# "Seeing red, feeling hot? – The impact of illumination on thermal comfort"

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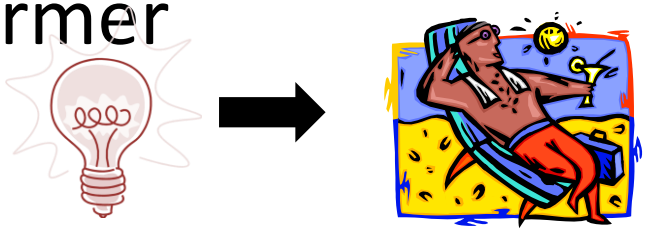
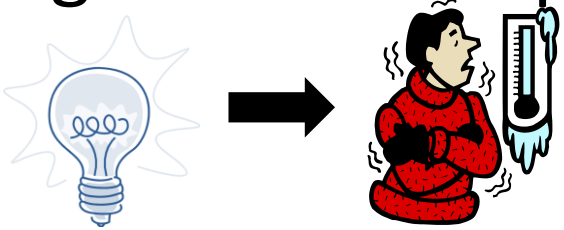
# The Hue-Heat-Hypothesis – "You feel what you see"

- Light with wavelengths at the red end of spectrum / of a low colour temperature make people feel warmer



- Light with wavelengths at the blue end of spectrum / of high colour temperature cooler



# Importance of studying the HHH

- 20 hours per day spent indoors - often under artificial illumination
- Non-domestic buildings[1] (commercial offices, hotels, shops, schools, hospitals, etc): 18% of total $CO_2$ emissions
  - 46% for space heating
  - 11% for cooling & ventilation
- Domestic buildings[2]: 26% of total $CO_2$ emissions
  - 60% for space heating

**Tool for energy savings!?**

[1] http://www.carbontrust.com/media/77252/ctc765_building_the_future__today.pdf

[2] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/201167/uk_housing_fact_file_2012.pdf

# The HHH – Previous research

| Support | No support |
|---|---|
| Itten (1961): individuals in a blue-green painted room started feeling cold at 15 °C, in the red one only at 11.1 – 12.2 °C. | Mogensen (1926): participants rated shapes as colder when they were covered with red or purple material |
| Clarke (1975): employees felt too hot in a cafeteria with orange walls at about 24 °C but not with light-blue painted walls. | Greene & Bell (1980): no effect of different fairly coloured walls on perceived temperature. |
| Fanger et al. (1977): subjects adjusted ambient temperatures to be 0.4 °C higher under extreme blue fluorescent light than in extreme red light. | Bennet & Ray (1972): thermal comfort judgements did not differ when participants wore blue, red, or clear googles. |
| Candas and Dufour (2005): 48 subjects preferred a colour temperature of 5000 K to that of 2700 when spending two hours in "slightly warm environments" (~5 points on a scale from 0 to 100). | Pedersen, Johnson, & West (1978): Temperature estimates were not affected by a room being painted and decorated in red-orange-yellow hues versus blue-green hues. |
| … | … |

Inconclusive results!

# Our approach

- Aim: To test the HHH under conditions that allow control of
  - Light
  - Temperature
  - Relative humidity
  - Air velocity
  - Clothing level
  - (Metabolic rate)

- Vary in systematic fashion between conditions (and measure correctly)

- Impact factors on thermal comfort (in addition to air temperature)
- Keep constant between conditions and subjects

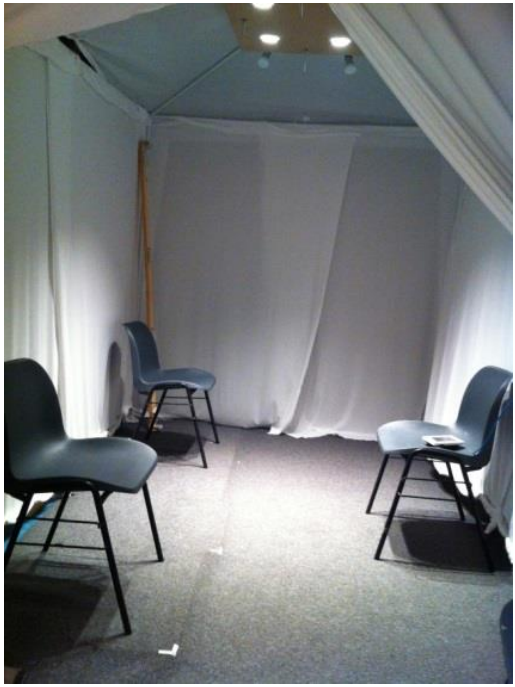
→ Experimental Design

# Subjects

- N = 32
- Recruited via the subject pool of the Psychology department
- Mean age = 24.18 years (SD = 4.01)
- Instructed to wear one specific level of clothing
- Background survey: age, gender, weight, height

# Procedure

- Participants arrive
  - Sedentary period
  - Aim: create similar adaptation to temperature / similar metabolic rate
- In climate chamber (60 minutes)
  - Every 10 minutes fill in thermal comfort survey (=dependent variable)
  - Temperatures (within-subject)
    - Cooling cycle: decrease gradually from 24 to 20 °C
    - Warming cycle: increase gradually from 20 to 24 °C
  - **Between-subject independent variable: Colour temperature of 2700 K versus 6500 K**

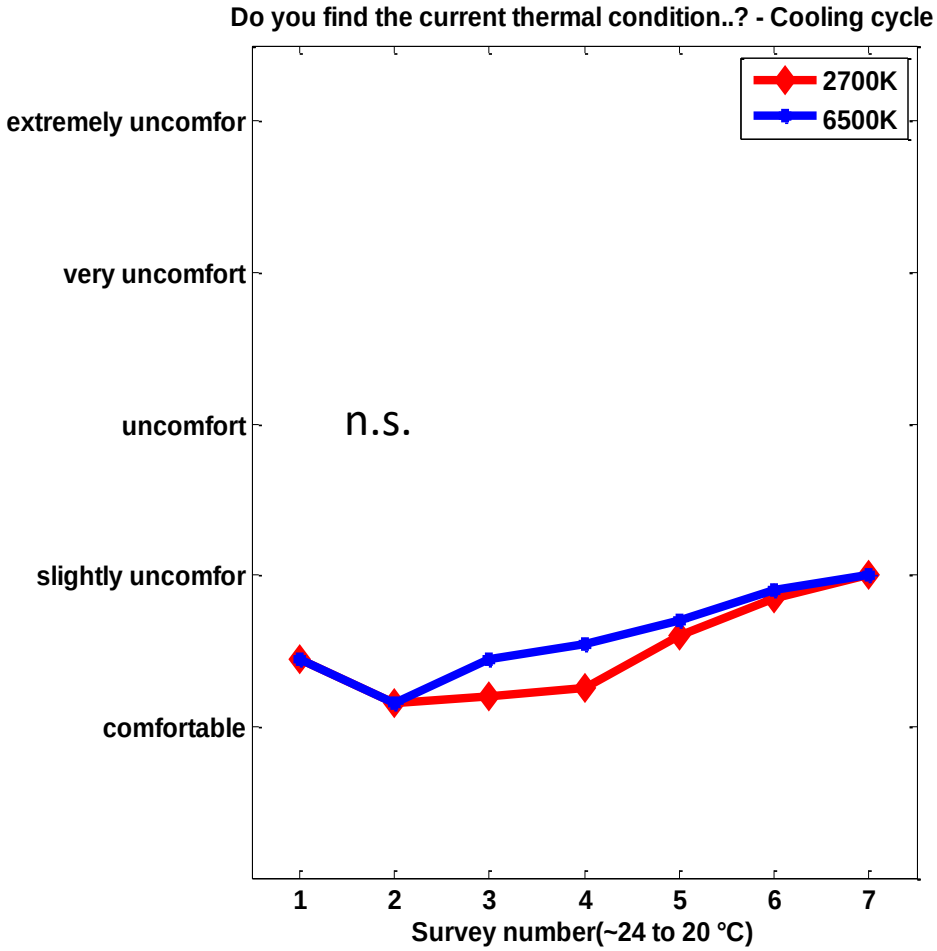


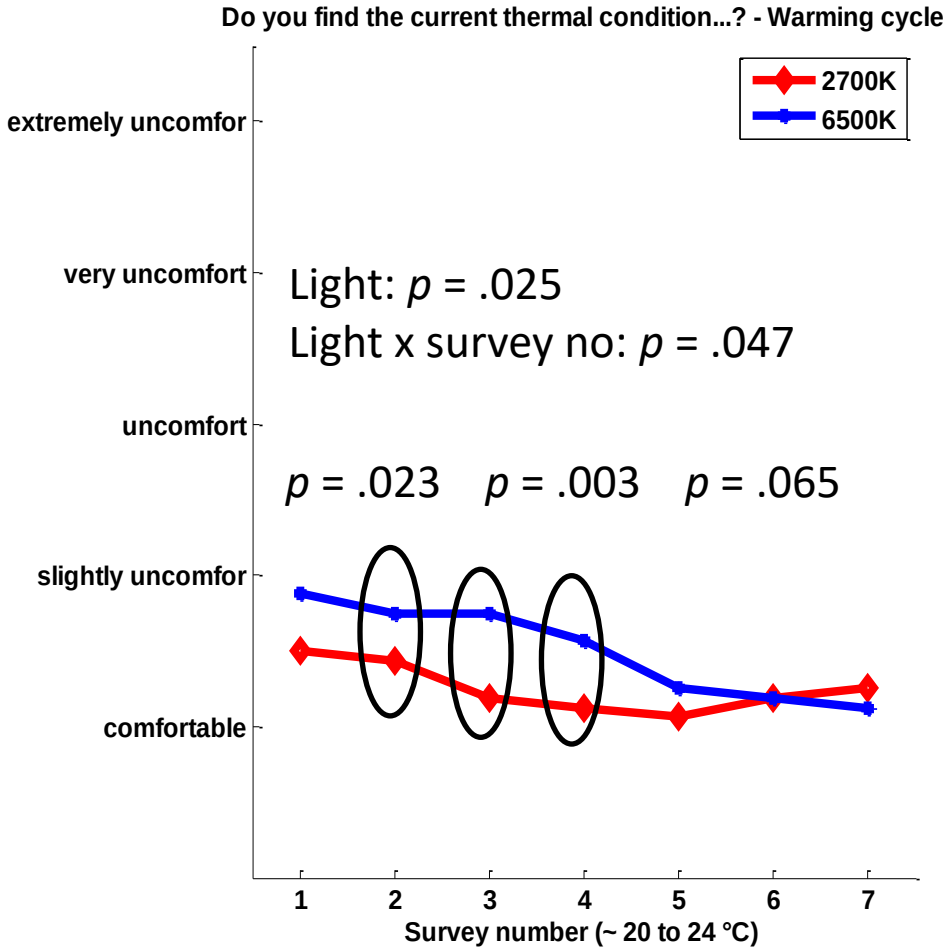
# Analysis

- Repeated-measures ANOVA
  - with within-subject factor “survey no”
  - between-subject factor “lighting” and “gender”
  - Light x survey_no interaction
  - Covariates: BMI, average temperature over session
- For Q4: logistic regression for repeated measures

Hypothesis:
Comfort **higher** under warm light than cold light
(at the lower temperatures).

# Q2


Do you find the current thermal condition..? - Cooling cycle
2700K
6500K
extremely uncomfor
very uncomfort
uncomfort
slightly uncomfor
comfortable
n.s.
1
2
3
4
5
6
7
Survey number(~24 to 20 °C)


Do you find the current thermal condition...? - Warming cycle
2700K
6500K
extremely uncomfor
very uncomfort
uncomfort
slightly uncomfor
comfortable
Light: p = .025
Light x survey no: p = .047
p = .023
p = .003
p = .065
1
2
3
4
5
6
7
Survey number (~ 20 to 24 °C)

# Results

| Question | Cooling cycle | Warming cycle |
|---|---|---|
| How are you feeling in this moment? | Main effect of light:<br>Warmer under warm light | Interaction effect:<br>At low temperatures colder under cold light. |
| Do you find the current thermal condition [comfortable – extremely uncomfortable]? | n.s. | Main effect of light<br>Interaction effect:<br>At low temperatures, less comfortable under cold light |
| How would you prefer to feel? | n.s. | Main effect of light |
| Would you accept thermal environment? | Main effect of light<br>Interaction effect:<br>At low temperatures less acceptable under cold light | Main effect of light |
| Do you find this environment [easy – difficult] to bear? | Interaction effect:<br>At low temperatures less bearable under cold light | Main effect of light |

# Lukewarm results

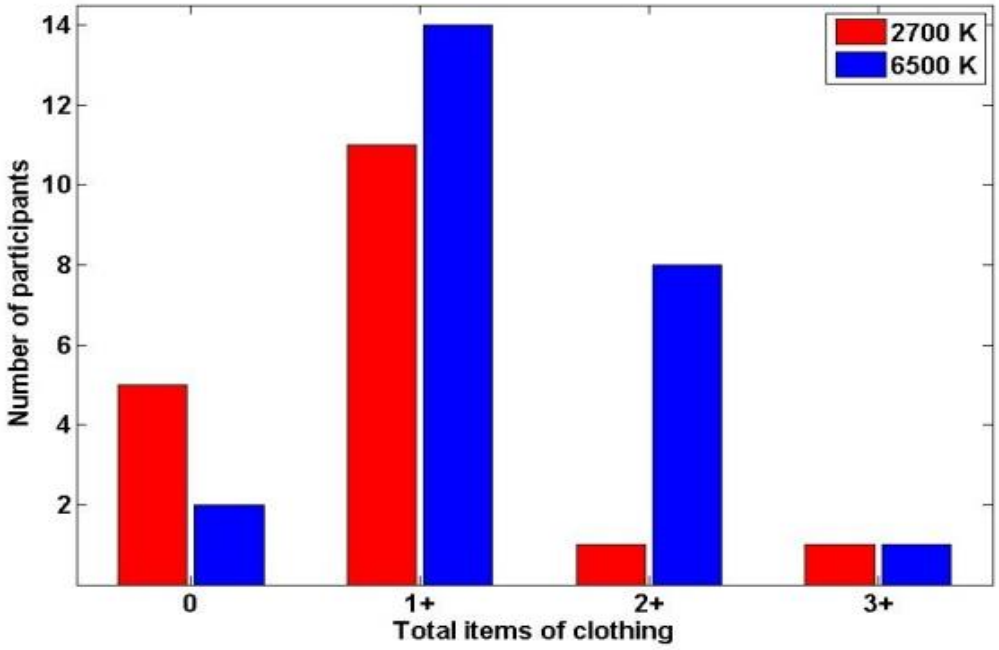
- Statistical significance?
  - Only for certain questions
  - Not consistent for warming and cooling cycle
  - Only for specific temperature “corridors”

- Bad measurement instrument?
  - Number of people  who do not show any modulation of comfort or “jump around”
  - Surveys not designed for dynamic conditions

# New study: Observation

- Same procedure as above
  - Cooling cycle only
  - N = 32 participants (16 under each light)
  - No comfort surveys
  - Participants instructed to bring a long-sleeve T-Shirt and a jumper to session, plus blanket provided
- Observation study: Changes in clothing
- Hypotheses:
  - **More** item of clothing put on under cold light than warm light.
  - Items of clothing put on **earlier** under cold light than warm light.

# Observation: Results




People put significantly more clothing on under cold light than warm light.

No significant temporal difference (only trend).

# Outlook

- Evidence for some effect of light on thermal comfort
- But: needs more testing
  - In ‘real world’
  - Better operationalization of ‘thermal comfort’

Thanks!

Questions?