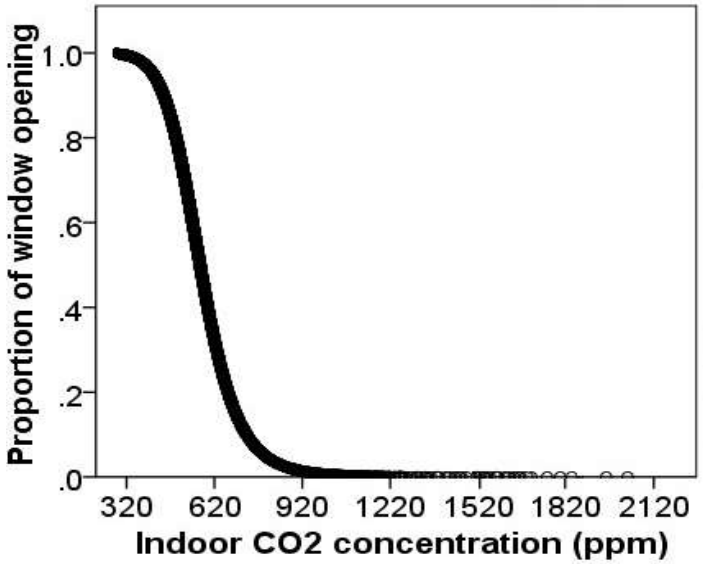
When do people use fan?

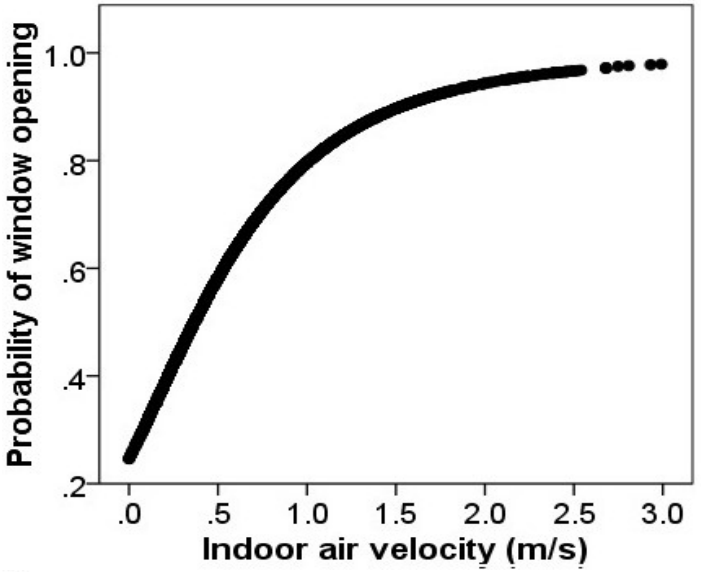


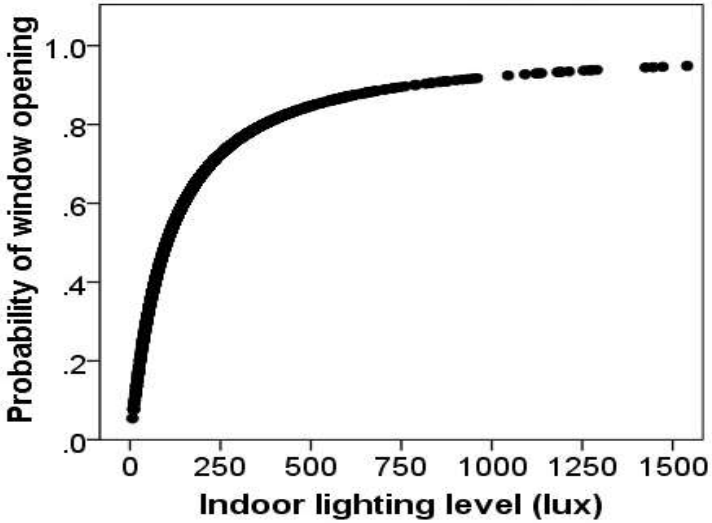


- Subjects use of fan is based on the combined effects of temperatures and relative humidity.
- Therefore, a good **adaptive comfort model should directly include relative humidity**

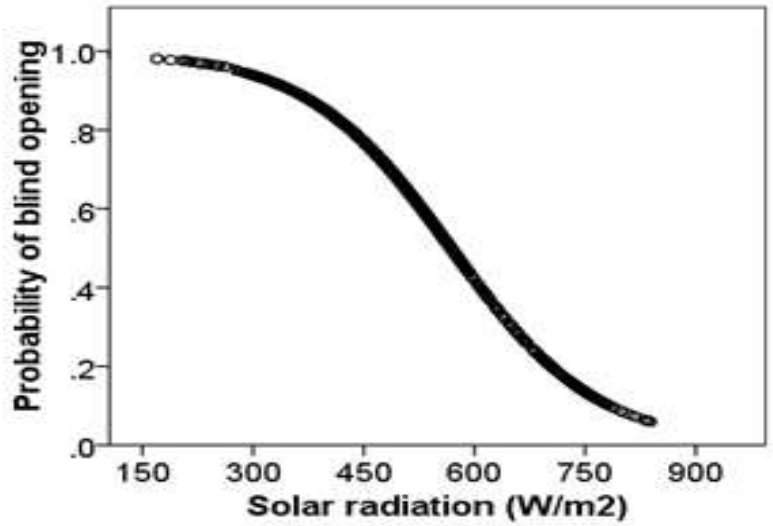
Window opening behaviour (Cont……)

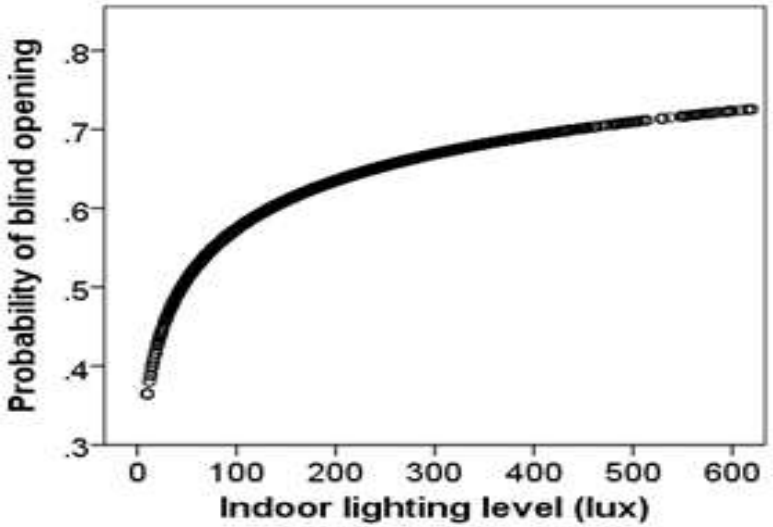


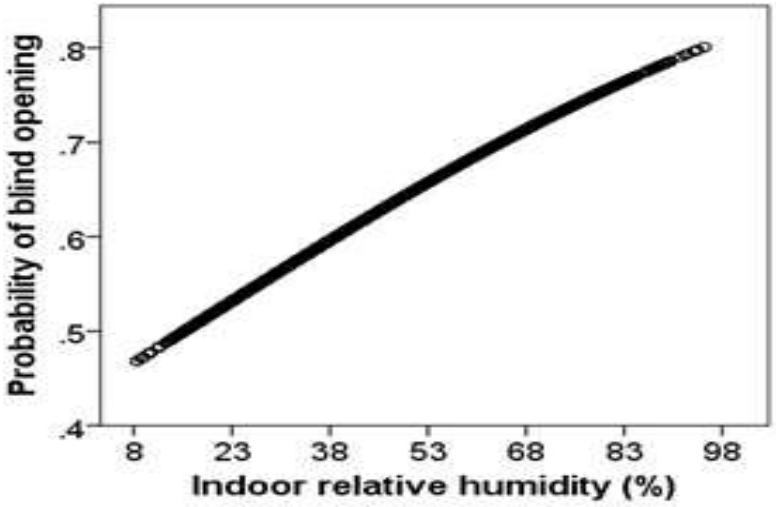


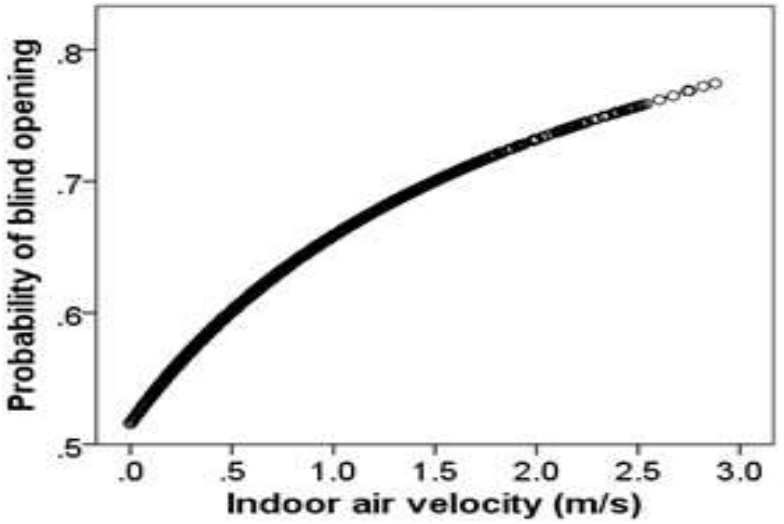


Use of Blind/curtain

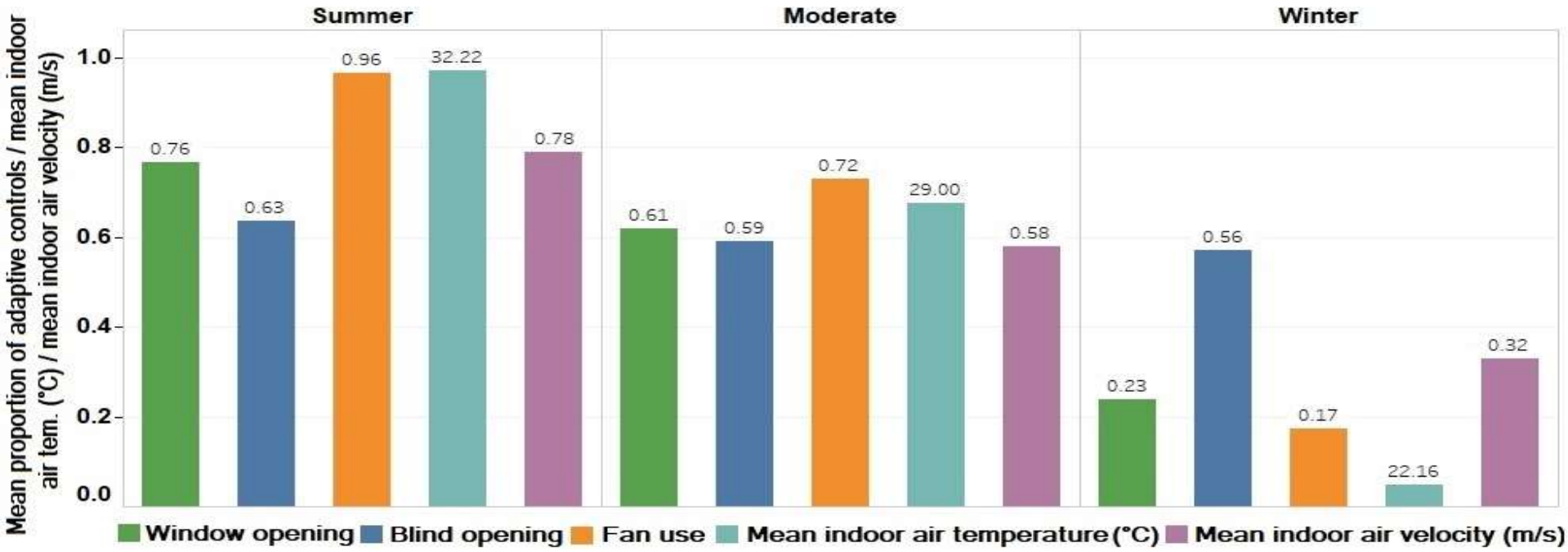








Use of adaptive controls across the seasons



Conclusion

Thermal adaptation is not a univariate problem!!

and/or

Univariate adaptive equations need to be read with their qualifiers/applicability limits

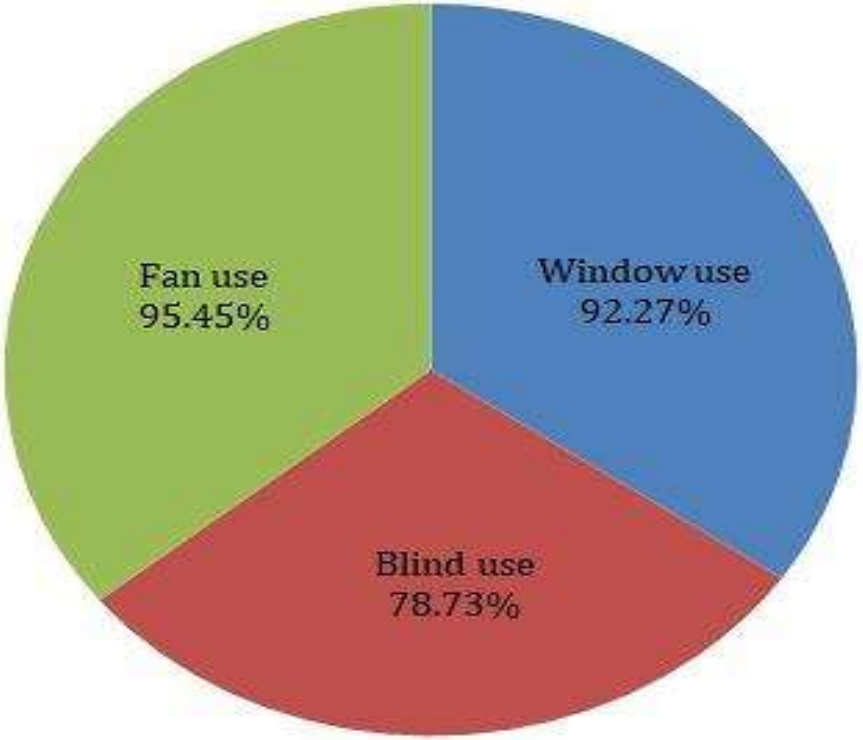
Multivariate fan use behavioural model

Surveyed buildings	Fan use behavioural models	R^2
All	$\log\left(\frac{p}{1-p}\right) = -17.714 + 0.558IAT + 0.033IRH + 8.660IAV + 1.123WS + 0.927BS$	0.85
Office	$\log\left(\frac{p}{1-p}\right) = -17.213 + \mathbf{0.588IAT} + \mathbf{0.042IRH} + \mathbf{7.062IAV} + \mathbf{1.485WS} + \mathbf{1.663BS}$	0.87
Residential	$\log\left(\frac{p}{1-p}\right) = -20.328 + \mathbf{0.606IAT} + \mathbf{0.050IRH} + \mathbf{9.447IAV} + \mathbf{0.786WS} + \mathbf{0.781BS}$	0.88
IAT = Indoor air temperature; IRH = Indoor relative humidity; IAV = Indoor air velocity; ILL = Indoor lighting level; WS = Window status and BS = Blind status		

Key findings

- IAT and IAT among the environmental variables and window state among categorical variables had acute effects on fan use.
- Higher value of regression coefficient with blind state in offices infers that subject often use fan with controlled blinds position to reduce the effect of glares and overheating on the working space.
- Simultaneous use of fan with windows and blinds in offices aided ventilative effects, reduced the effects of high relative humidity and controlled glare.

Validation of results

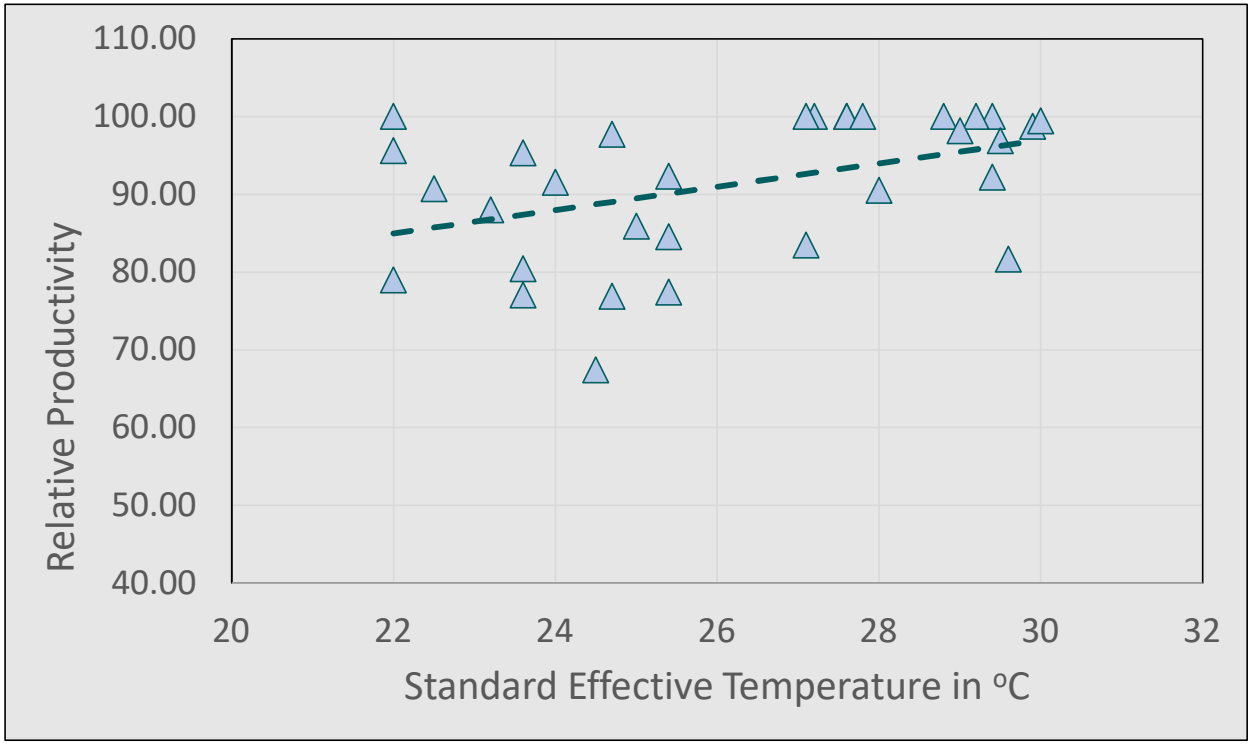


Predictive accuracy of adaptive behavioral models.

Predictive accuracy of window opening behavioral model = 92.3%
Predictive accuracy of blind opening behavioral model = 78.7%
Predictive accuracy of fan use behavioral model = 95.4%

Preliminary findings of thermal comfort on productivity

- How do we investigate productivity in residences?
- Are we most productive when we are most comfortable?



Thanks!!

Acknowledgement
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