Indoor Temperature Modulations: A New Way to Save Cooling Energy and Maintain Alliesthesia-based Comfort

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Overview

Introduction

Alliesthesia

Research Procedure & Results

- Building Simulations
- Human Comfort Experiments

Conclusions

Introduction

Motivation

- Trend toward sustainability
- Energy in buildings

Research Objectives

- Evaluate impact of modulating setpoints
  - Energy
  - Comfort

Impact of Research

- On buildings
- On future research

Alliesthesia - Literature Review

Coined by Michel Cabanac in 1971

- From esthesia (sensation) and ellios (changed)
- "Pleasure is only observed in transient states." (1992)

Recent studies by Richard de Dear, Thomas Parkinson, Christhina Candido

- Improved comfort model (2011)
- Increased sensitivity to cooling compared to heating (2015)
- Alliesthesia can be experienced within the thermoneutral zone. (2015)

Nikopoulou and Steemers (2003)

- Study showed people enjoyed feeling warm (+1)

Research Procedure

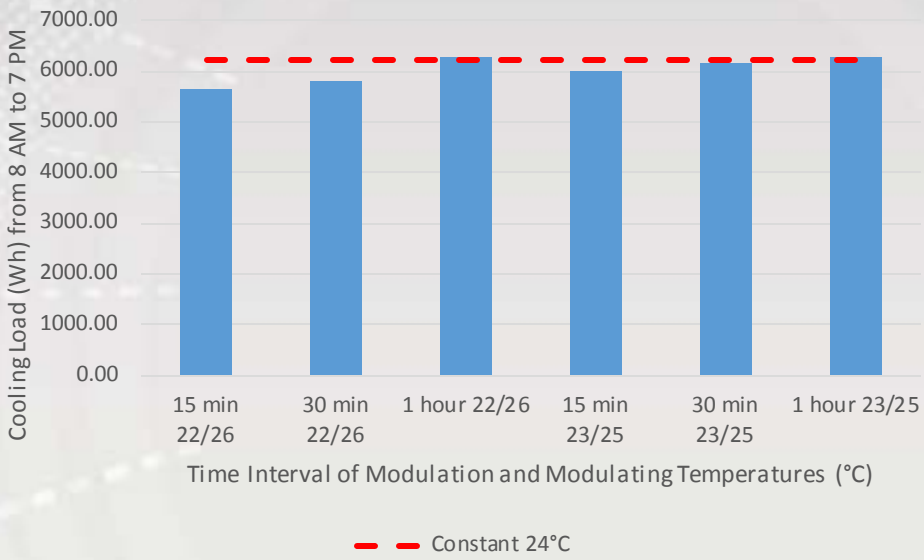
Building Energy Simulations with EnergyPlus

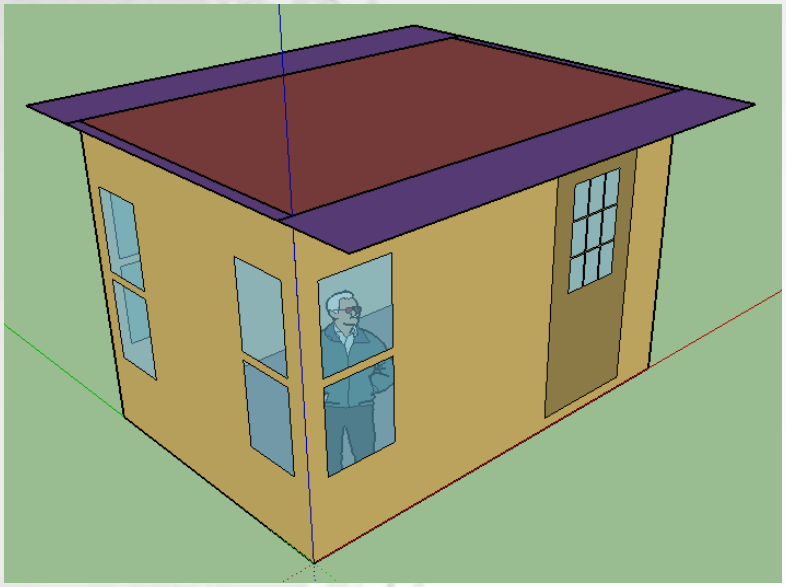
- Mini lab simulations
- Commercial building simulations

Human Comfort Experiments

- Cooling experiment
- Heating experiment

Mini Lab Simulations

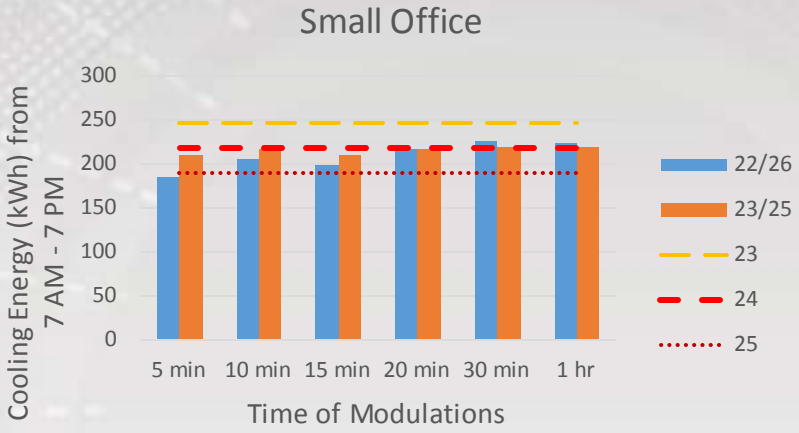


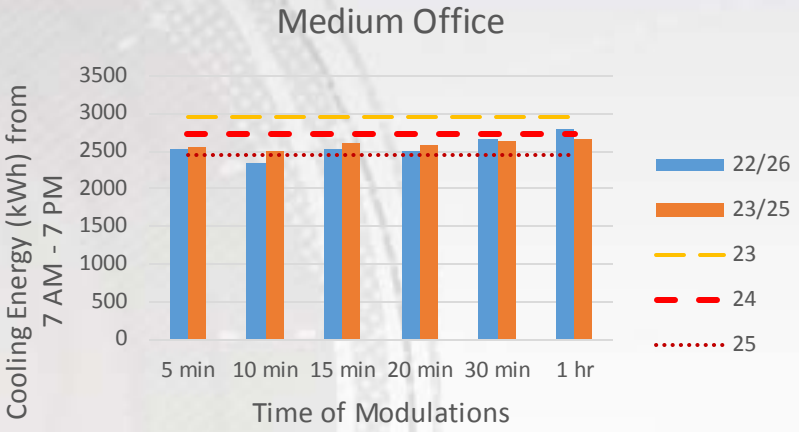


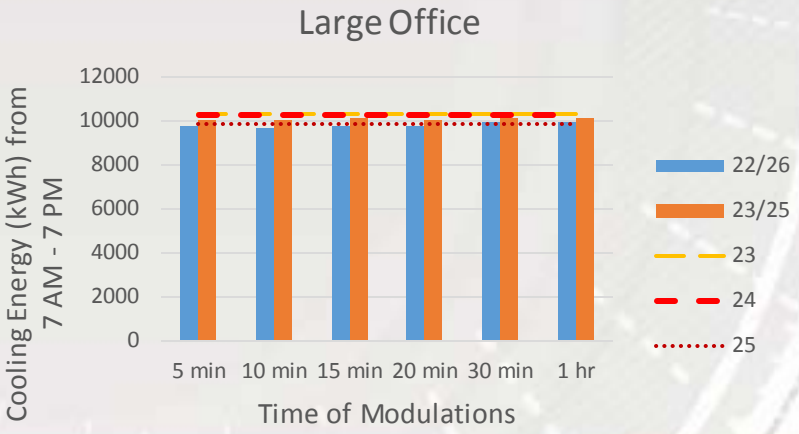
- Up to 9% energy savings
- Shorter, wider modulations had greater energy savings

Commercial Building Cooling Simulations

Office Buildings - Houston

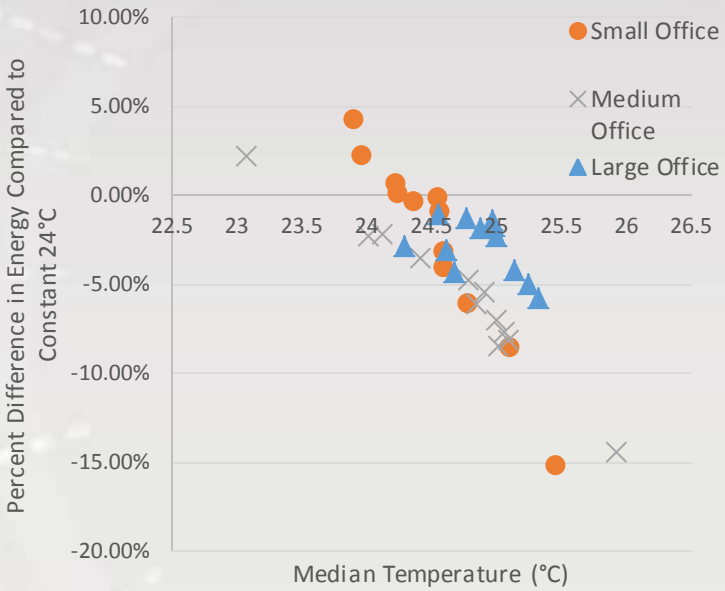






Commercial Building Cooling Simulations

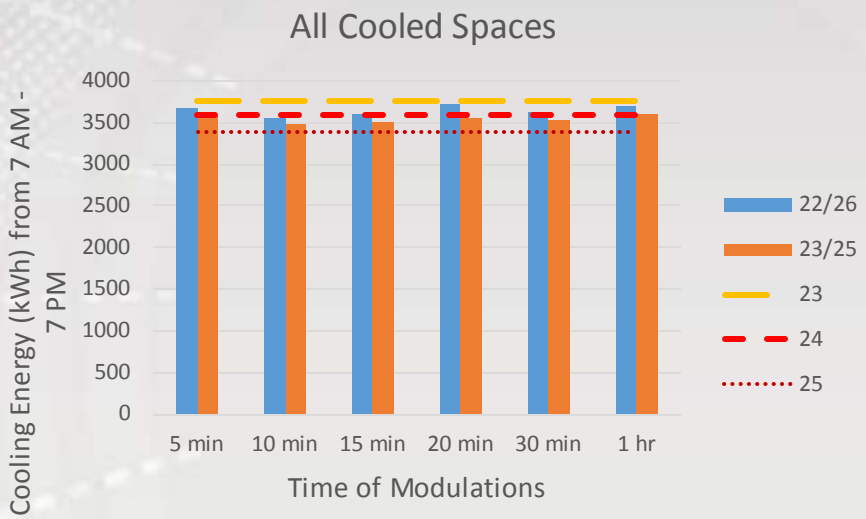
Office Buildings – Temperature Analysis

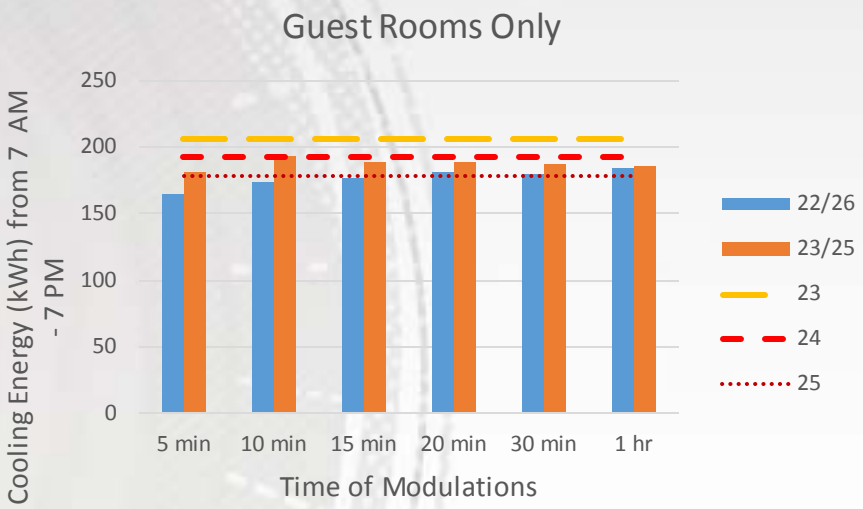


	Regression Line	Intercept with 0% savings
Small Office	y = -0.1153x+2.8018	24.300°C
Medium Office	y = -0.056x+1.3258	23.675°C
Large Office	y = -0.0245x+0.5791	23.637°C

Commercial Building Cooling Simulations

Large Hotel - Houston





Improved energy savings (4-10%) with smaller zones

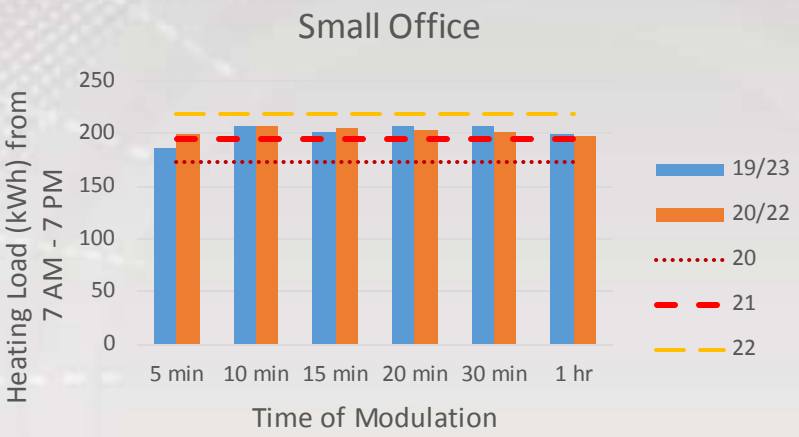
Cooling Simulations

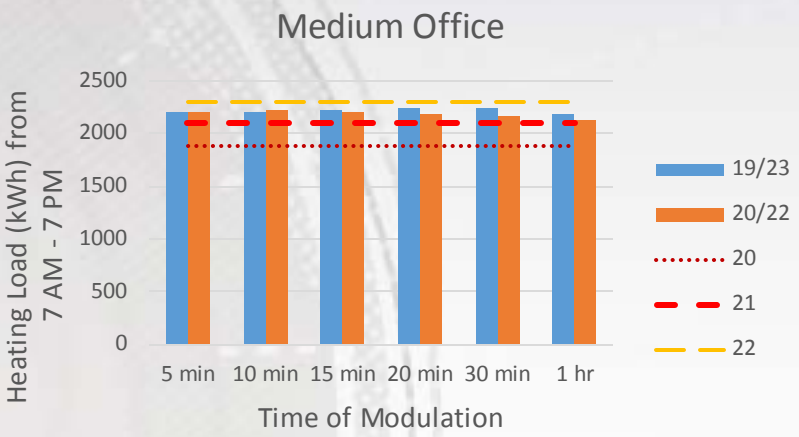
Energy Saving Trends

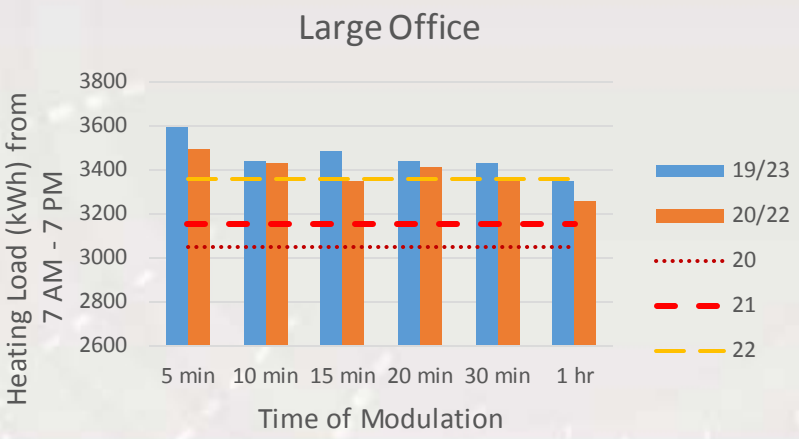
- 5-10% energy savings
- Wider, shorter modulations
- Larger buildings
- Smaller zones

Heating Simulations

Office Buildings - Chicago







Modulations increased energy usage.

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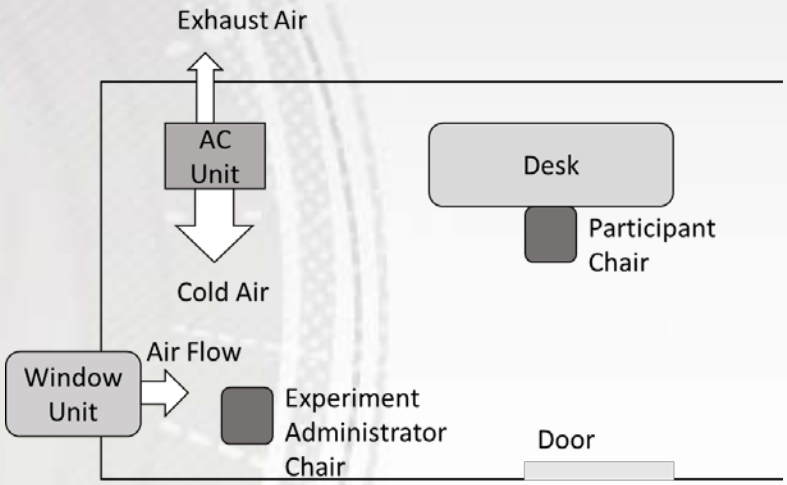
Human Comfort Experiments

Single participant in mini lab at a time
- Participants divided into two groups of about 10 participants each

45 minute procedure
- 5 minute adjustment period
- 40 minute experiment
  - Constant temperature for control group
  - 10 minute modulations of ±2°F for experimental group
  - Survey every 2.5 minutes



Human Comfort Experiments

Surveys

Please rate your thermal sensation by circling one of the options below

-3	-2	-1	0	1	2	3
Cold	Cool	Slightly Cold	Neutral	Slightly Warm	Warm	Hot

How pleasant are the thermal conditions?

-3	-2	-1	0	1	2	3
Very Unpleasant	Unpleasant	Slightly Unpleasant	Neither Pleasant nor Unpleasant	Slightly Pleasant	Pleasant	Very Pleasant

Would you rate the current thermal conditions as acceptable or unacceptable?

0	1
Unacceptable	Acceptable

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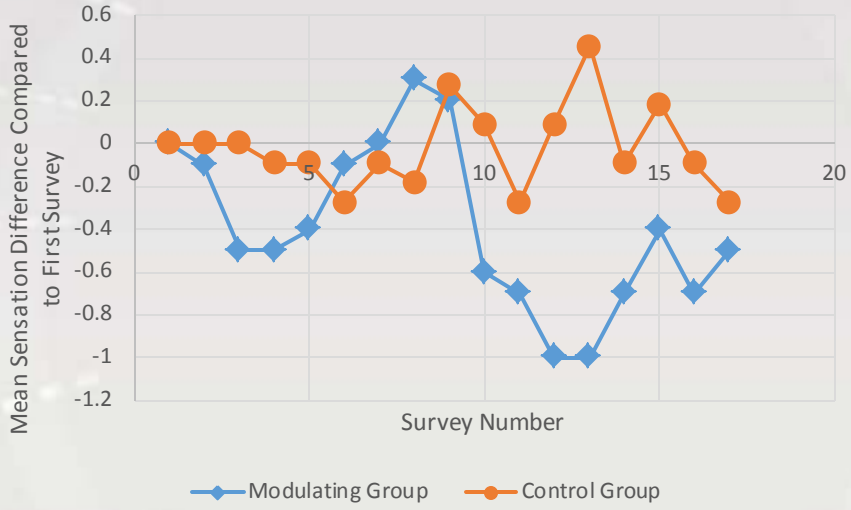
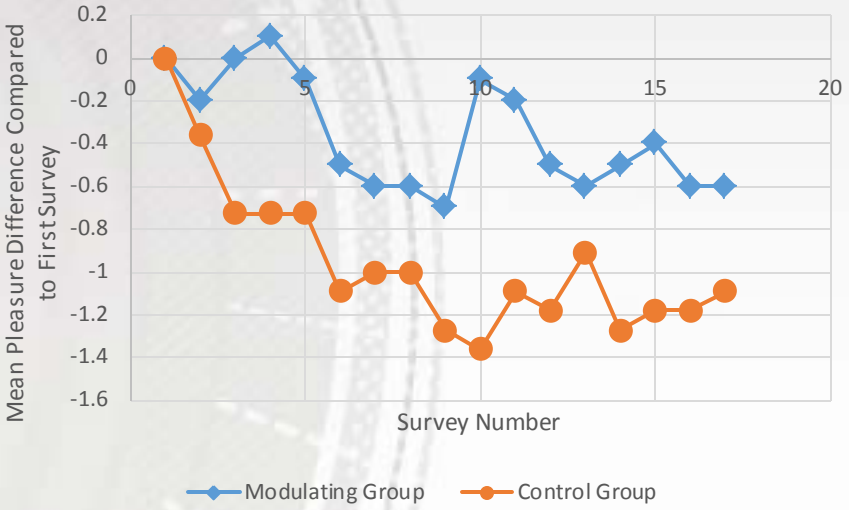
Human Comfort Experiments

Cooling Experiment Results

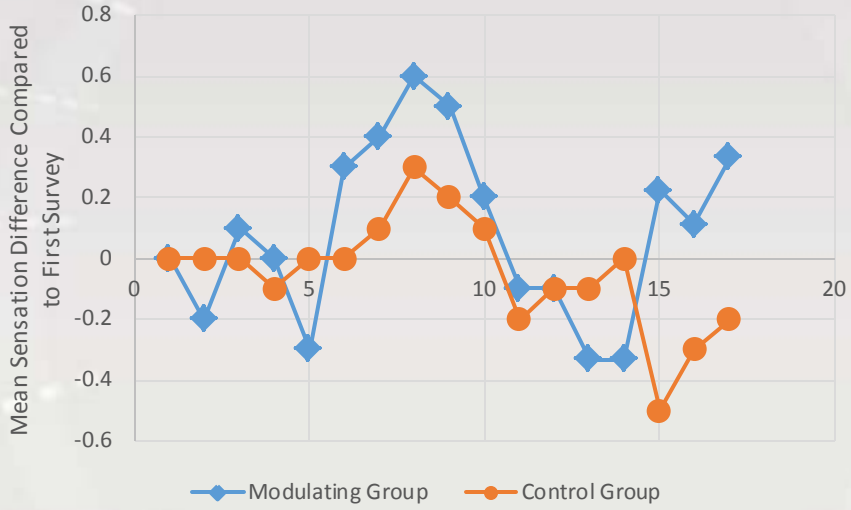


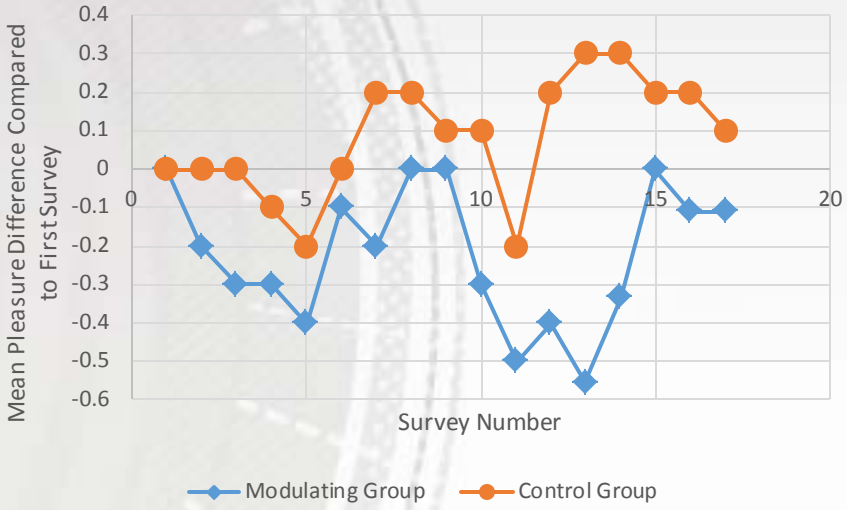


Thermal comfort decreases for constant temperature but is "reset" by decrease in temperature.

Human Comfort Experiments

Heating Experiment Results





Thermal comfort does not decrease for constant temperature.

Conclusions

Applicable in cooling environments

- Ideal: large building with many small zones
- Sedentary work
- Occupants in spaces for long periods of time

Benefits

- Energy savings
- Increased comfort by “resetting” pleasure

Future Work

- Further comfort testing
- Complex scheduling

Thank you!
Questions?