The effect of real-time context-aware feedback on occupants' heating behaviour and thermal adaptation

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1. WHY this study?

- **Heating energy use** represents 57% of the total domestic energy consumption in UK [1].
- **Occupant behaviour** is now being recognized as a significant contributor to this consumption [2].
- Monitoring of electricity feedback has been done many times before. Very few studies have investigated the effect of feedback on occupants’ heating behaviour and thermal adaptation [3].


2. Background

The dynamic model of thermal adaptation
3. Aim of the study

Observe and quantify the effect of feedback on:

- **Cognitive and psychological factors**
  *Does feedback increase perceived environmental control?*

- **Occupant behavioural adaptation**
  *Are feedback able to prompt “good” adaptive actions (clothing and ventilation rates)?*

- **Thermal comfort**
  *To which extent can energy feedbacks reshape occupant neutral temperatures?*
4. Experimental Design

• 15 monitored rooms at the University of Bath campus
• Overall duration of six weeks (from 16 Feb 2015 to 29 Mar 2015), divided into two phases of 3 weeks each
  ✓ The first phase (control phase) consisted of monitoring the student rooms;
  ✓ In the second phase (experimental phase), students were provided with feedback via their smartphones, with a specially developed in-house application.
5. Hardware

• In-deep Monitoring
  ✓ Environment sensors (temperature and relative humidity)
  ✓ PIR sensor
  ✓ CO₂ sensor
  ✓ Radiator sensor

• Feedback and interaction
  ✓ Smartphones
6. Architecture design
7. Application
8. Energy saving tips

- **If Friday:**
  The weekend is coming! Remember to turn off the radiator (by adjusting the valve to zero) if you don’t plan to be in your room.

- **If between 8PM and 10PM:**
  Do you feel cold when you go to sleep? Rather than turning up the radiator have you tried wearing a heavy pyjama or using extra blankets? Drawing your curtains can also help to keep the heat in!

- **If CO$_2$ < 600 ppm:**
  Oops! You might have opened both your window and door, which means that if the radiator is on, you are heating the outside air! If you opened these because your room was feeling stuffy, then remember to close them back quickly to save energy.

- **If CO$_2$ > 1800 ppm:**
  Your room is getting stuffy! Open your window for a while and get some fresh air! Remember to close it back though as otherwise you are just heating the outside air!

- **If room temperature > 21 °C:**
  Your room temperature is more than 21°C at the moment. Most people find this quite warm. Turning down your radiator would help save energy. If you still feel cold, have you tried wearing warmer clothes instead?
9. Psychological measurements

- Two daily questionnaires adapted from ASHRAE and ISO 7730 including the following information:
  - Current clothing
  - Activity level
  - Thermal sensation vote (TSV)
  - Thermal preference vote (TPV)
  - Thermal acceptability vote (TAV)
  - Perceived air quality

- Two additional questionnaires (at the end of the first and second experimental phases) designed to measure:
  - Overall satisfaction with the room
  - Perceived environmental control
10. Results I
11. Results I I

- overall perceived environmental control increased (Group 1),
- thermal and air quality satisfaction levels increased (Group 1).
Thank you! Any question?