ProLiM 2022

Profiling Lighting at Monash

Presentation Overview

1 Background and Significance

Background and Significance

Perceive

Assess

Aware

React
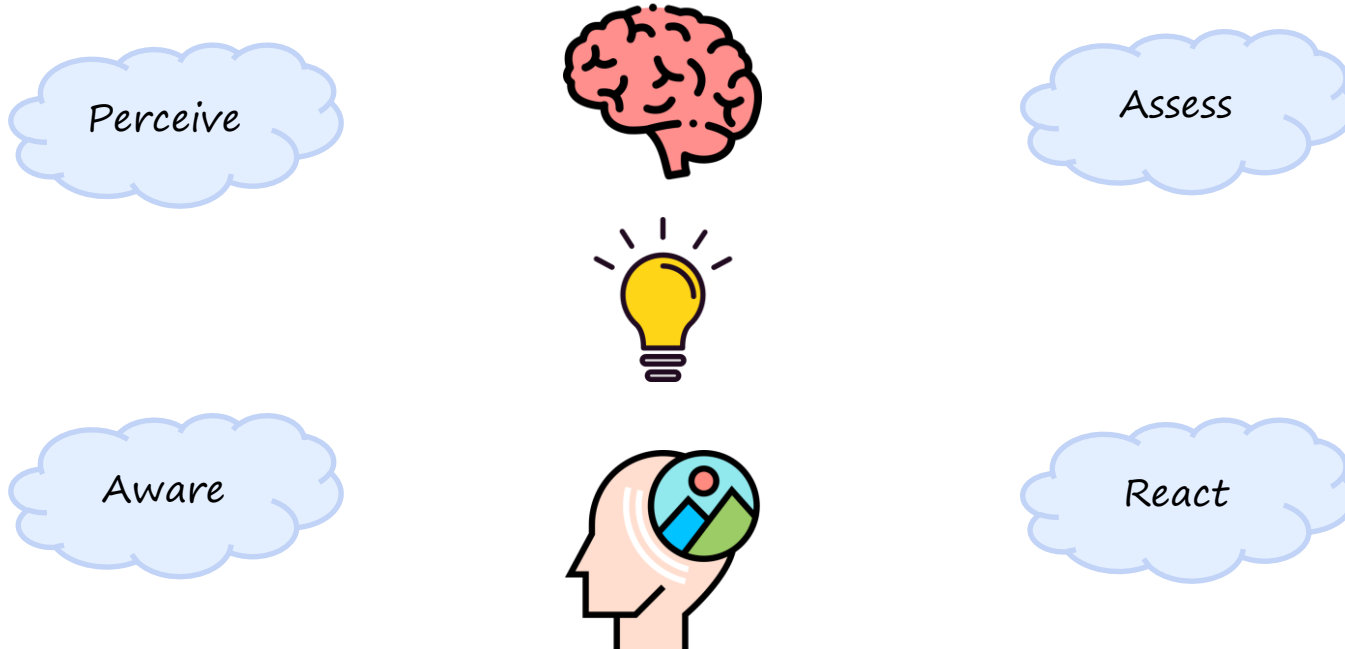
Background and Significance

- Light influences human behaviours in physical, physiological, and psychological ways [1], [2], [3]

- Good lighting

  - Necessary to perform visual tasks

  - High productivity and performance

Background and Significance

- Non-visual Effects

  - Human Circadian Rhythm

    - Controlled by Melanopsin

- Human Satisfaction Levels

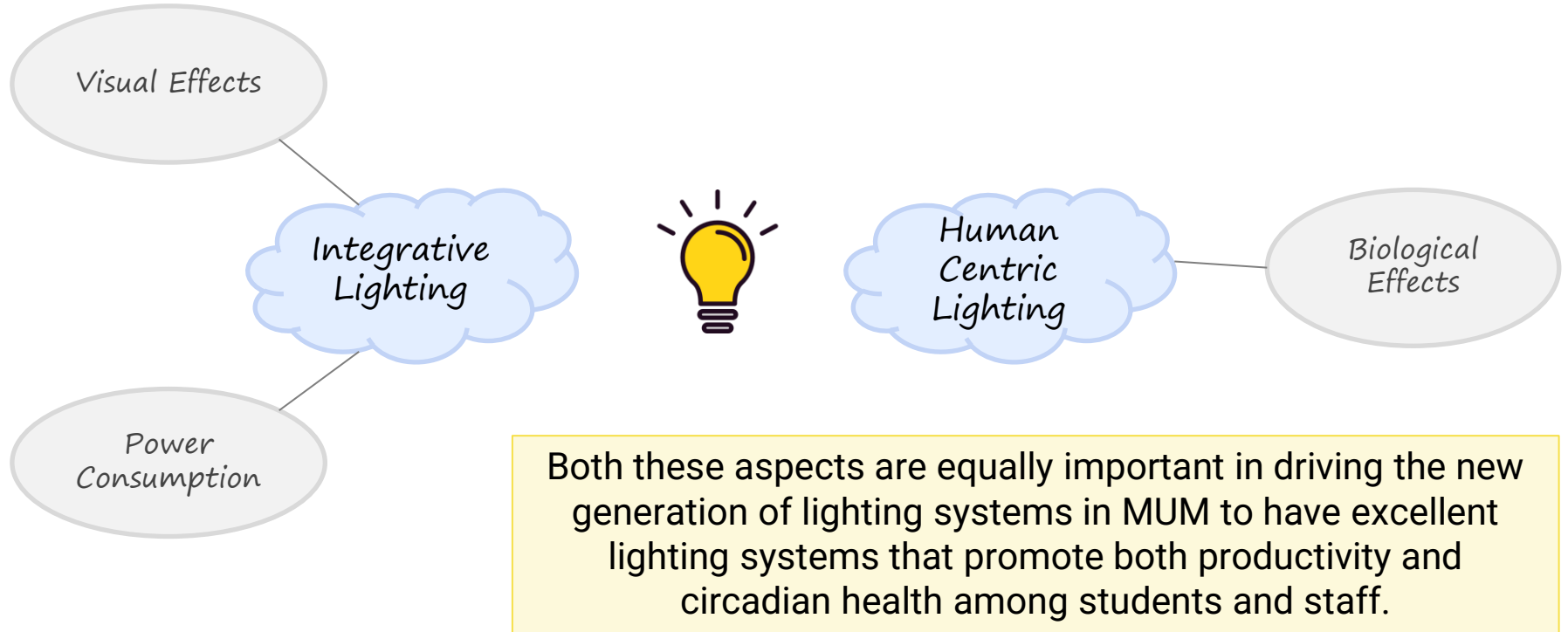# Background and Significance

Fluorescent Light

LED

Background and Significance

- Various efforts to improve on the lighting systems have been made so that various lighting standards can be met depending on the type of space.

- Benchmarking standards for the lighting conditions

  - Traditional – visual metrics of light

    - Eg. Photopic Illuminance

  - Recent – non-visual indices of light

    - Eg. melanopic equivalent daylight illuminance (MEDI) levels

    - assess light performance based on its ability to maintain human circadian cycles

Background and Significance

Visual Effects

Integrative Lighting

Power Consumption

Human Centric Lighting

Biological Effects

Both these aspects are equally important in driving the new generation of lighting systems in MUM to have excellent lighting systems that promote both productivity and circadian health among students and staff.

2 Objective

Objectives

- To **profile lighting** for various teaching and non-teaching spaces in Monash University Malaysia
- To **create a dataset (ProLiM)** consisting of visual, non-visual, and subjective parameters of light
- To analyze the results by performing **gap analysis** with chosen international and national lighting standards, and research findings in the relevant field
- To **provide recommendations** so that the lighting conditions in Monash University Malaysia can be improved

3 Method
- Visual metrics
- Nonvisual metrics
- Subjective measures
- Data analysis
- Experiment design

Method

1 **Metrics:**
- Visual, nonvisual, subjective
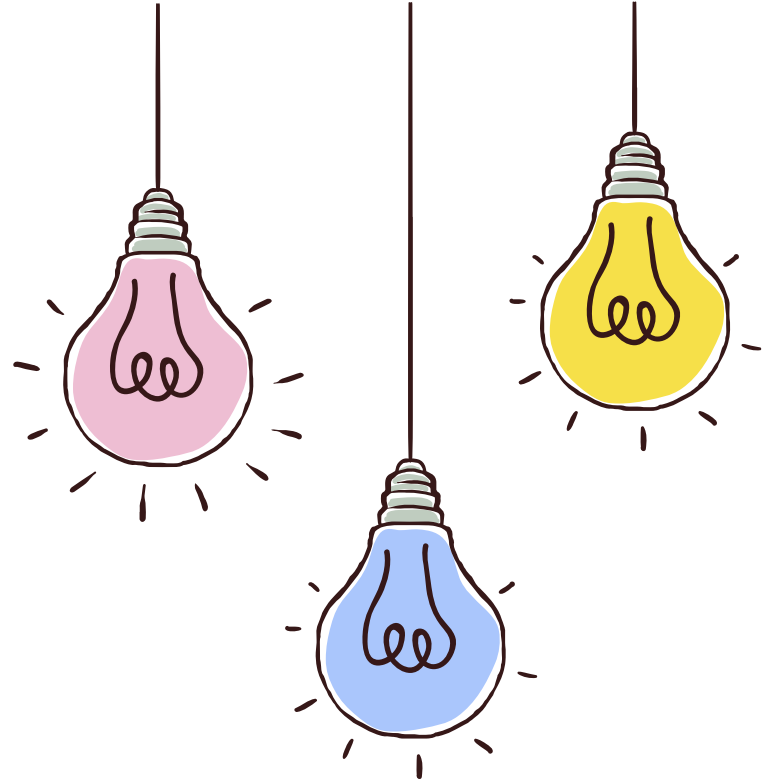- Data Analysis
- Experimental Design

2 **Methodology:**
- Random sampling based on area & workplane height

3 **Standards**
- International (IES, CIE)
- National (Malaysian, Australian)

Method

1

Metrics:
- Visual, Non-Visual, Subjective

Visual Metrices Standards for Illuminance
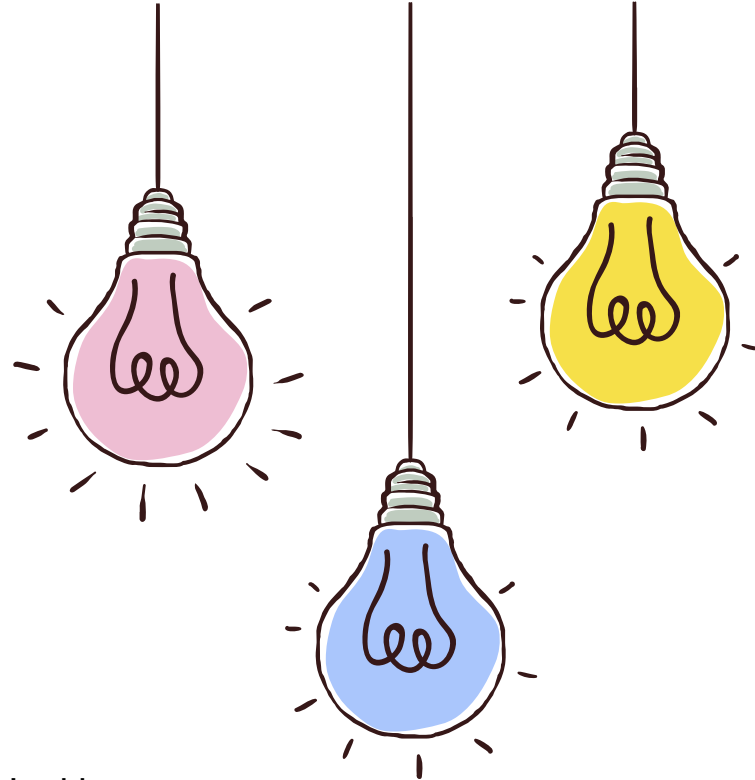<u>International</u>
- IES: The Lighting Handbook (10th ed.)
- CIE: CIE S008/E-2001

<u>National</u>
- Australian: AS/NZS 1680 & AS 2560:1:2018
- Malaysian: Guideline on Occupational Safety & Health for Lighting at Workplace 2018

<u>Standard for Uniformity</u>
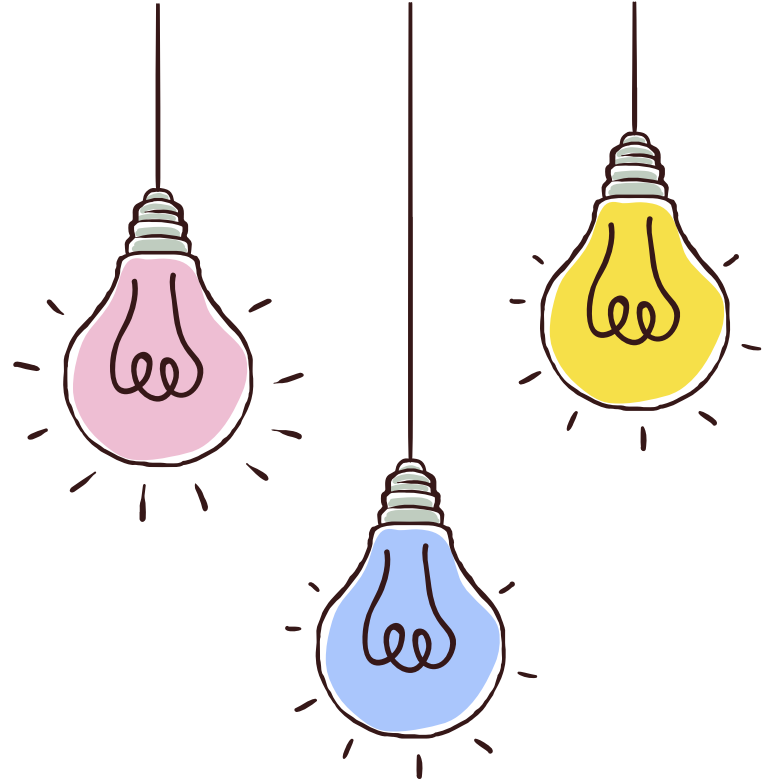- IES: The lighting Handbook (10th ed.)

Method

1

Metrics:
- Visual, Non-Visual, Subjective

Non-Visual Metrices Benchmarks
- 1-Point Q2 2022 WELL Standard
- 3-Point Q2 2022 WELL Standard
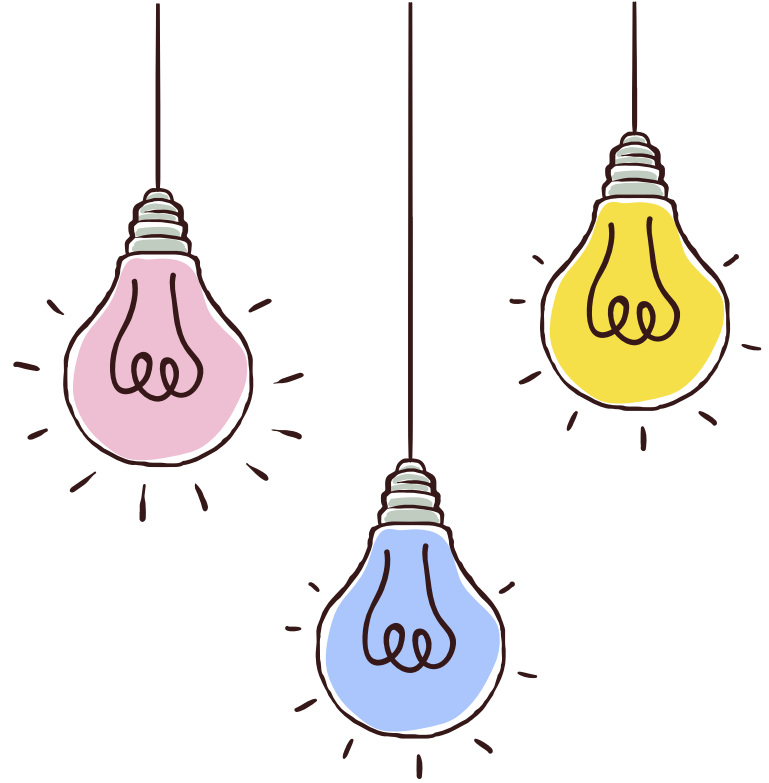- Brown-Recommended MEDI [4]

Method

1

Metrics:
- Visual

Measures:
- Photopic Lux
- Illuminance Uniformity

Workplane:
- Horizontal – Tables
- Vertical – Whiteboard / Projector Screens

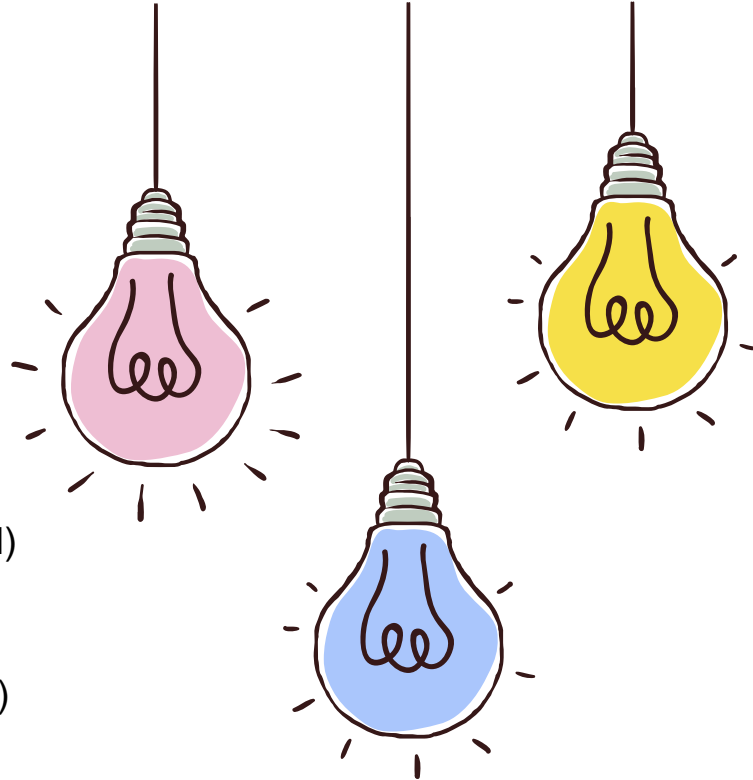# Method

(1)

Metrics:
- Non-Visual

Measures:
- Melanopic Equivalent Daylight Illuminance (MEDI)

Workplane:
- Vertical – Average Malaysian Eye Level (~149cm)

Benchmark:
- 1-Point Q2 2022 WELL Standard
- 3-Point Q2 2022 WELL Standard
- Brown-Recommended MEDI [4]
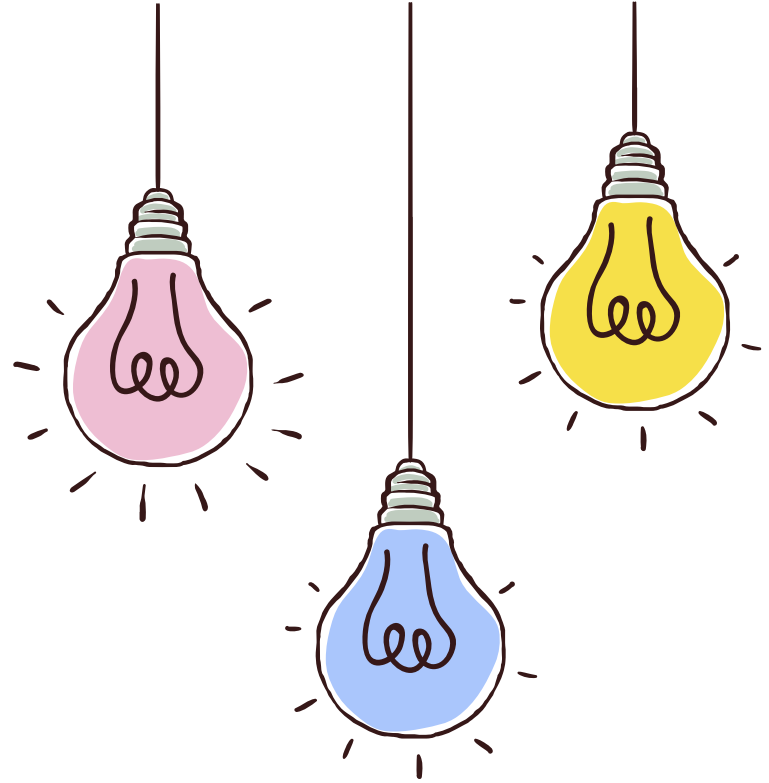
Method

1

Metrics:
- Subjective Measures

Measures: Psychological effects

Studies have shown that favorable environmental conditions affects humans in a positive manner
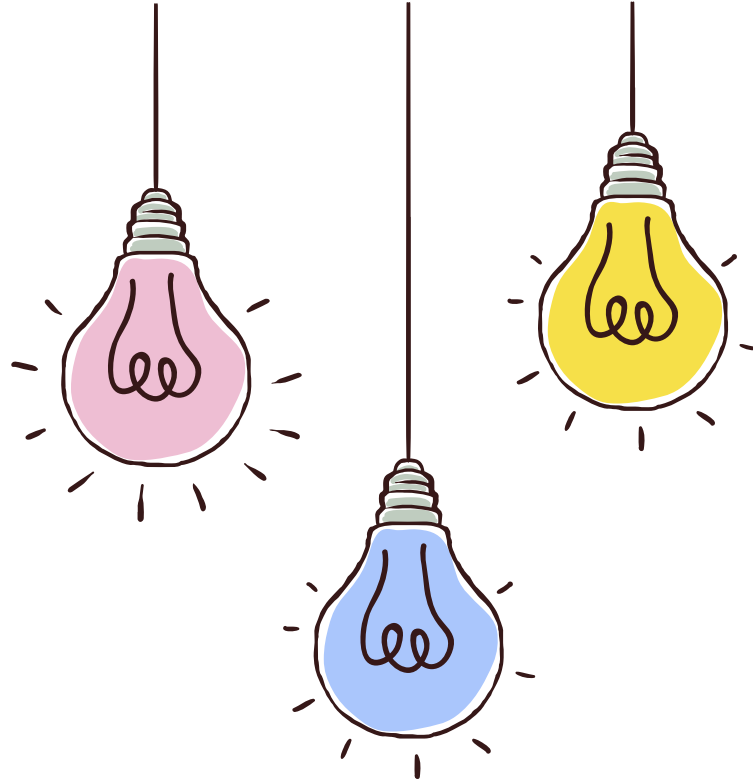
Method

1

Metrics:
- Subjective Measures

7-Point Scale Questionnaire
Physical lighting impressions
- Bright vs. Dim
- Spacious vs. Confined
- Uniform vs. Non-uniform
- Warm vs. Cool
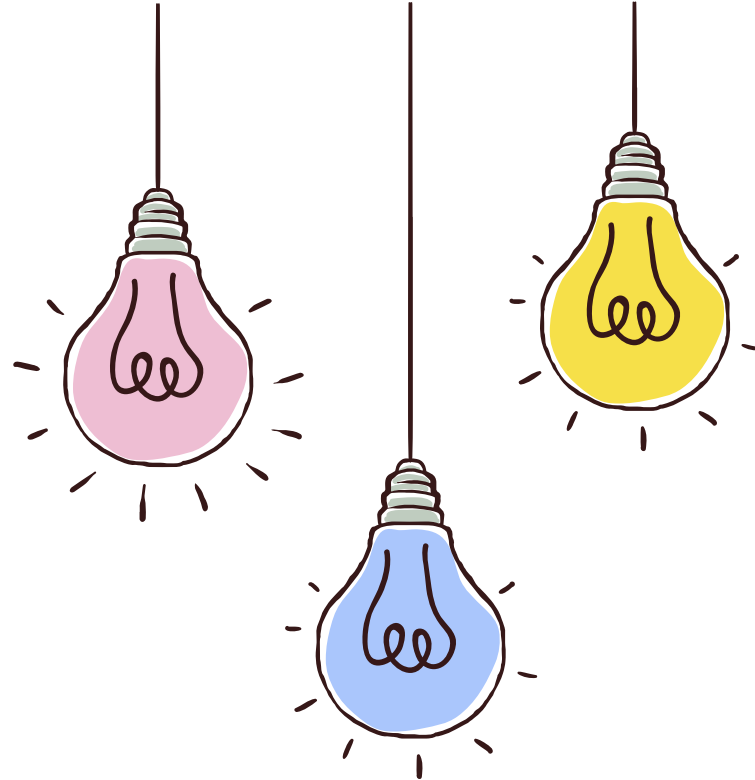- Glare vs. No Glare
- Colorful vs. Colorless

Method

1

Metrics:
- Subjective Measures

7-Point Scale Questionnaire
Emotional Mood States
- Pleasant vs. Unpleasant
- Comfortable vs. Uncomfortable
- Attractive vs. Unattractive
- Natural vs. Unnatural
- Like vs. Dislike
- Relaxing vs. Tense
- Happy vs. Unhappy
- Interested vs Bored
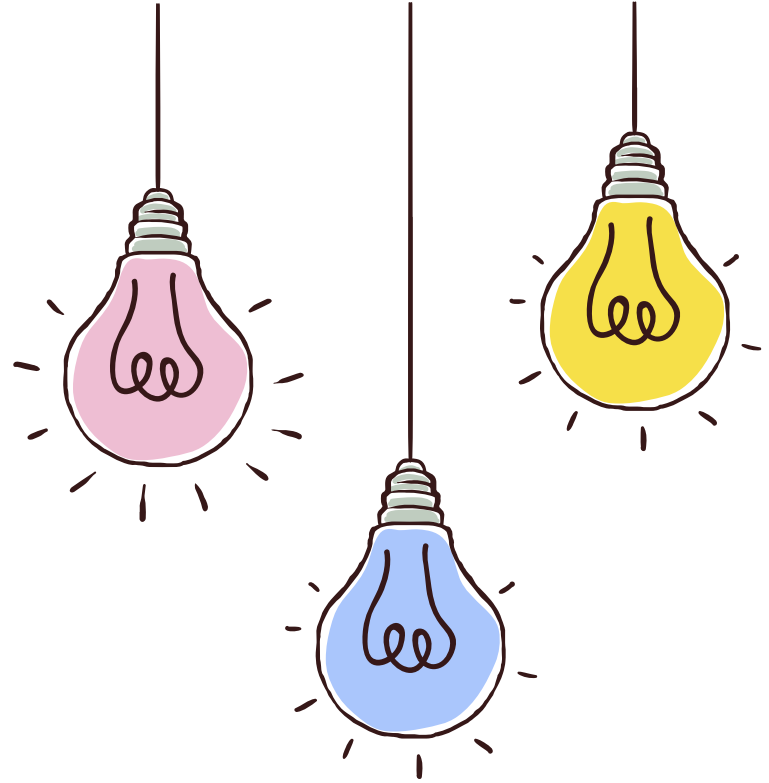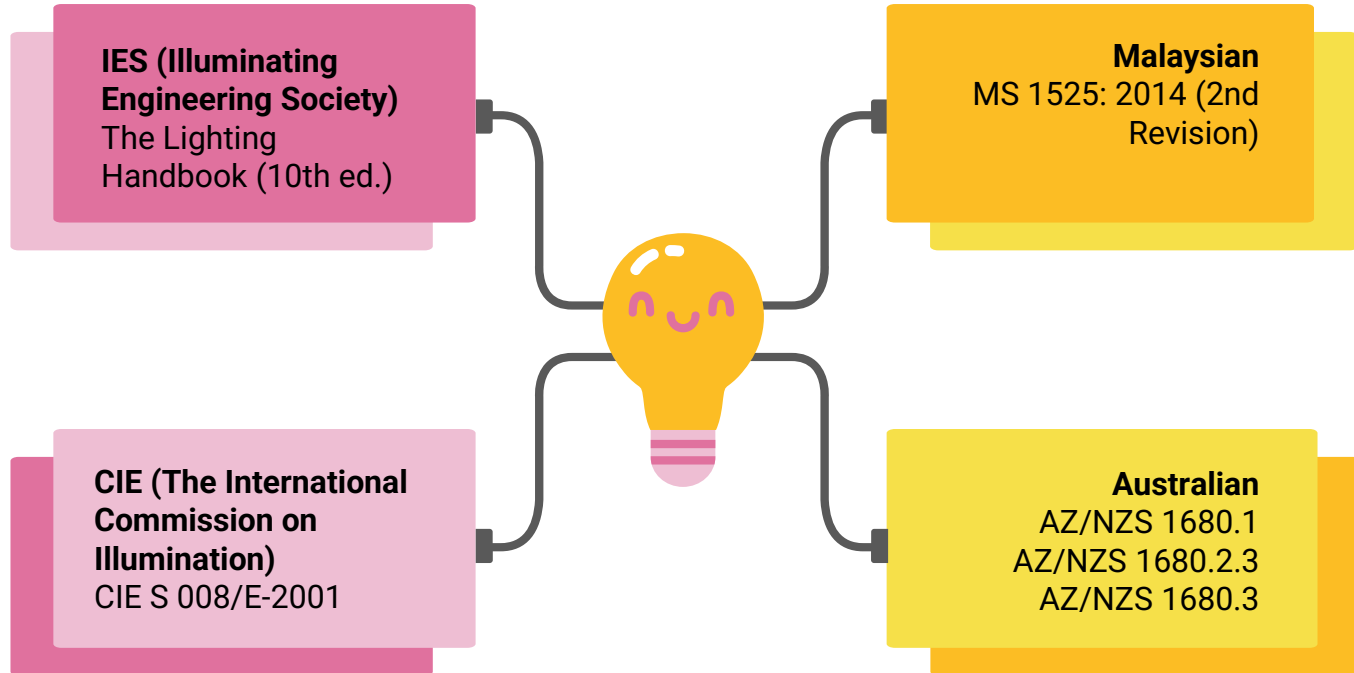- Good Mood vs. Bad Mood
- Relaxed vs. Aroused

Method

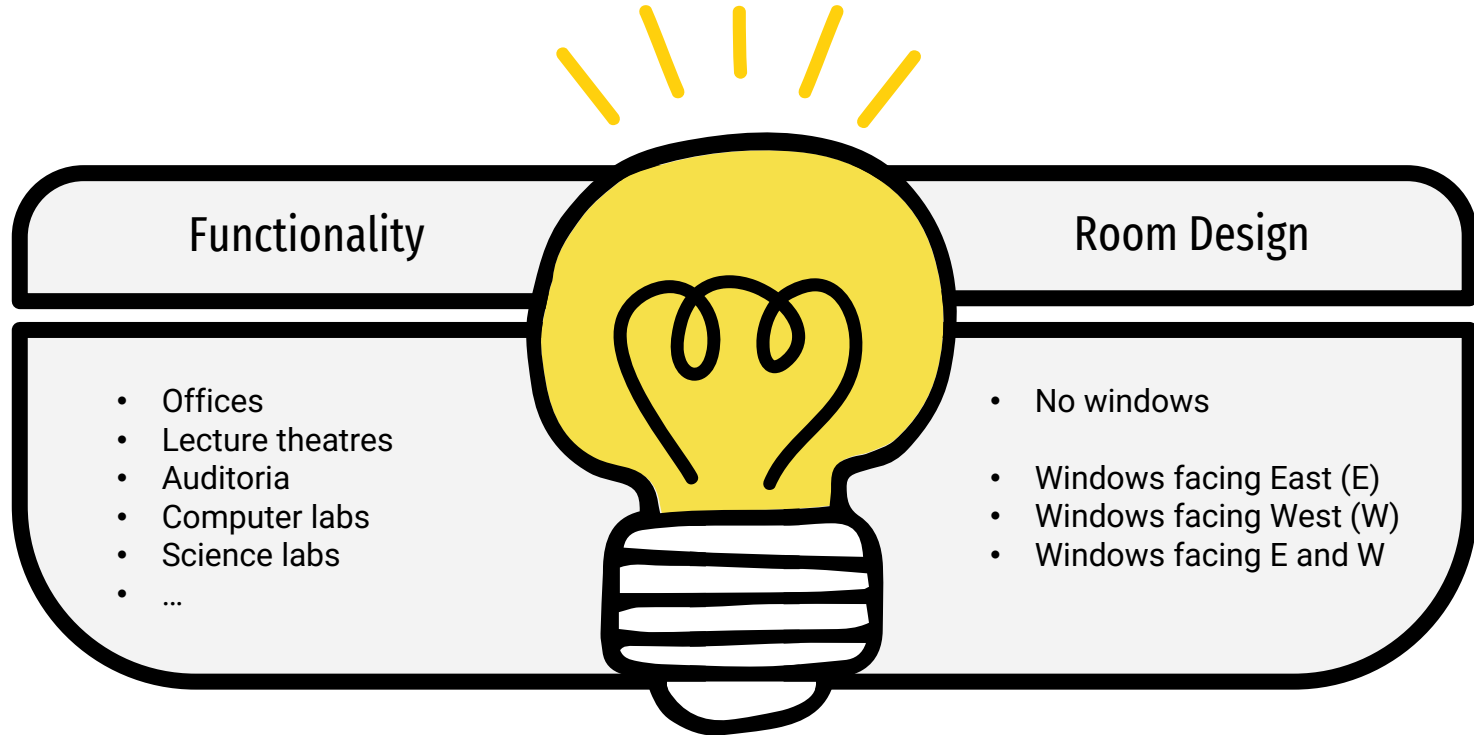**1**

Metrics:
- Subjective Measures

7-Point Scale Questionnaire
- Skin Tone Preference
- KSS (Karolinska Sleepiness Scale)

Standards (visual metrics)

**IES (Illuminating Engineering Society)**
The Lighting Handbook (10th ed.)

Malaysian
MS 1525: 2014 (2nd Revision)

CIE (The International Commission on Illumination)
CIE S 008/E-2001

Australian
AZ/NZS 1680.1
AZ/NZS 1680.2.3
AZ/NZS 1680.3

Room Classification

Functionality

- Offices
- Lecture theatres
- Auditoria
- Computer labs
- Science labs
- …

Room Design

- No windows

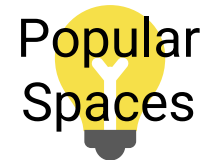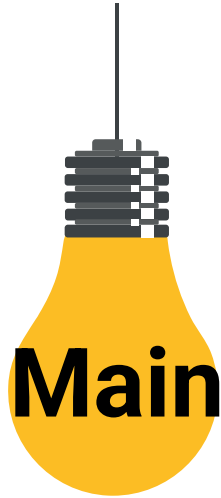- Windows facing East (E)
- Windows facing West (W)
- Windows facing E and W

Experiment Design

1 Determine whether to measure once or 3 times (morning, evening & night) based on windows in room

2 Horizontal visual effect is measured **randomly** at work plane (table) height
No. of sampling points = room area / 4

3 Vertical visual effect is measured **randomly** at whiteboards and projection screens
No. of sampling points = screen area / 0.25

4 Non-visual effect is measured **randomly** at average Malaysian eye level height (149 cm)
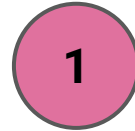**No. of sampling points = room area / 4**

2 m
2 m

5212

Locations

Main

Others

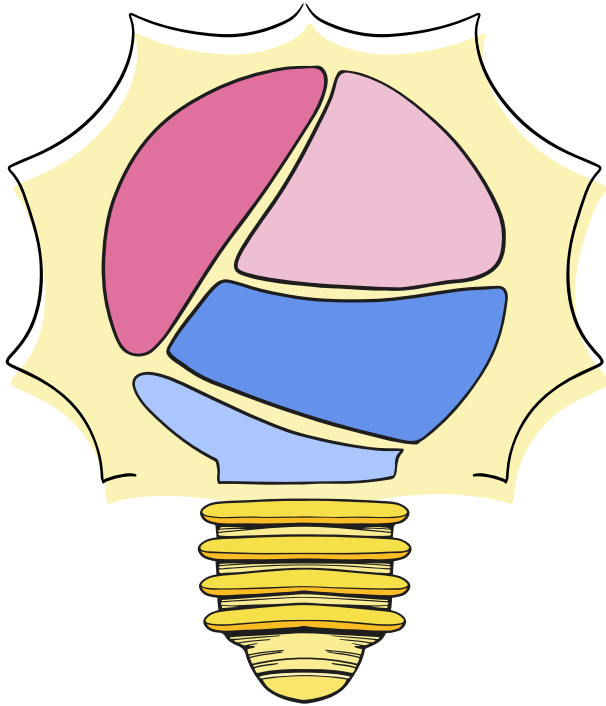Building 5

Building 6

Academic Offices
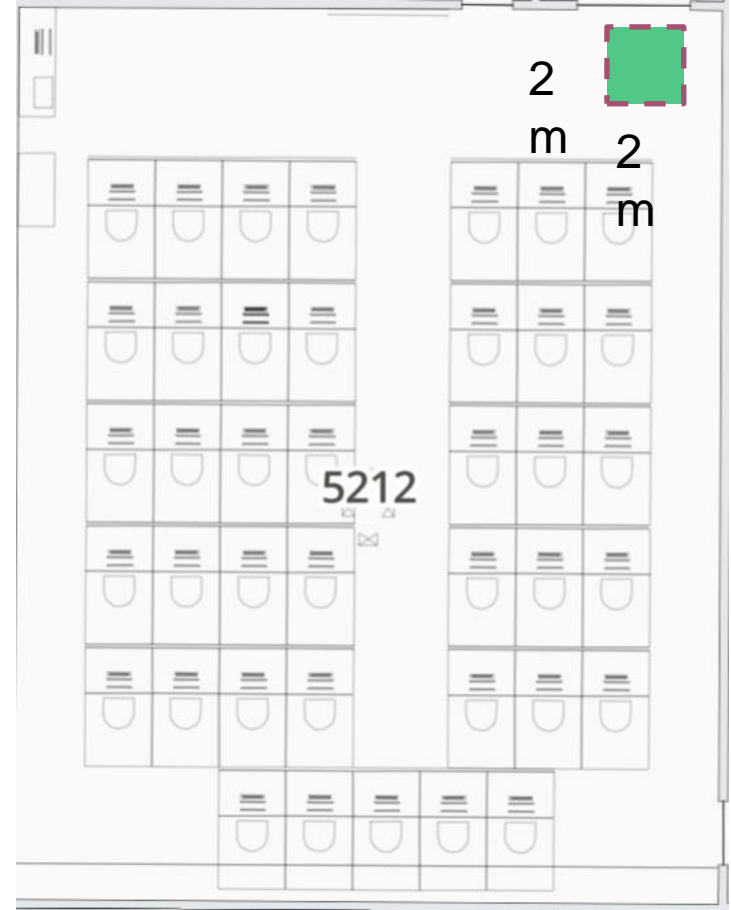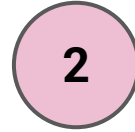
Popular Spaces

Room selection for Buildings 5 and 6

Ignore rooms (NOT measuring)

1. M&E
2. Rooms with no light
3. Lift void
4. Rooms that need special request for access

Data Collection Procedures

1 All members fill in Google Form to evaluate lighting conditions subjectively

2 Use MSS to record visual measurements

3 Use MSS to record non-visual measurements

4 Measurements are repeated depending on the locations

Data Analysis

SPD (Spectral Power Distribution) in 1nm intervals

Photopic lux, 5 α-opics (including **melanopic lux**), [X,Y,Z], (x,y), (u',v'), CCT
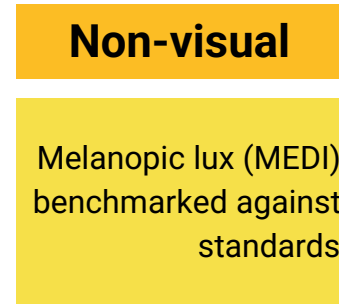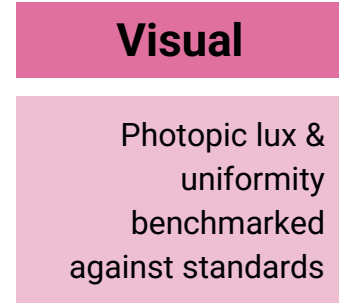
Maximum, minimum, **average**, standard deviation, **uniformity**

Visualize with box plots, scatter plots and bar charts

Gap Analysis

Subjective

Find correlation using confusion matrix

Visual

Photopic lux & uniformity benchmarked against standards

Non-visual

Melanopic lux (MEDI) benchmarked against standards

4
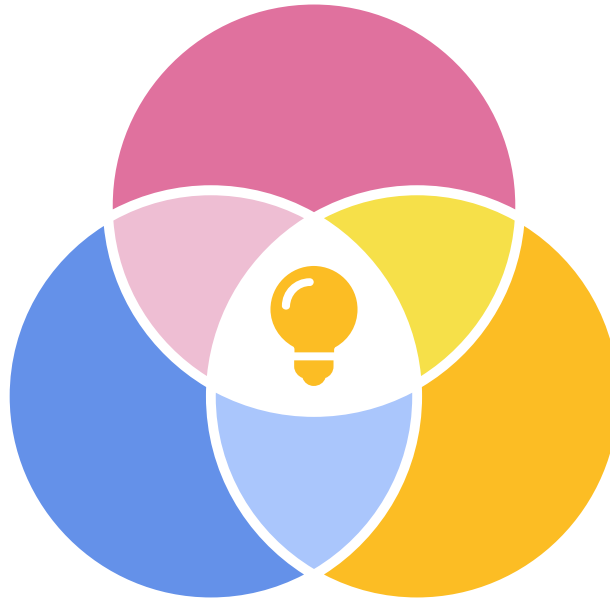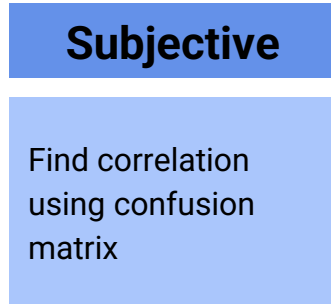
Results and Recommendations

- Visual metrics
-
-

Results: Visual

Legend:
- Red: IES
- Black: CIE/MS
- Blue: AS/NZS
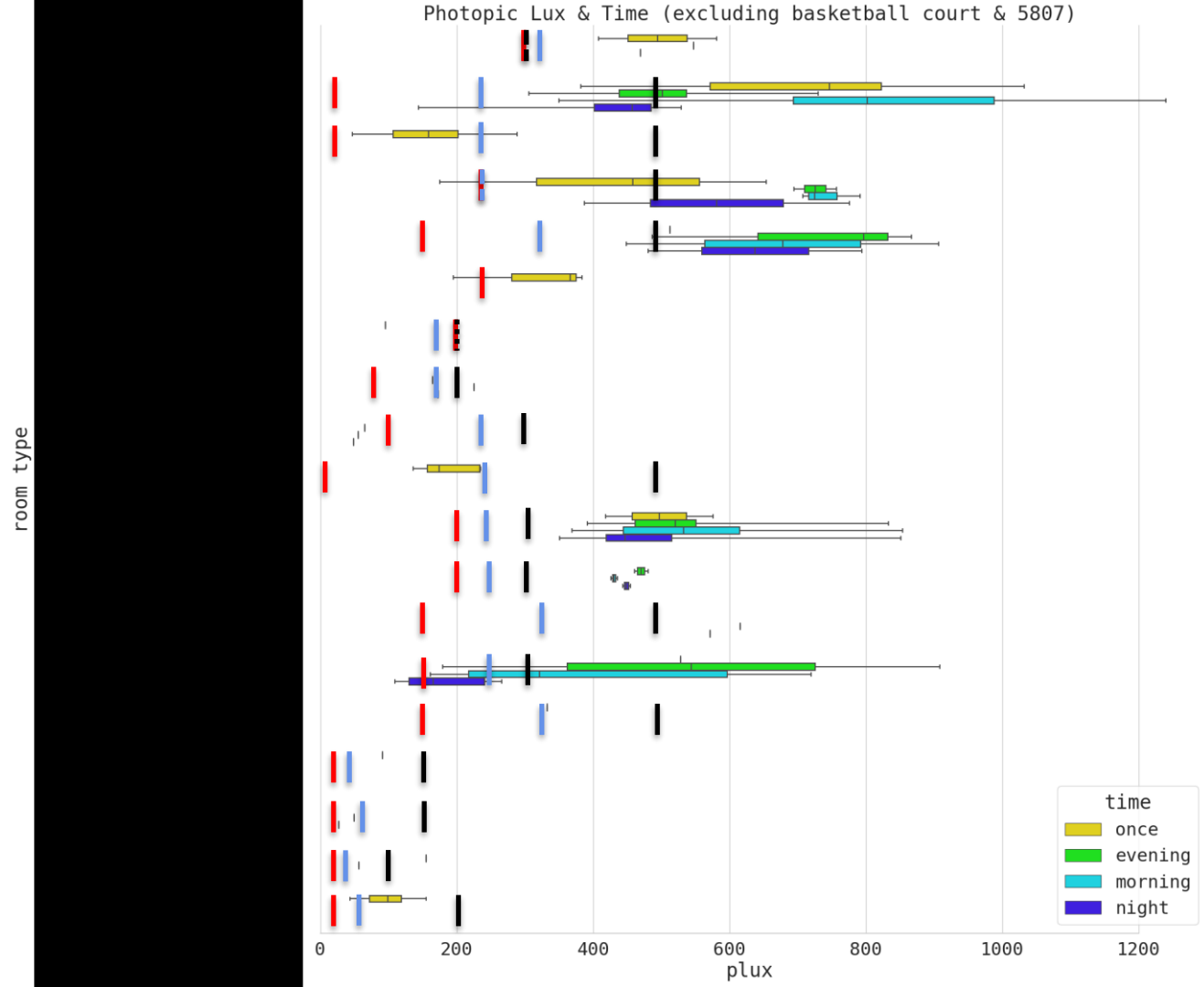
Photopic Lux & Time (excluding basketball court & 5807)

Results: Visual

Legend:
- Black: Whiteboard
- Blue: Screen

Photopic Lux & Time (whiteboard & screen)

Results: Visual

Uniformity & time (excluding basketball court & 5807)

Results: Visual
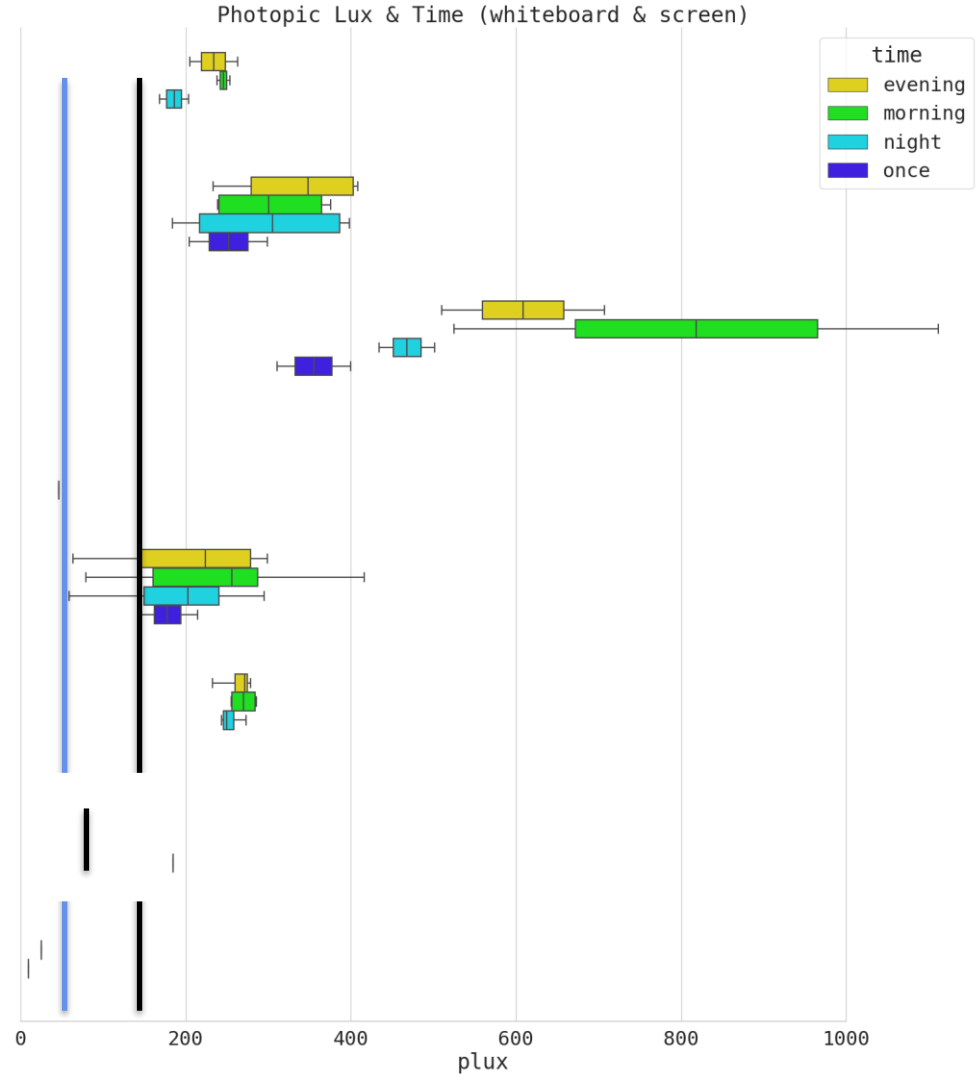
Legend:
- Black: Whiteboard
- Blue: Screen
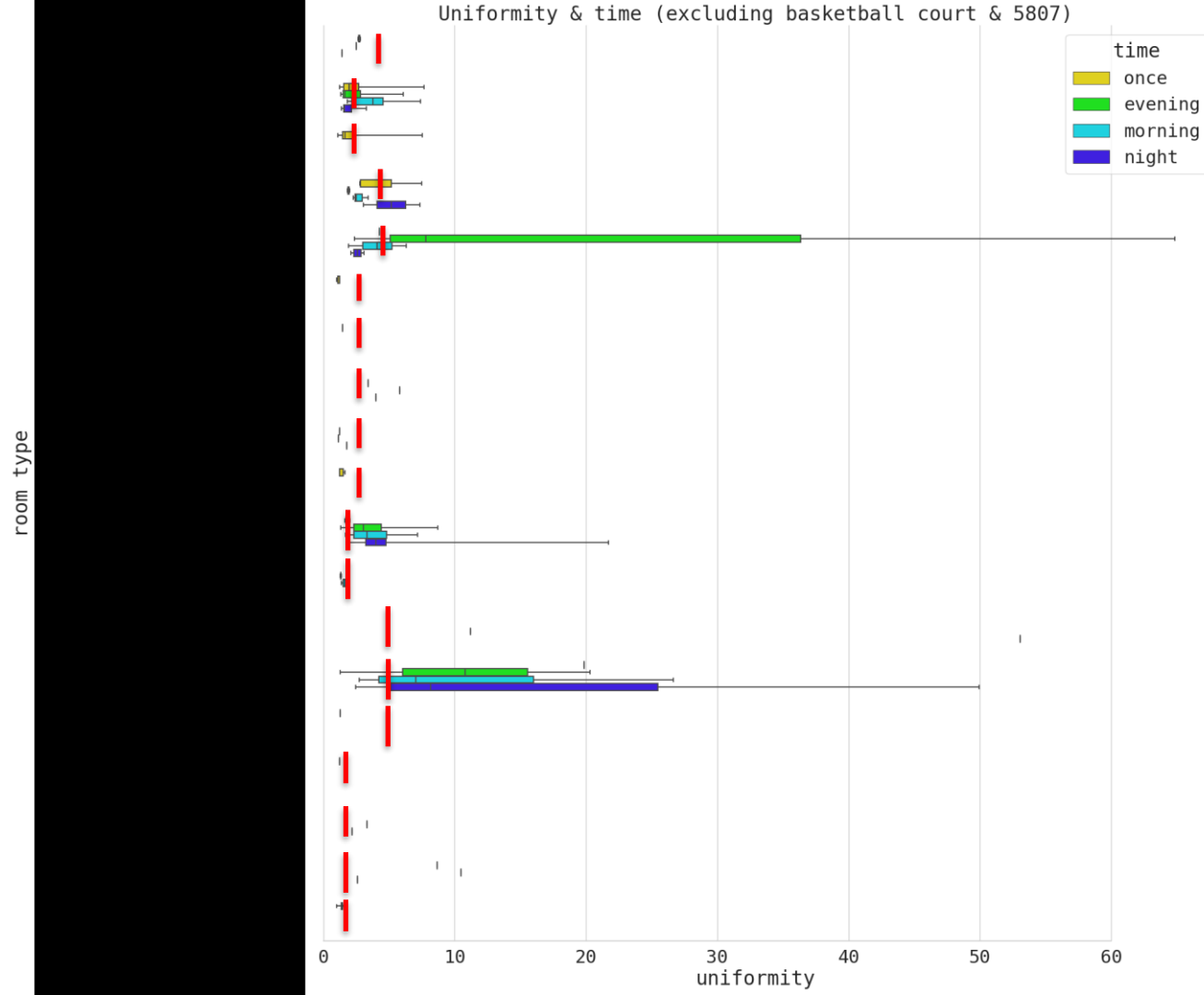
Uniformity & time (whiteboard & screen)
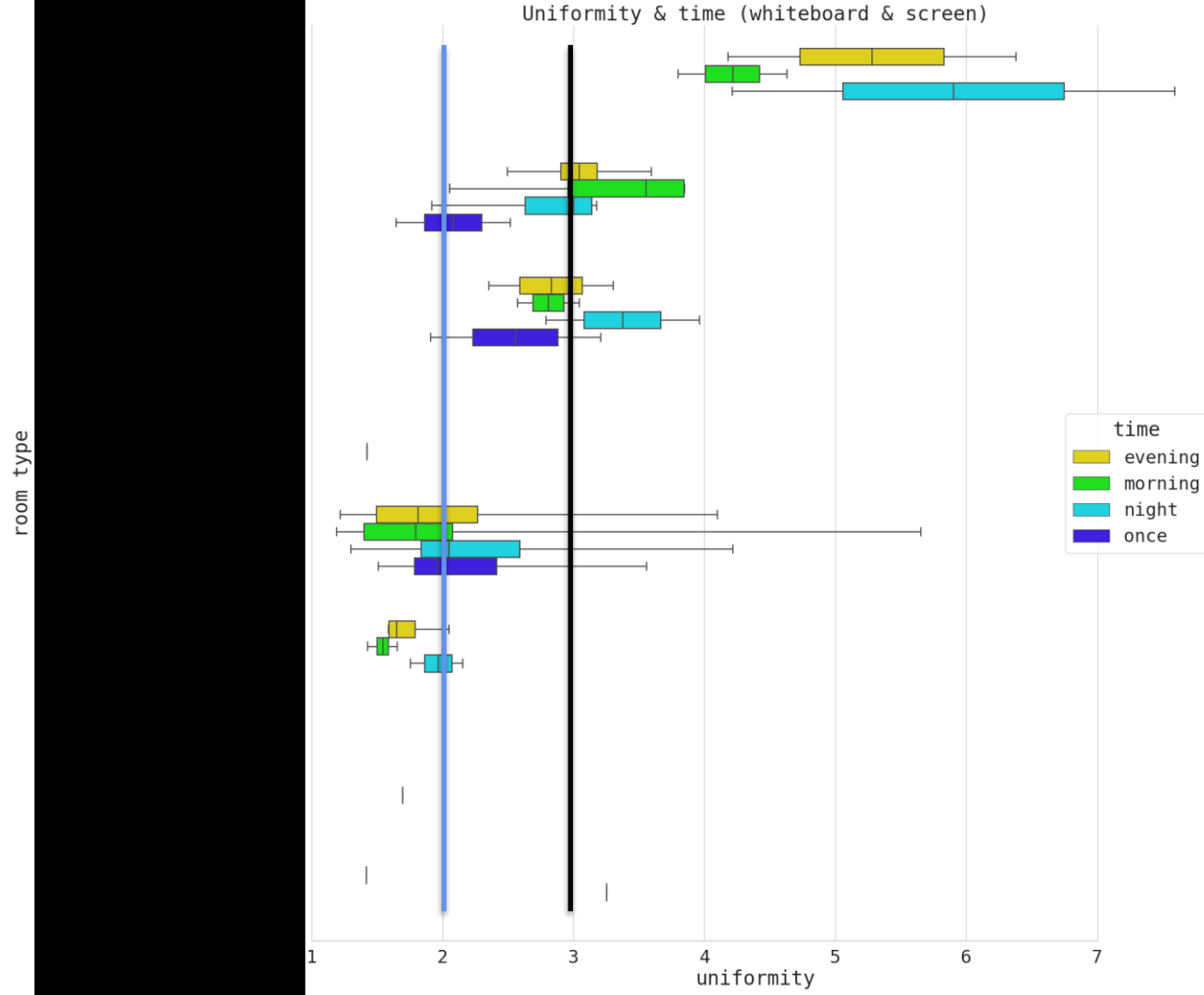
Results: Visual (Teaching and learning spaces)

- **Auditorium & lecture theatres**

    - All meet at least 1 illuminance standard, average uniformity

    - ███████ does not meet CIE standards for average illuminance and IES standards for uniformity

    - Install wall luminaires and dimmable luminaires for higher rows

- **Discussion rooms & seminar rooms:**

    - Good illuminance and uniformity

Results: Visual (Teaching and learning spaces)

- **Classrooms, labs, informal study areas:**
  - Interactive rooms ███████ and tutorial rooms meet illuminance standards with large margins but fail uniformity standards
    - Have more evenly spaced luminaires
    - Install dimmable luminaires to reduce power consumption
  - Informal study areas fail illuminance standards at night
    - Increase the number of luminaires

Results: Visual (Summary)

- Most spaces satisfy at least one of the standards by quite large margins for illuminance

    - Can use dimmable luminaires to reduce power consumption, especially in the day

- Uniformity is poor for many spaces

    - May be due to random sampling issues

    - Increase the number/type of luminaires where necessary

4 Results and Recommendations
-
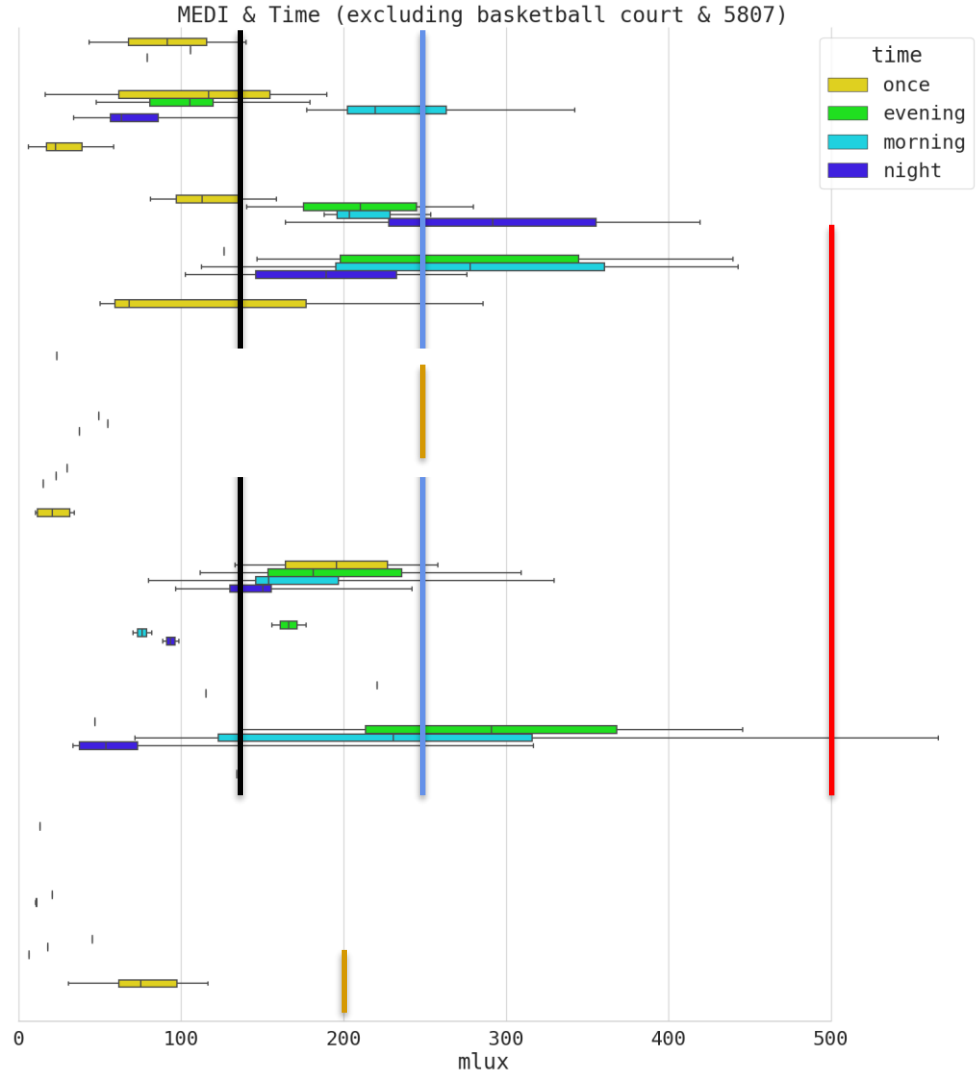- Nonvisual metrics
-

Results: Non-visual

Legend:
- Black: 1-point WELL Q2 2022
- Blue: 3-point WELL Q2 2022
- Red: Recommendation
- Yellow: WELL Q4 2020

MEDI & Time (excluding basketball court & 5807)

Results: Non-visual

Ideal value for MDER = 1

MDER & Time (excluding basketball court & 5807)
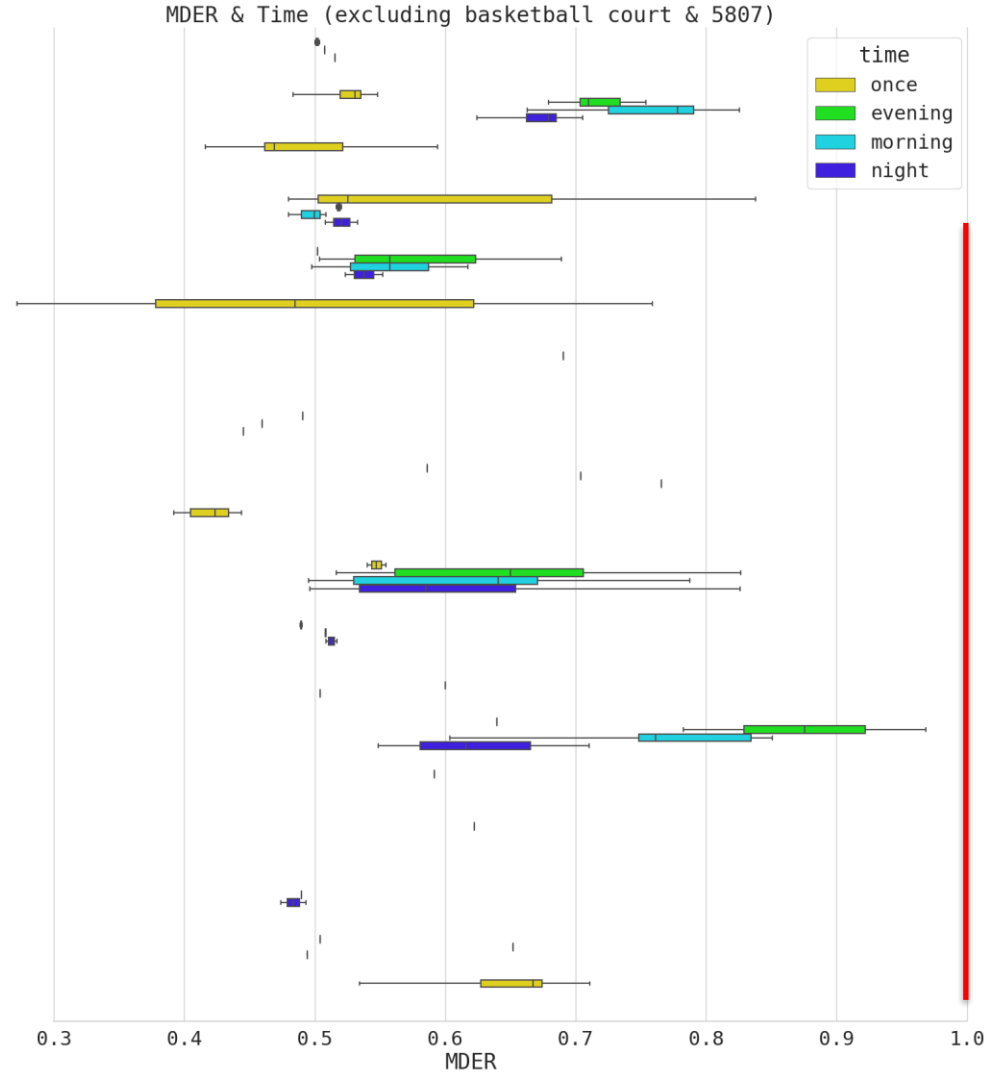
Results: Nonvisual (Teaching and learning spaces)

- Most spaces satisfy 1-point WELL standard (basic requirement)
- Roughly half of the spaces satisfy 3-point WELL standard
- Only 1 spaces satisfies recommended levels
- Install BioUp-technology integrated luminaires [5]

  - Advanced luminaires have enhanced biological effects
- Design classroom layout so that there is natural light in classrooms

  - Sunlight supports circadian cycle stability [6]

4

Results and Recommendations

-
-
- Subjective measures

Results and Recommendations - Subjective Measures
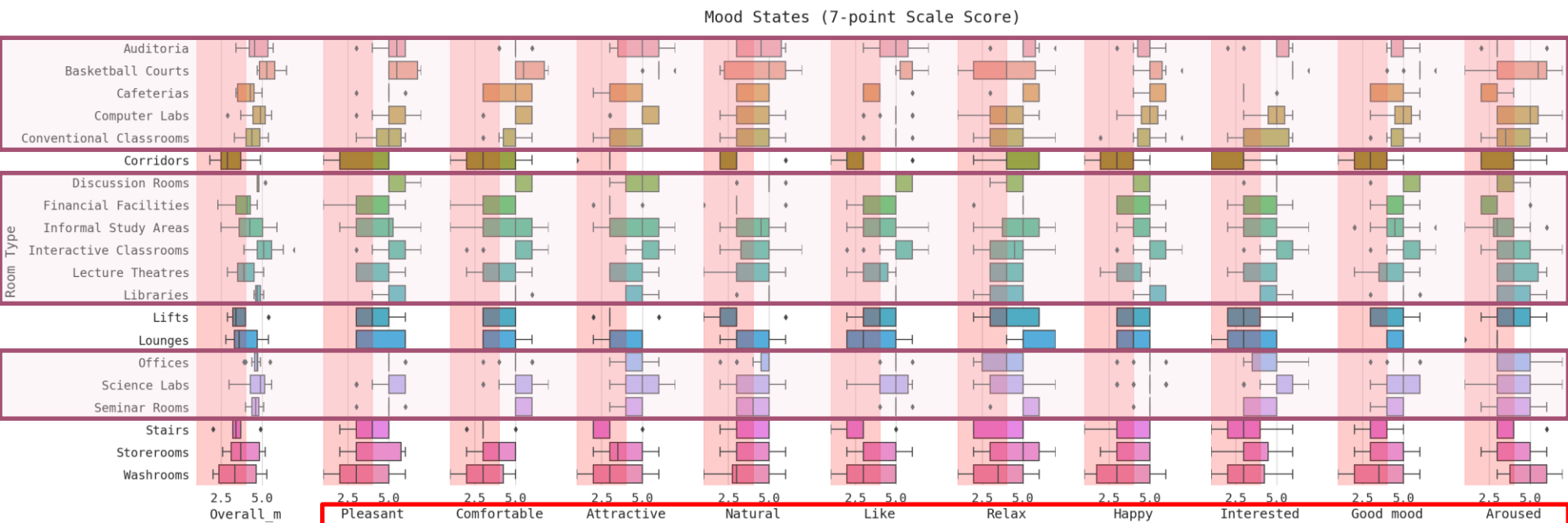
Physical Attributes (7-point Scale Score)

Results and Recommendations - Subjective Measures

Mood States (7-point Scale Score)

Results and Recommendations - Subjective Measures

Skin Tone Preference and Sleepiness
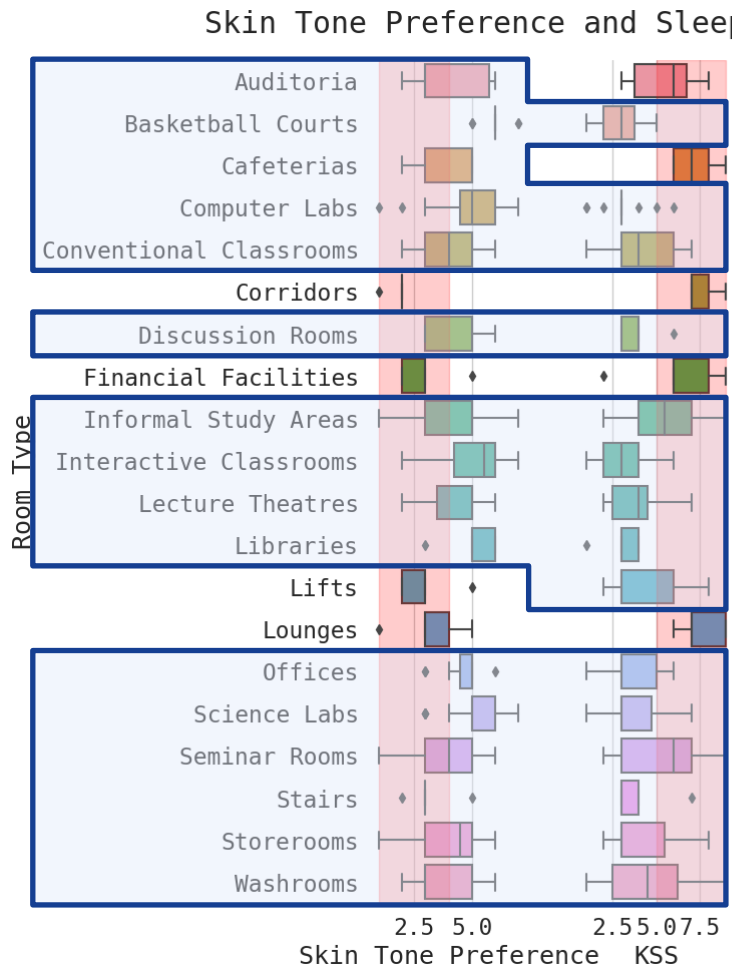
Correlations between subjective measures and visual parameters
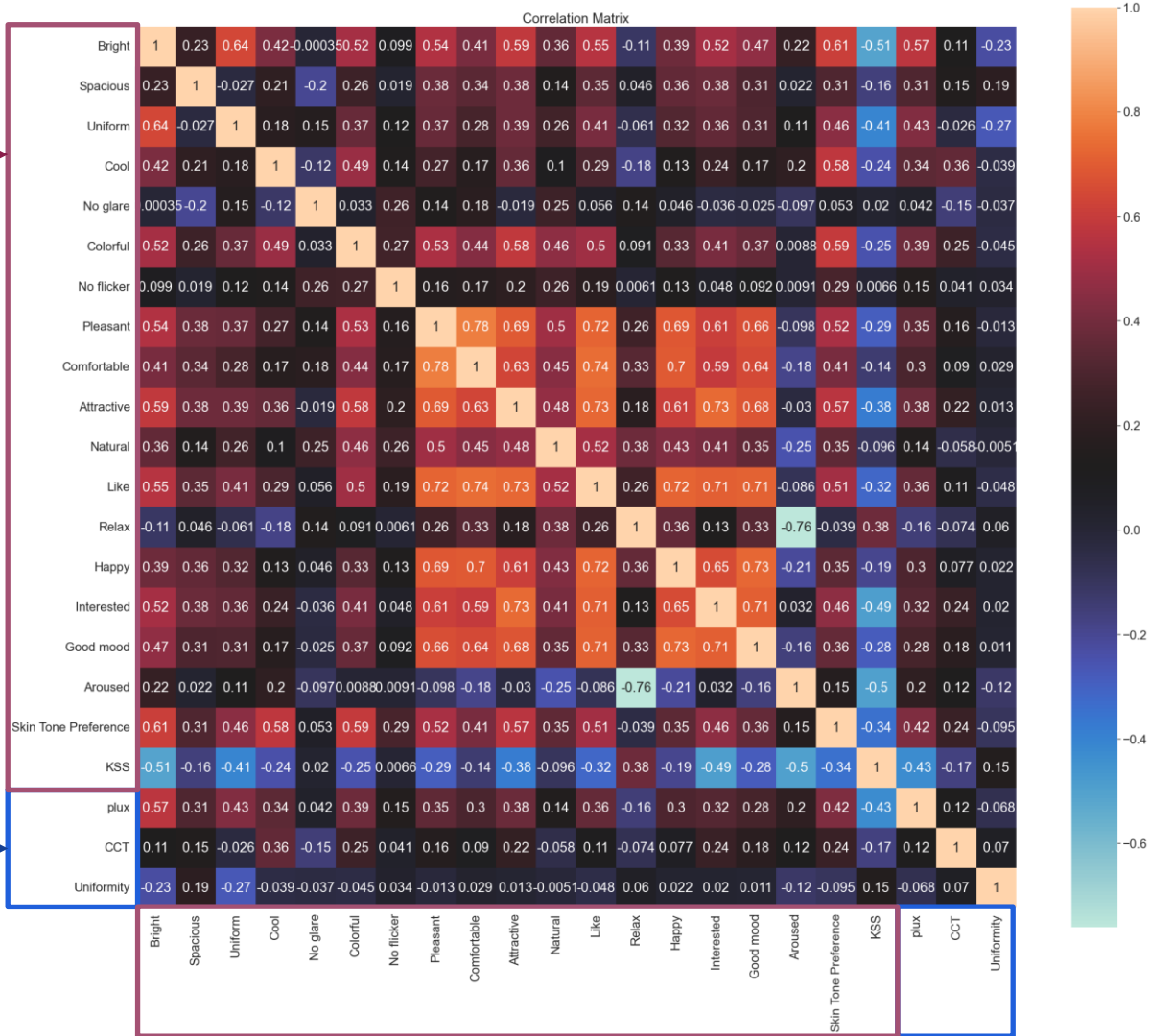
Correlations between subjective measures and visual parameters

plux	Subjective Measures
Moderate correlation (0.4 to 0.6) with perceived	- Brightness - Uniformity - Skin tone preference - Sleepiness (negative)
Weak correlation (0.2 to 0.4) with perceived	- Spaciousness - Coolness - Colorfulness - All mood states besides naturalness and relaxedness
CCT	Subjective Measures
Weak correlation (0.2 to 0.4) with perceived	- Coolness - Colourfulness - Attractiveness - Interest - Skin tone preference
Uniformity	Subjective Measures
Weak correlation (0.2 to 0.4) with perceived	- Brightness - Uniformity

5 | Systematic Challenges

Systematic Challenges

- **Miniature Spectral Sensor (MSS)**
  - Hard to switch on
  - Bluetooth communication range decreases a lot when battery level drops by more than 10% from being fully-charged
- **Human error**
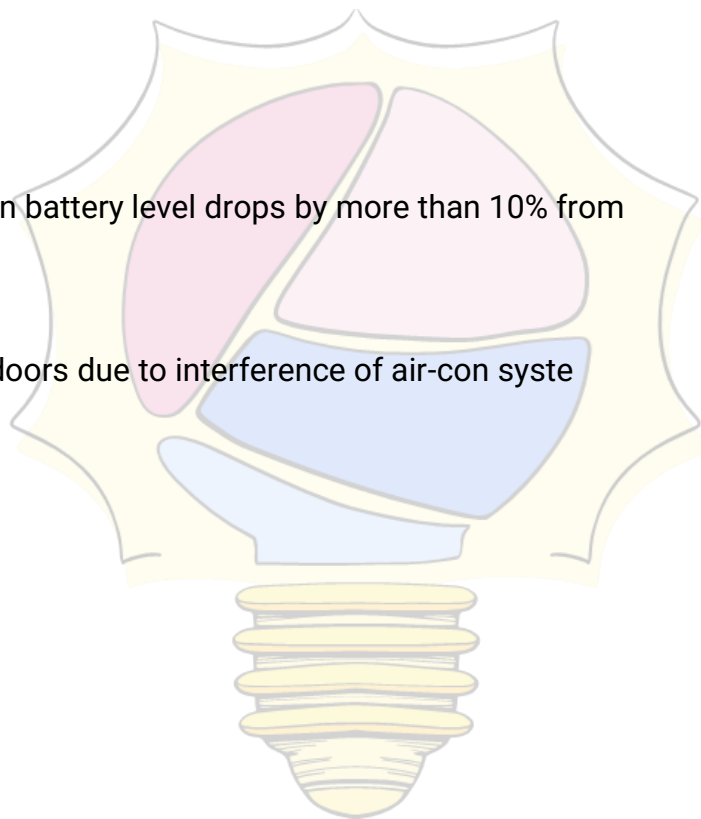 - Manual measurements as drones cannot be used indoors due to interference of air-con syste
  - Maintain MSS at fixed height
- **Short timeframe**
  - Only spent three weeks due to high workload
  - No access to laboratories at night
  - Grid sampling not possible
- **Subjective measures**
  - Only 5 participants
  - Stayed only a short time in a room

6   Conclusion

Conclusion

What we have done
- A lighting dataset of MUM
- Gap analysis
- Recommendations for lighting system improvement
- A framework for future comprehensive lighting profiling

What we found
- Most teaching spaces have good illuminance and uniformity
- Other spaces have bad uniformity
- Some areas are too bright
- Almost all spaces fail nonvisual effect benchmarks

Recommendations
- Improve uniformity by adding luminaires at dark spots, using denser number of luminaires or reduced brightness at top rows
- Reduce brightness for overbright areas to save energy
- Advanced luminaires to improve nonvisual effects
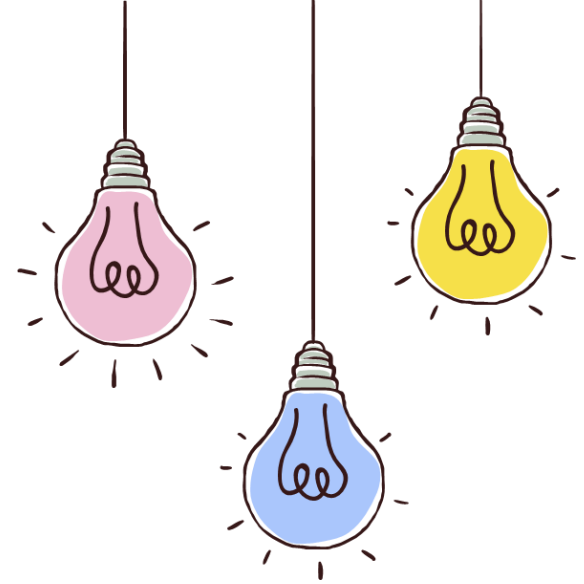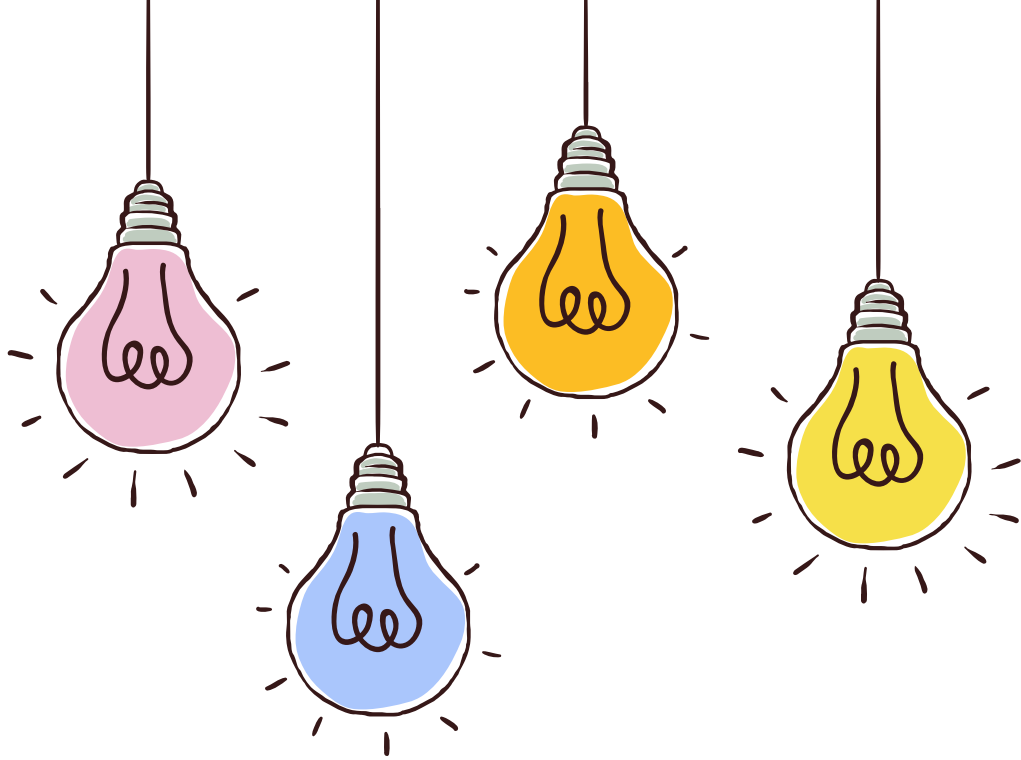
Thank you

References

[1]   W. J. M. van Bommel and G. J. van den Beld, "Lighting for work: a review of visual and biological effects," Light. Res. Technol., vol. 36, no. 4, pp. 255-266, Dec. 2004, doi: 10.1191/1365782804li122oa

[2]   W. J. M. van Bommel, "Non-visual biological effect of lighting and the practical meaning for lighting for work," Appl. Ergon., vol. 37, no. 4, pp. 461-466, Jul. 2006, doi: https://doi.org/10.1016/j.apergo.2006.04.009.

[3]   Z. Kong, Q. Liu, X. Li, K. Hou, and Q. Xing, "Indoor lighting effects on subjective impressions and mood states: A critical review," Build Environ, vol. 224, pp. 109591, Oct. 2022, doi: https://doi.org/10.1016/j.buildenv.2022.109591.

[4]   T. M. Brown et al., "Recommendations for daytime, evening, and nighttime indoor light exposure to best support physiology, sleep, and wakefulness in healthy adults," (in Eng.), PLoS Biol, vol. 20, no. 3, pp. e3001571, Mar. 2022, doi: 10.1371/journal.pbio.3001571.

[5]   Signify. "Increase wellbeing in the office by applying melanopic lighting. " assets.signify.com. [Online]. Available: https://www.assets.signify.com/is/content/Signify/Assets/philips-lighting/global/20210520-brochure-melanopic-light.pdf (accessed. Oct. 9, 2022).

[6]   L. Heschong, R. L. Wright, and S. Okura, "Daylighting impacts on human performance in school," J Illum Eng Soc, vol. 31, no. 2, pp. 101-114, 2002.

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