

# **A Comparison of Daylight and Electrical Lighting: The Effects on Alertness, Vitality and Cognitive Performance**

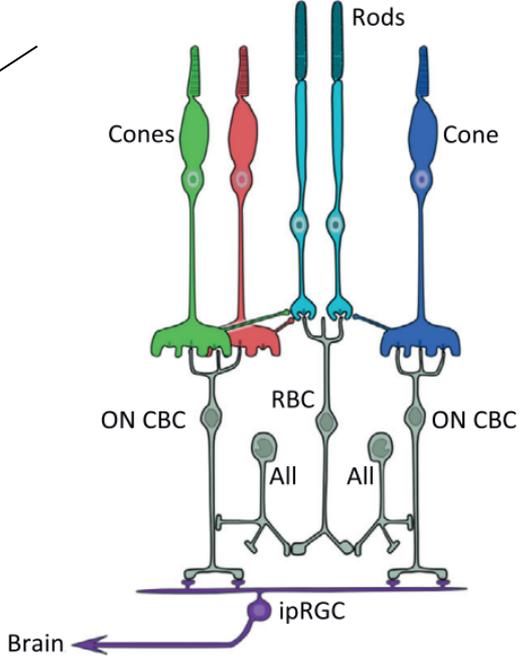
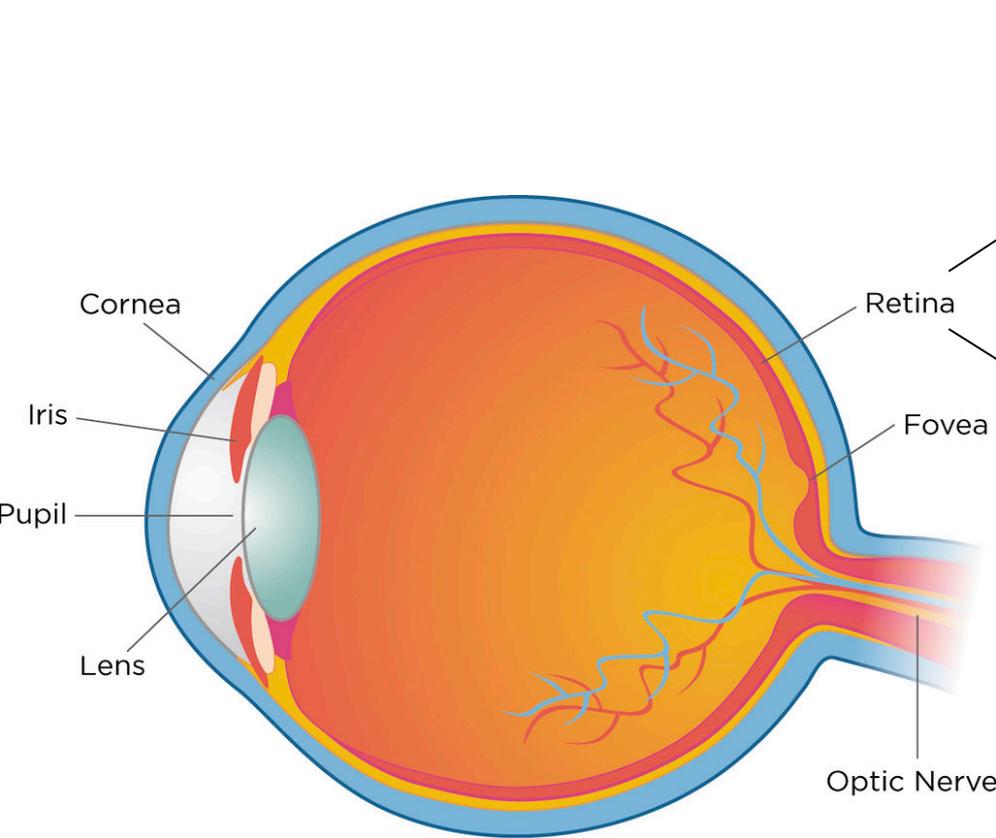


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# Background

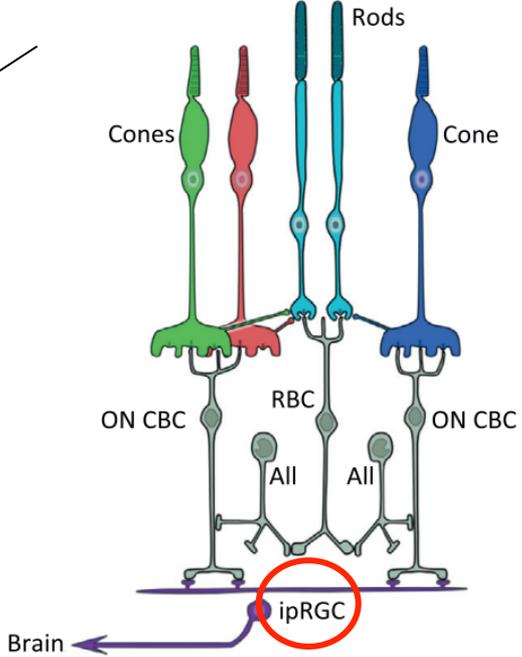
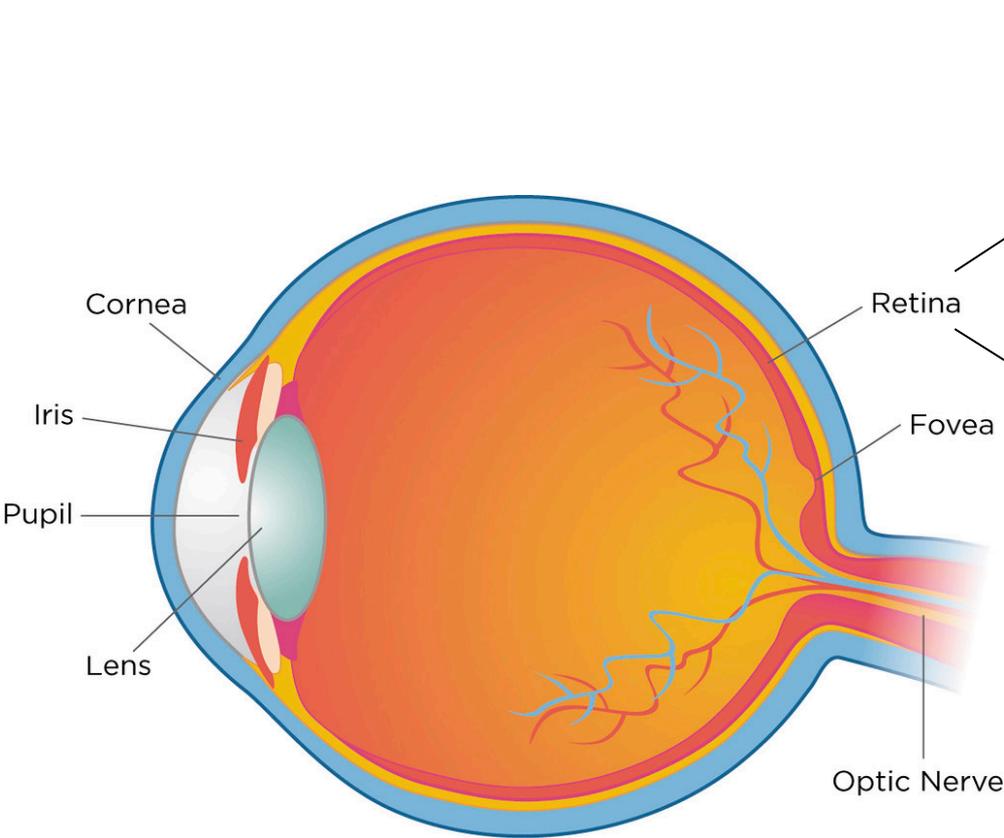


# Photoreceptors in Human Retina



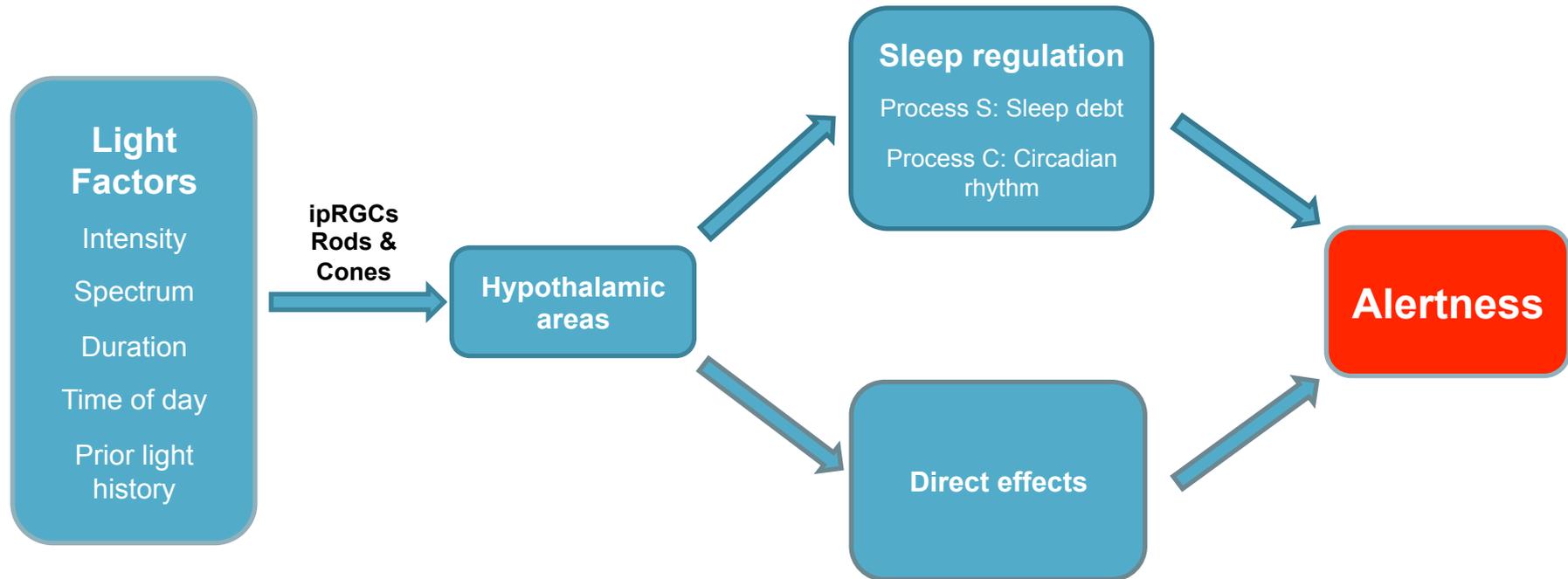
(Adapted from Lucas *et al.* (2014))

# Photoreceptors in Human Retina

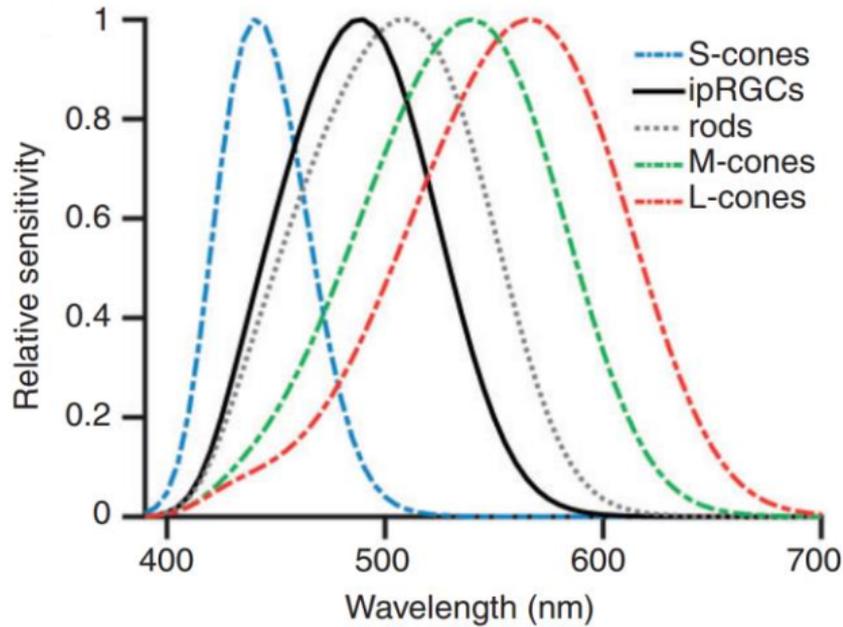


(Adapted from Lucas *et al.* (2014))

# Potential Mechanism of Alerting Effects



# Spectral Sensitivity of Photoreceptors



Photoreceptor	Photopigment	$\lambda_{max}$ (nm)
S-cone	Cyanolabe	419
M-cone	Chlorolabe	531
L-cone	Erythrolabe	558
Rod	Rod opsin	496
<b>ipRGCs</b>	<b>Melanopsin</b>	<b>480</b>

(Adapted from Lucas *et al.* (2014))

# Quantifying Melanopic Responses

- Equivalent Melanopic Lux (EML) ( Lucas *et. al*, 2014)

$$E_m = K_m \int E_{e,\lambda}(\lambda) N_m(\lambda) d\lambda \cdot \int V(\lambda) d\lambda / \int N_m(\lambda) d\lambda$$

- Melanopic Daylight Equivalent Illuminance (MDEI) (Gall & Bieske, 2004)

$$E_{v,mel} = \frac{K_m}{a_{cf,D65}} \cdot E_{e,mel}$$

- Circadian Light ( $CL_A$ ) and Circadian stimulus (CS) (Rea *et. al*, 2010)

$$CL_A = \begin{cases} 1622 \left[ \int Mc_\lambda E_\lambda d\lambda + \left( a_{b-y} \left( \int \frac{S_\lambda}{mp_\lambda} E_\lambda d\lambda - k \int \frac{V_\lambda}{mp_\lambda} E_\lambda d\lambda \right) - a_{rod} \left( 1 - e^{-\frac{\int V'_\lambda E_\lambda d\lambda}{RodSat}} \right) \right) \right] & \text{if } \int \frac{S_\lambda}{mp_\lambda} E_\lambda d\lambda - k \int \frac{V_\lambda}{mp_\lambda} E_\lambda d\lambda \geq 0 \\ 1622 \int Mc_\lambda E_\lambda d\lambda & \text{if } \int \frac{S_\lambda}{mp_\lambda} E_\lambda d\lambda - k \int \frac{V_\lambda}{mp_\lambda} E_\lambda d\lambda < 0 \end{cases}$$

## WELL Standard v2

Electric light only		Electric light and daylight	Points
At least 150 EML [136 melanopic equivalent daylight D65]	OR	The project achieves at least 120 EML [109 melanopic equivalent daylight D65] with electric light and at least 2 points in Feature L05: Enhanced Daylight Access.	1
At least 240 EML [218 melanopic equivalent daylight D65]	OR	The project achieves at least 180 EML [163 melanopic equivalent daylight D65] with electric light and at least 2 points in Feature L05: Enhanced Daylight Access.	3

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# Dynamic Lighting



**ENERGY IN THE MORNING**  
4000K white + blue-enriched



**HAPPINESS AT MIDDAY**  
4000K - 3000K white



**RELAXATION IN THE EVENING**  
3000K - 2700K white

(Accessed from: <https://www.essystem.pl/en/light-management/hcl>)

# Dynamic Lighting



(Accessed from: <https://www.essystem.pl/en/light-management/hcl>)

# Aims



# Aims and Objectives

## Research question:

- Whether the blue-enriched artificial light sources could be an acceptable alternative to daylight, in terms of acute alerting effects and visual acceptance.

## Objectives

- Testing is there any difference of alertness, vitality and cognitive performance when exposed to artificial lighting, which provides same level of EML as daylight
- Investigating how people evaluate electric lighting and daylight at different levels of EML and illuminance.

# Methodology



# Alertness, Vitality and Cognitive Performance

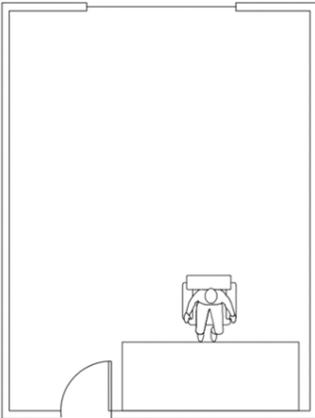
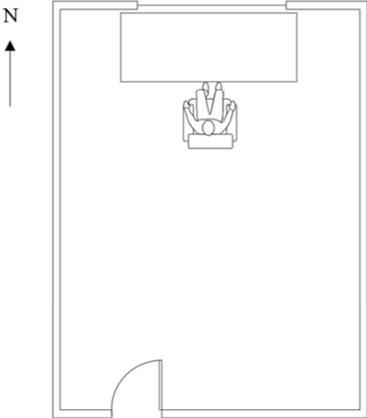
## **Subjective Measurements:**

- Karolinska Sleepiness Scale (KSS)
- Subjective Vitality Scale (SVS)
- Brightness and visual comfort
- Confounding factors: time awake, sleep duration and time spent outdoors.

## **Objective measurements:**

- Psychomotor Vigilance Task (PVT)
- Letter Digits Substitution Test (LDST)

# Daylight vs. Electric Light



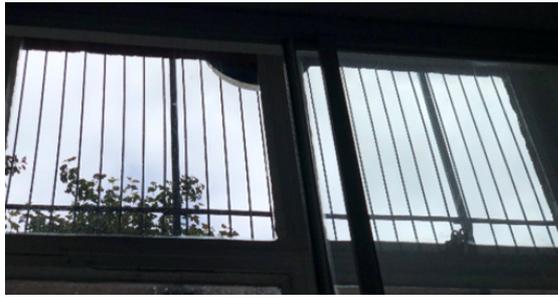
# Sky Conditions



Clear Blue Sky

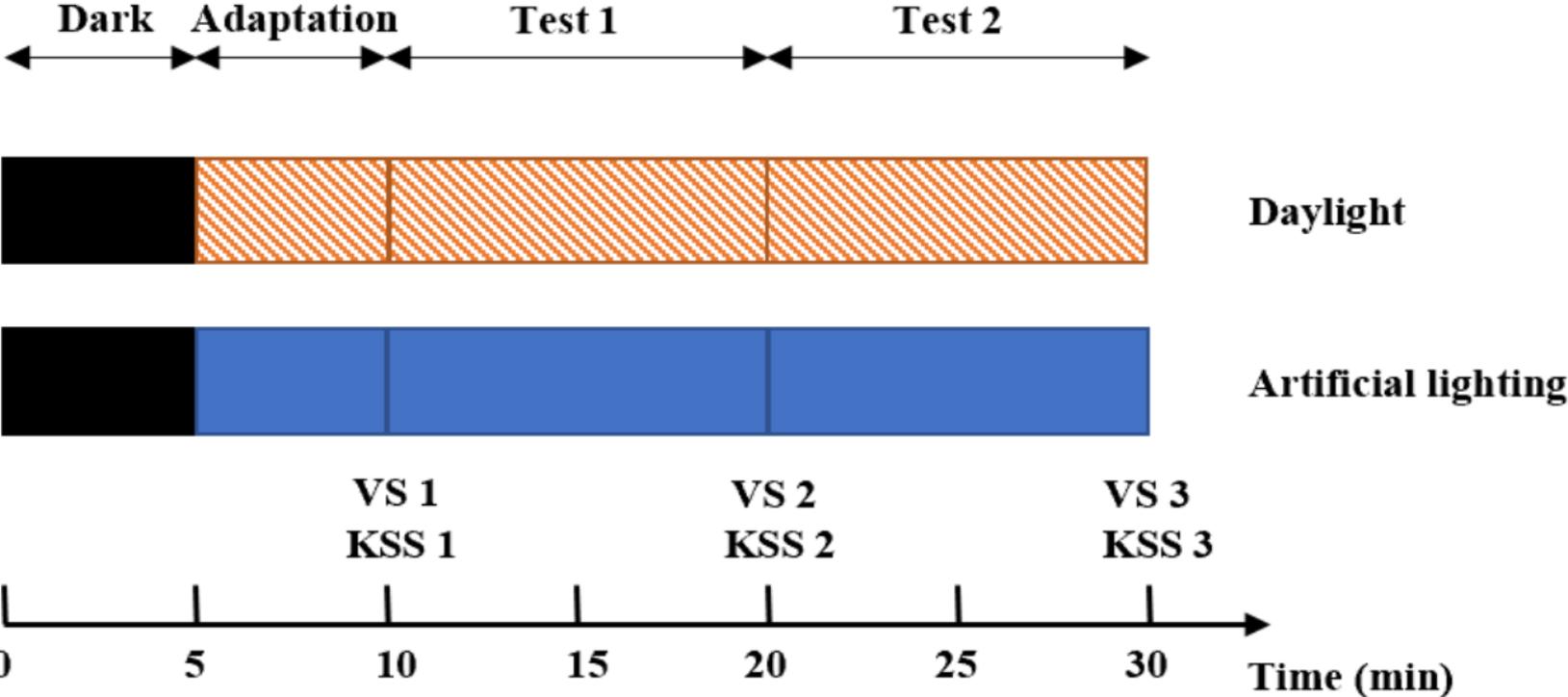


Partly Cloudy



Overcast sky

# Experimental Procedures



# Results



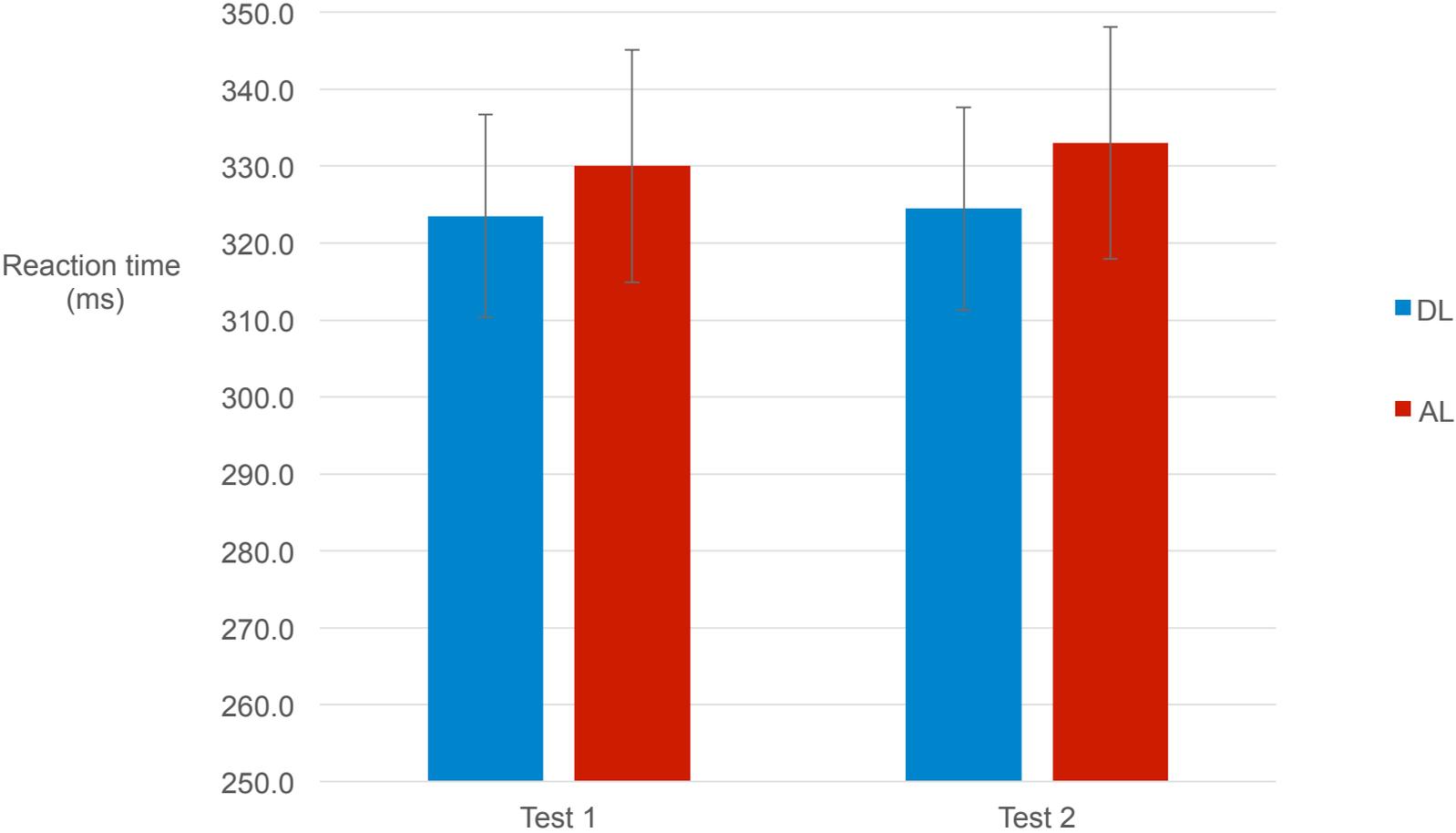
## Measurements: Lighting Conditions

	Illuminance (lx)		CCT		EML	
	Daylight	Fluorescent	Daylight	Fluorescent	Daylight	Fluorescent
<b>Clear Blue sky</b>	146	176	9776	6140	199	198
<b>Partly Cloudy</b>	313	325	7062	6265	364	362
<b>Overcast sky</b>	430	391	5907	6234	437	437

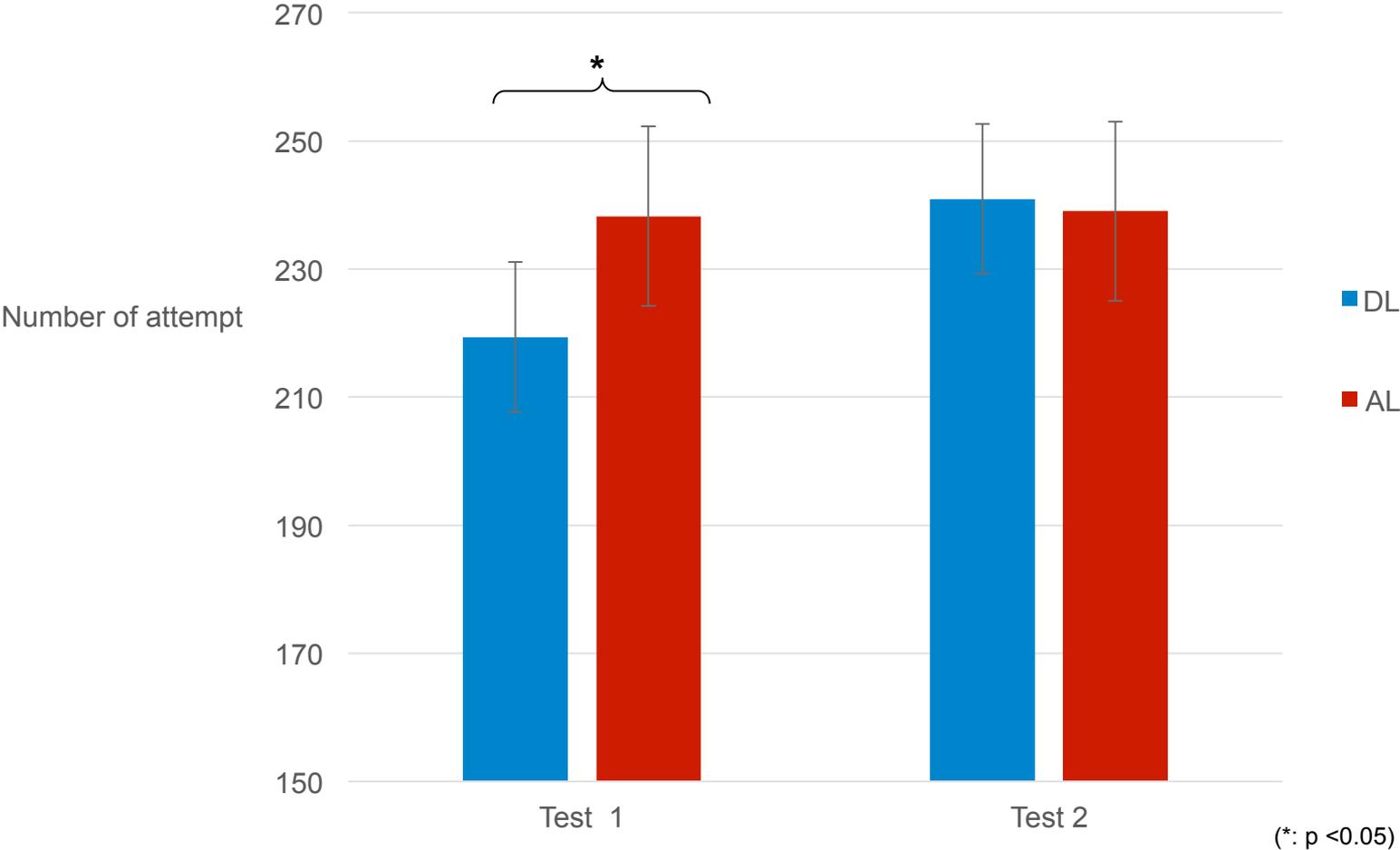
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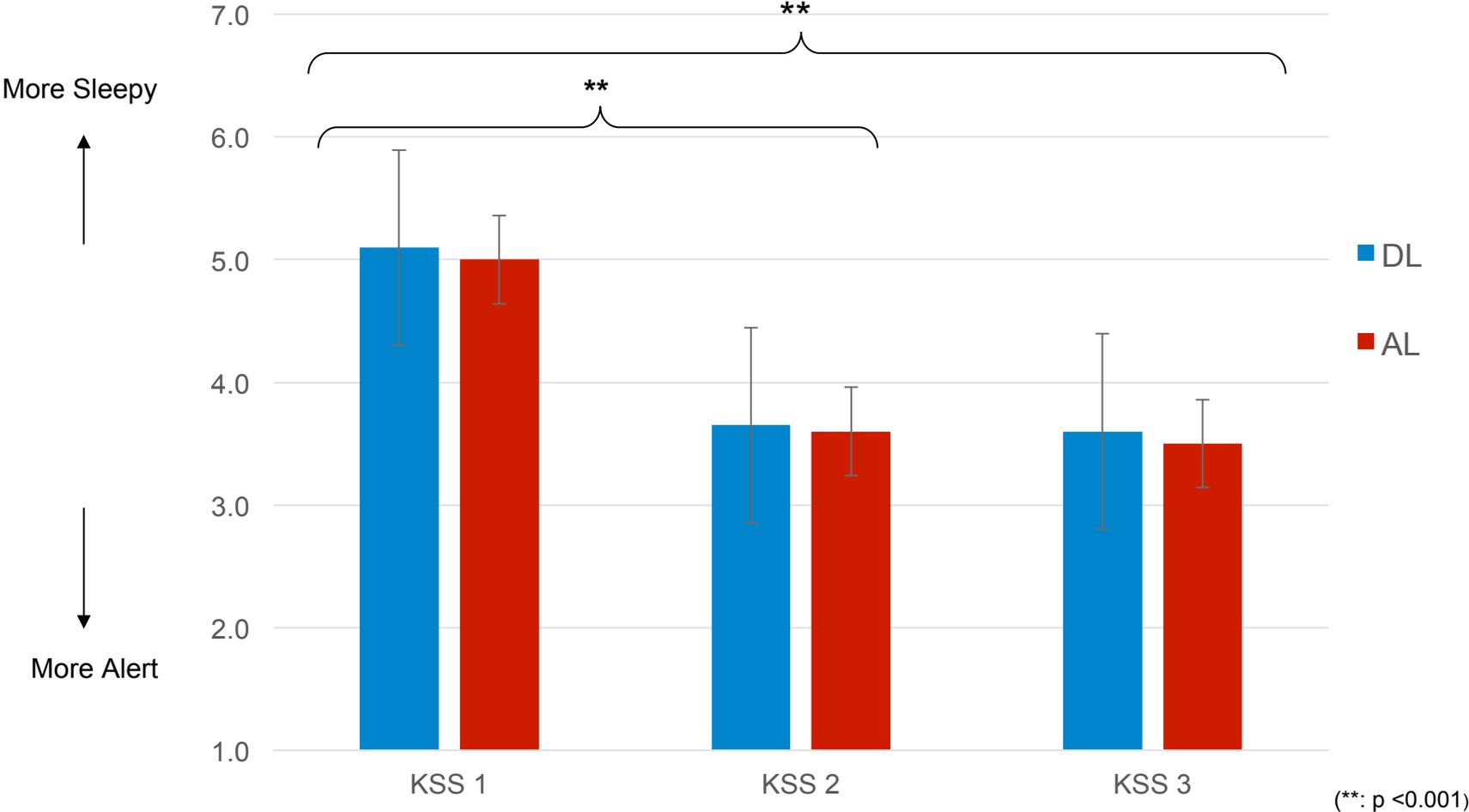
# Impacts of Light Sources on Reaction Time



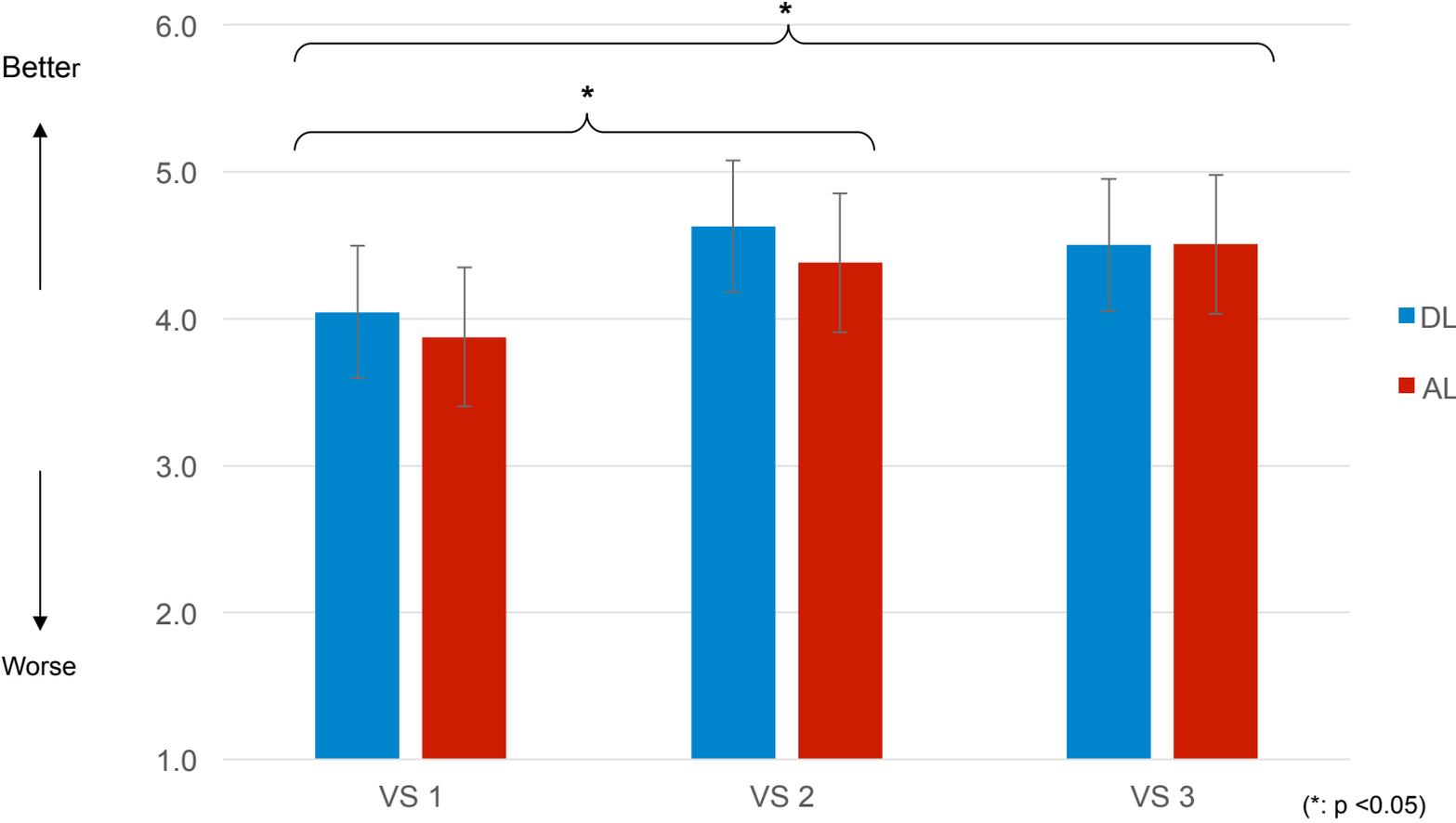
# Impacts of Light Sources on Working Memories



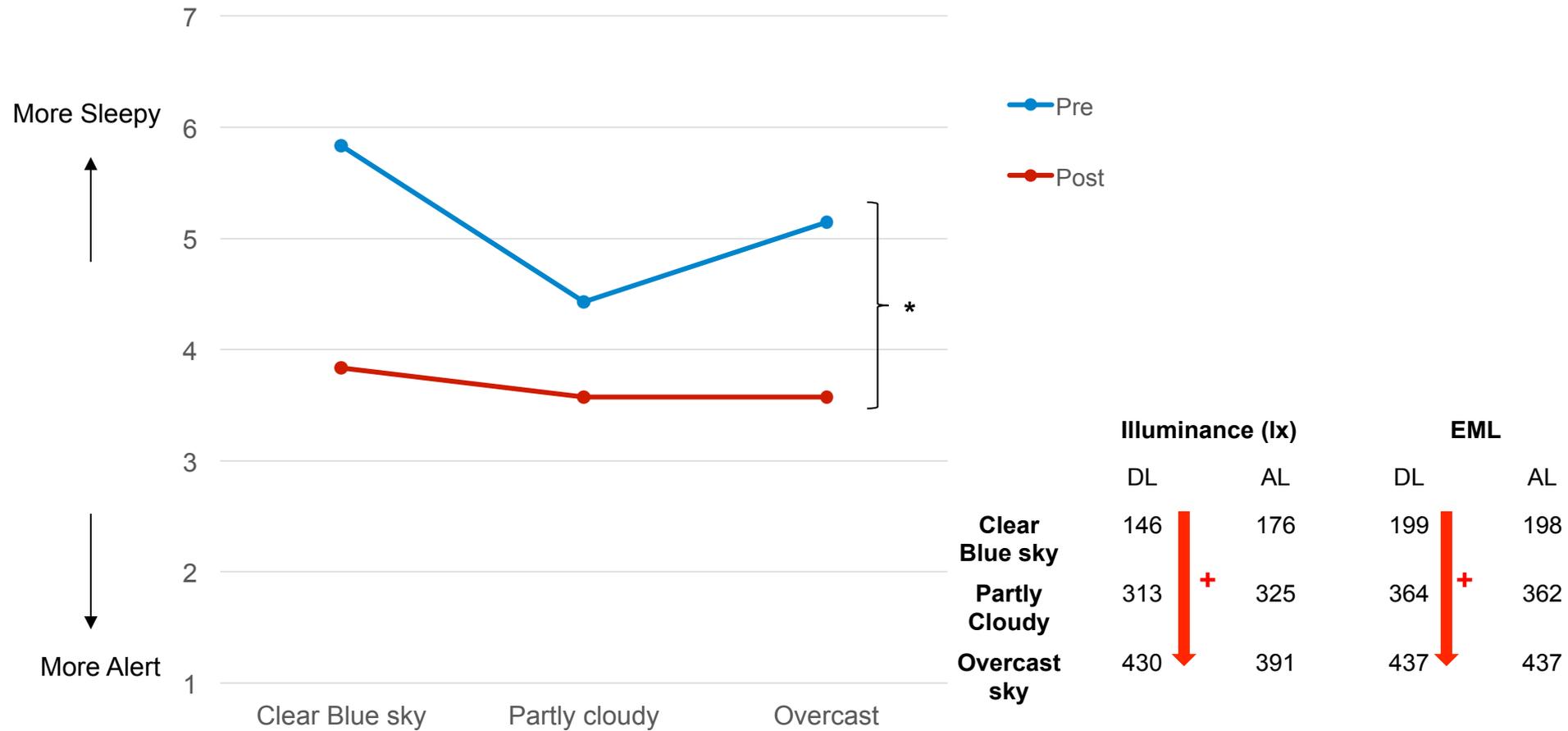
# Impacts of Light Sources on Subjective Sleepiness



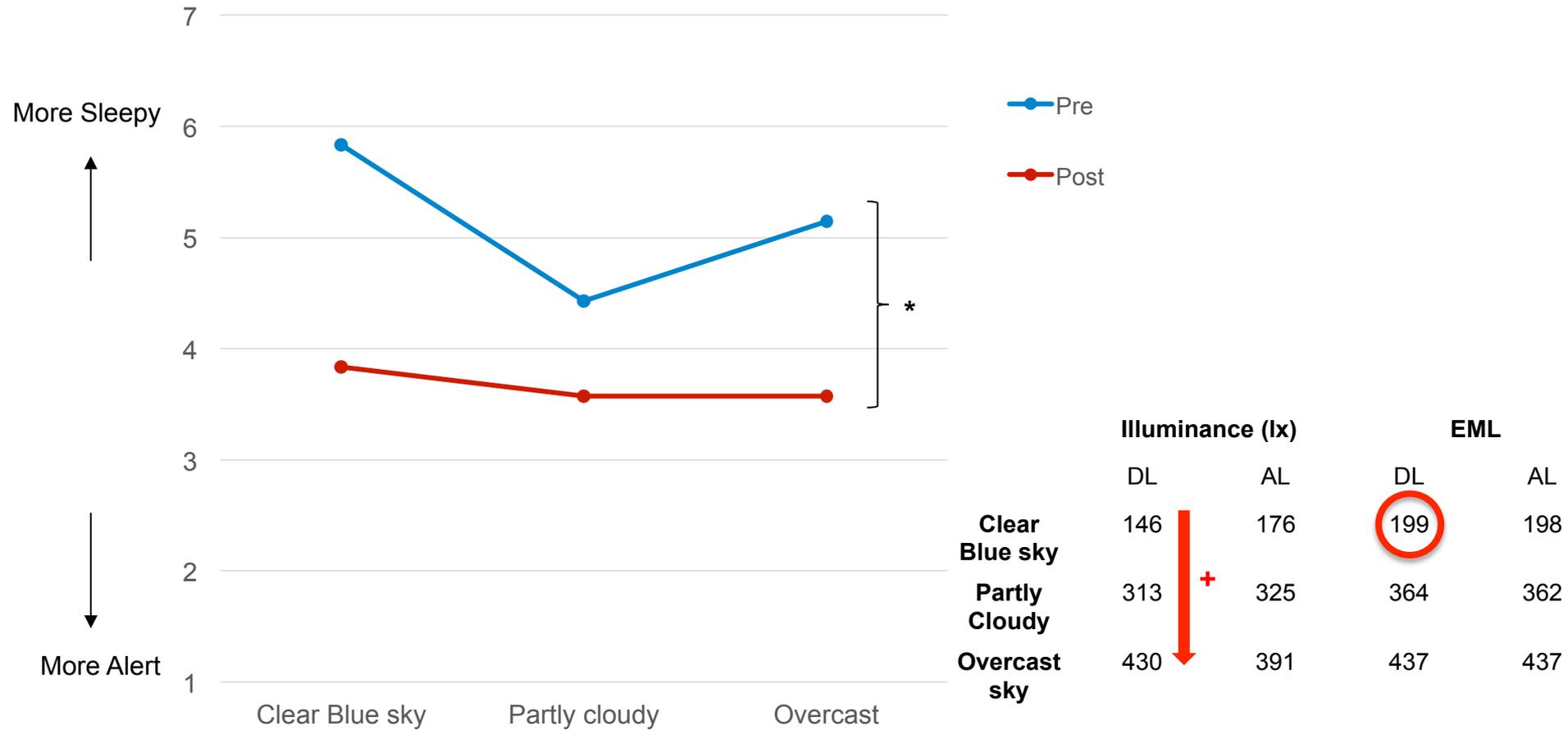
# Impacts of Light Sources on Subjective Vitality



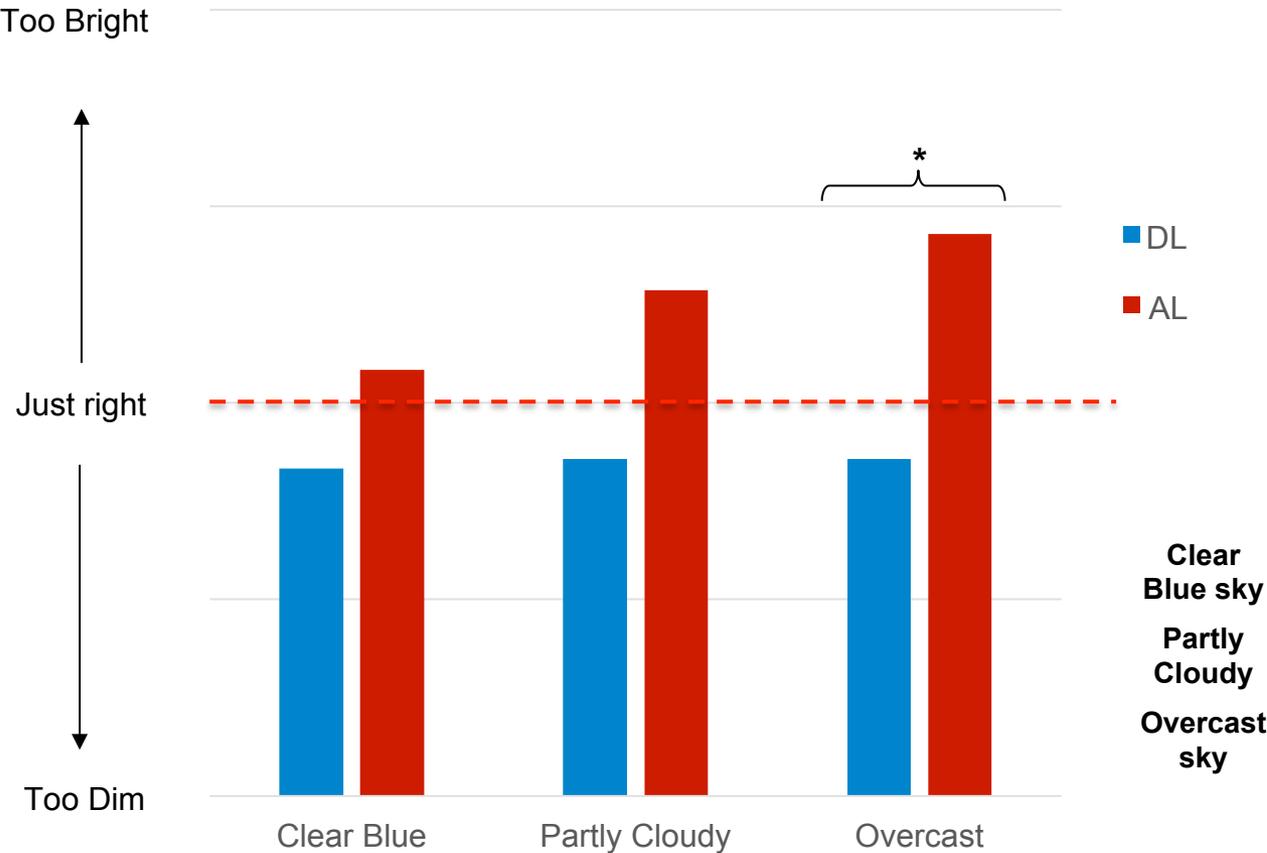
# Sky Conditions: Subjective Sleepiness



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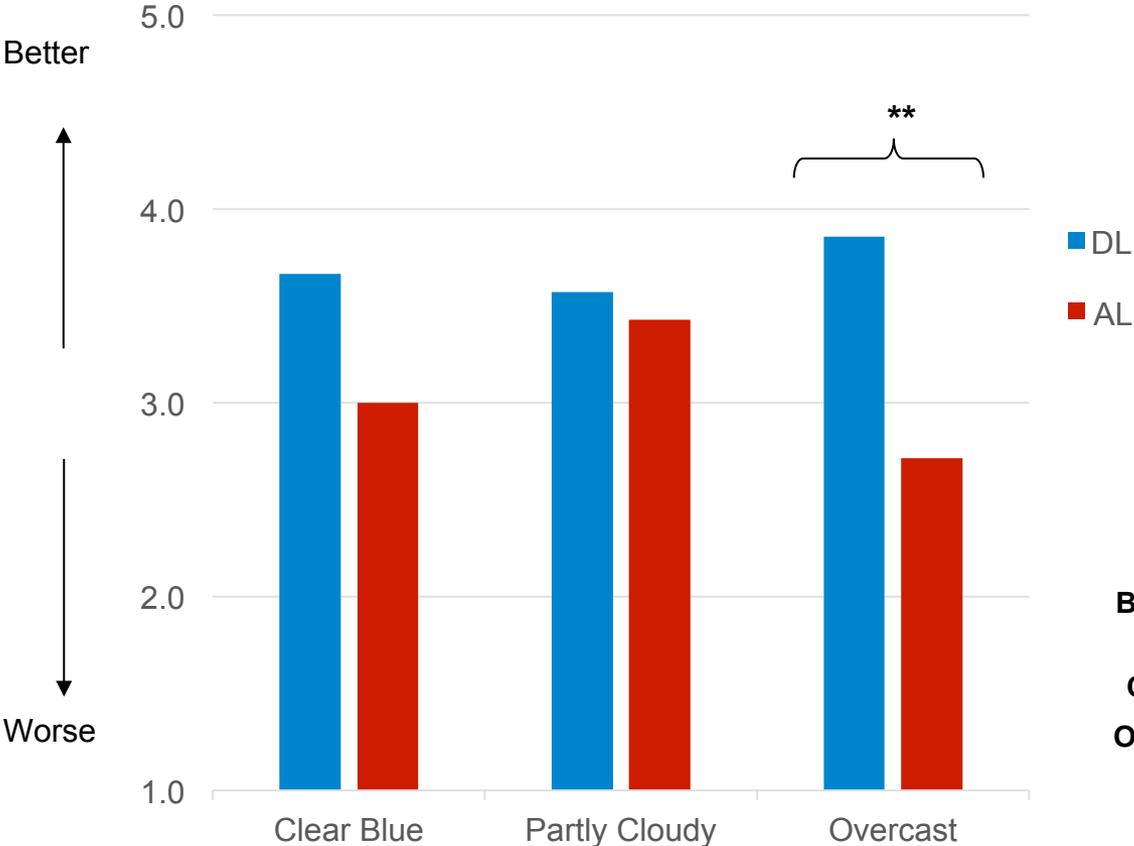
# Sky Conditions: Perceived Brightness



Illuminance (lx)		EML	
DL	AL	DL	AL
146	176	199	198
313	325	364	362
430	391	437	437

(\*: p < 0.05)

# Sky Conditions: Visual Comfort



(\*\*: p < 0.001)

	Illuminance (lx)		EML	
	DL	AL	DL	AL
Clear Blue sky	146	176	199	198
Partly Cloudy	313	325	364	362
Overcast sky	430	391	437	437



# Conclusion



## Key Findings

- Exposure to 200 EML or above in the morning may reduce subjective sleepiness and increase subjective vitality. There was no difference between daylight and fluorescent.
- At different levels of EML, there were no observed differences in reaction time and cognitive performance.
- At the same level of EML and similar illuminance, the light provided by fluorescent was considered brighter and less comfortable compared to daylight.

## Limitations & Further Studies

- Short exposure duration
- Small sample size
- Light distribution of daylight and fluorescent were different.
- Only one type of electric light, i.e. One spectrum of electric light

## More Questions

- Is daylight generally more acceptable as an cold white light source than electric lights?
- Does spectrum affect people's acceptance of cold white light sources?
- Can we distinguish between daylight and electric light of the same CCT and intensity?
- Will we still prefer daylight over electric light without seeing the light sources?

**Thank You!**