# Metropolis: *by LIGHT*

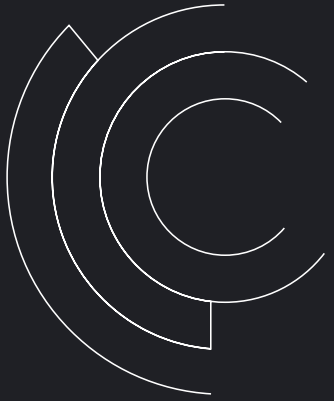**Biological Lighting**

 **- effects on health and well beeing**

**2 cases from Lighting Metropolis**

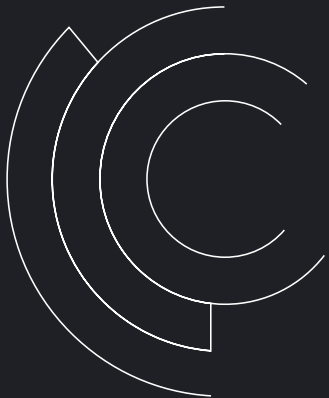*Ellen Kathrine Hansen, Aalborg University*

What is biological lighting?

# What is biological lighting?

# - and how does it affect health and well beeing?

By: Ellen Kathrine Hansen, Lighting Design, Dep. Architecture, Design and Media Technology, 13.09.18
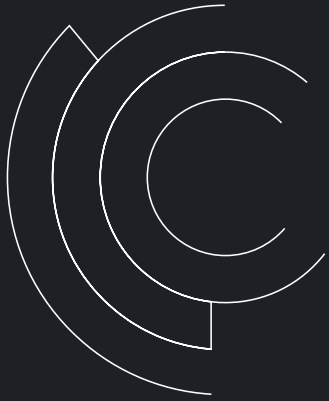
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Three types of biological lighting

- Light Penetrating the Skin
- Visual effects – image forming
- Non visual effects – non image forming

# Light penetrating our skin
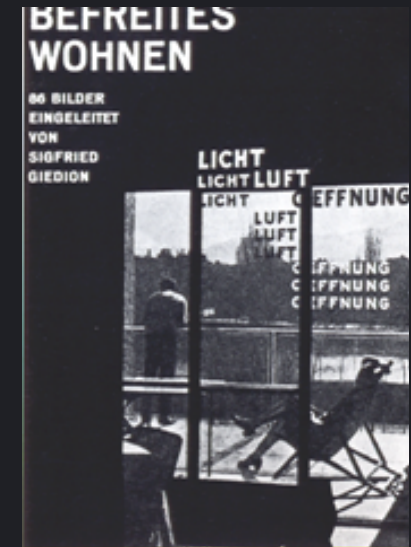
UVb-light to get vitamin D3

## Light Theraphy

To kill bacteria, Tuberculosis, Niels Finsen (1860-1904).

Used both daylight and artificial lighting

Observations, no medical explanations.

In 1903 Finsen receives the Nobel Prize in Physiology and Medicine



Sigfred Giedion's bog
'Befreites Wohnen' 1929
Lys, luft og åbning

Ref.: Volf, Carlo; PhD Theses "Light Architecture and Health" AAA 2013

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# Visual effects – image forming light

# Lighting as Formgiver to create an atmosphere
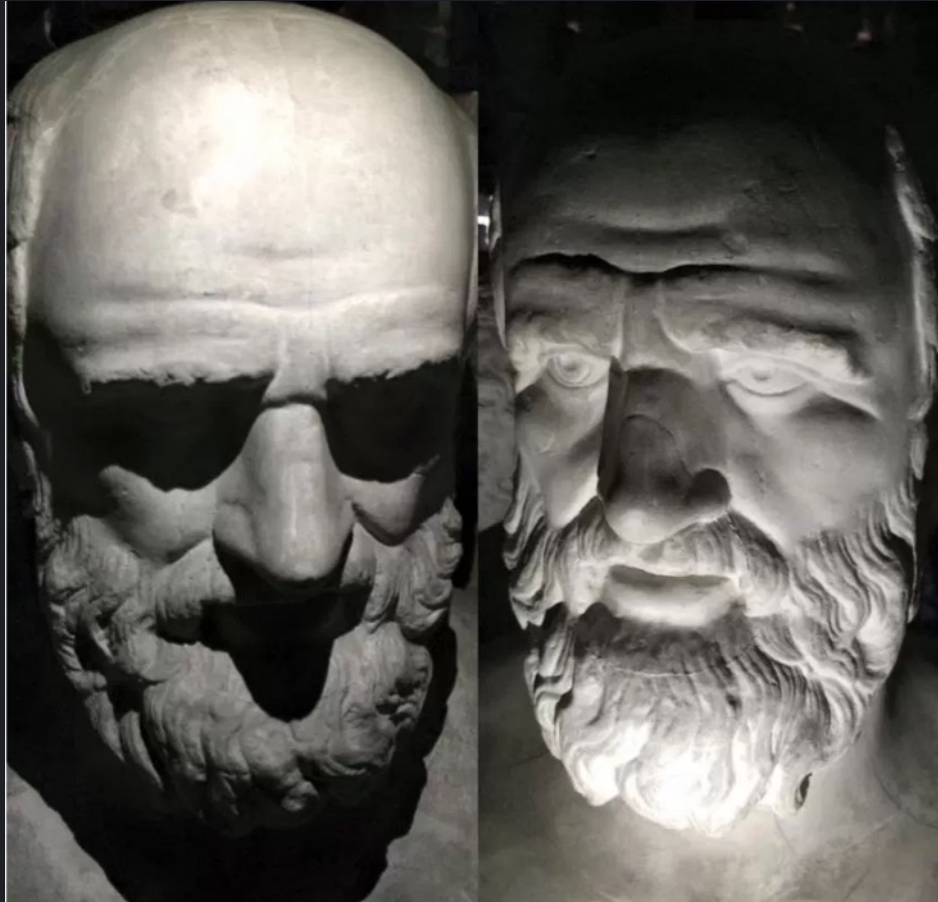


*Play with shadows, LiD7 students kick off project Cast Collection 2016*



*'Støvkornenes dans i solstrålerne' Hammershøj 1900*

*Ordrupgårdsamlingen*

# Visual effects – image forming light

## Perception and Lighting as Formgiver for Architecture
## Biological needs

*"Light has always been recognized as one of the most powerful formgivers available to the designer, and great architects have always understood its importance as the principal medium which* **puts man in touch with his environment***."*

*Lam W., 1977, p.10*

- Orientation,

- Physical security,

- Relaxation of the body and the mind,

- **Adjustment of the biological clock (Time orientation),**

- Contact with nature, sunlight, and with other living beings

- Definition of personal territory

WILLIAM M.C. LAM
PERCEPTION AND LIGHTING
AS FORMGIVERS FOR ARCHITECTURE

*Lam, 1977, p.20 /*

# Non Visual effects – Non Image Forming

## „Human Centric Lighting"

Light stimulates **ganglion cells** (photoreceptors - ipRGCs)
Creates alertness

Affects production of **melatonin**

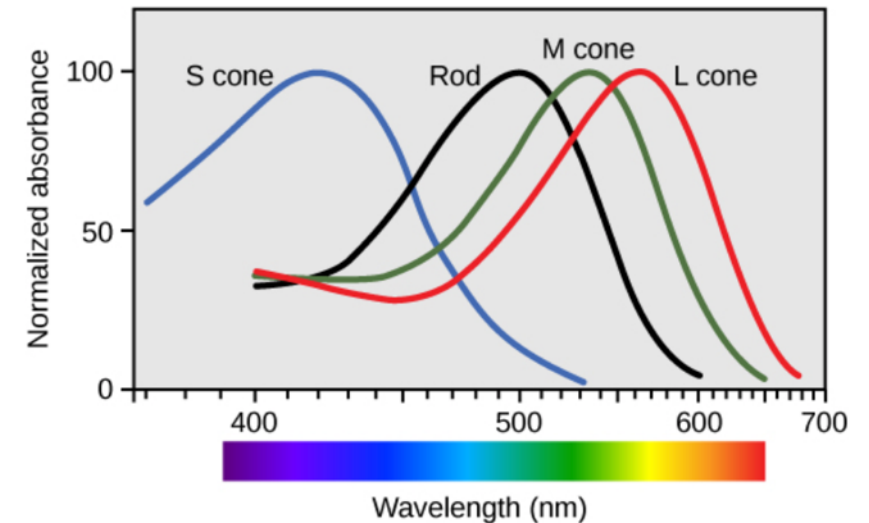https://www.chronobiology.com/wp-content/uploads/2016/12/the-eyes-role-in-circadian-rhythm-entrainment-2.jpg

https://opentextbc.ca/biology/chapter/17-5-vision/



④ Too much melatonin, or secretion of the hormone that's out of phase with sleep-wake signals, may be a cause of seasonal affective disorder

LIGHT

③ Pineal gland secretes melatonin, the "darkness" hormone

① Light exposure triggers a signal from retina in the eye to the suprachiasmatic nucleus, the brain's pacemaker

Suprachiasmatic nucleus

Superior cervical ganglia

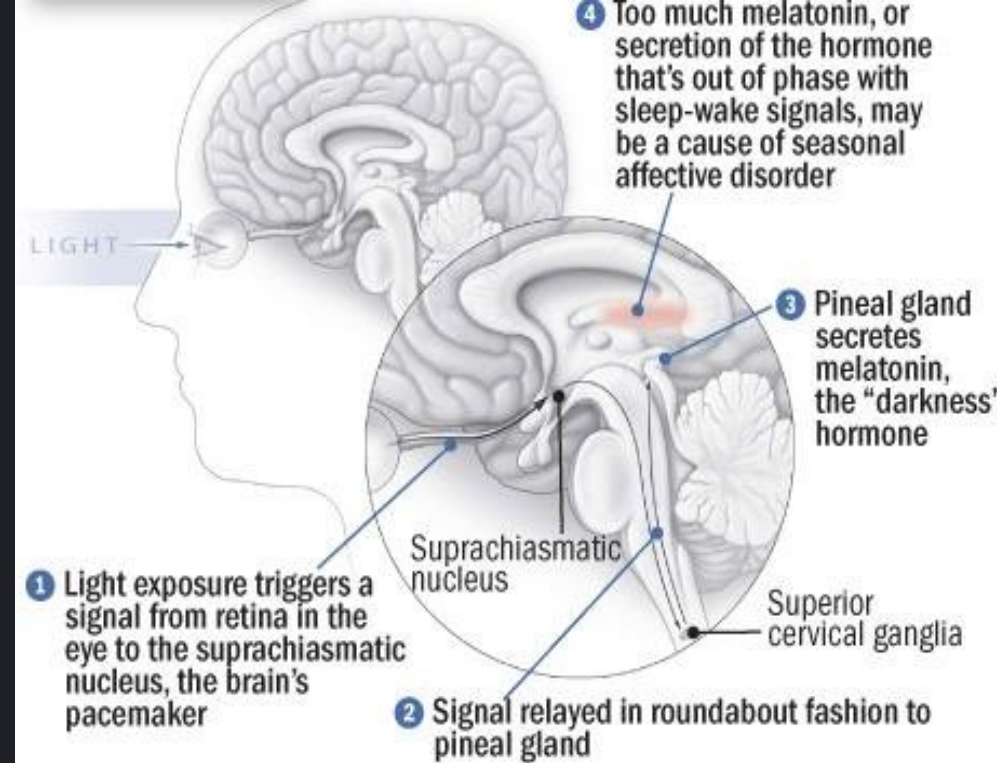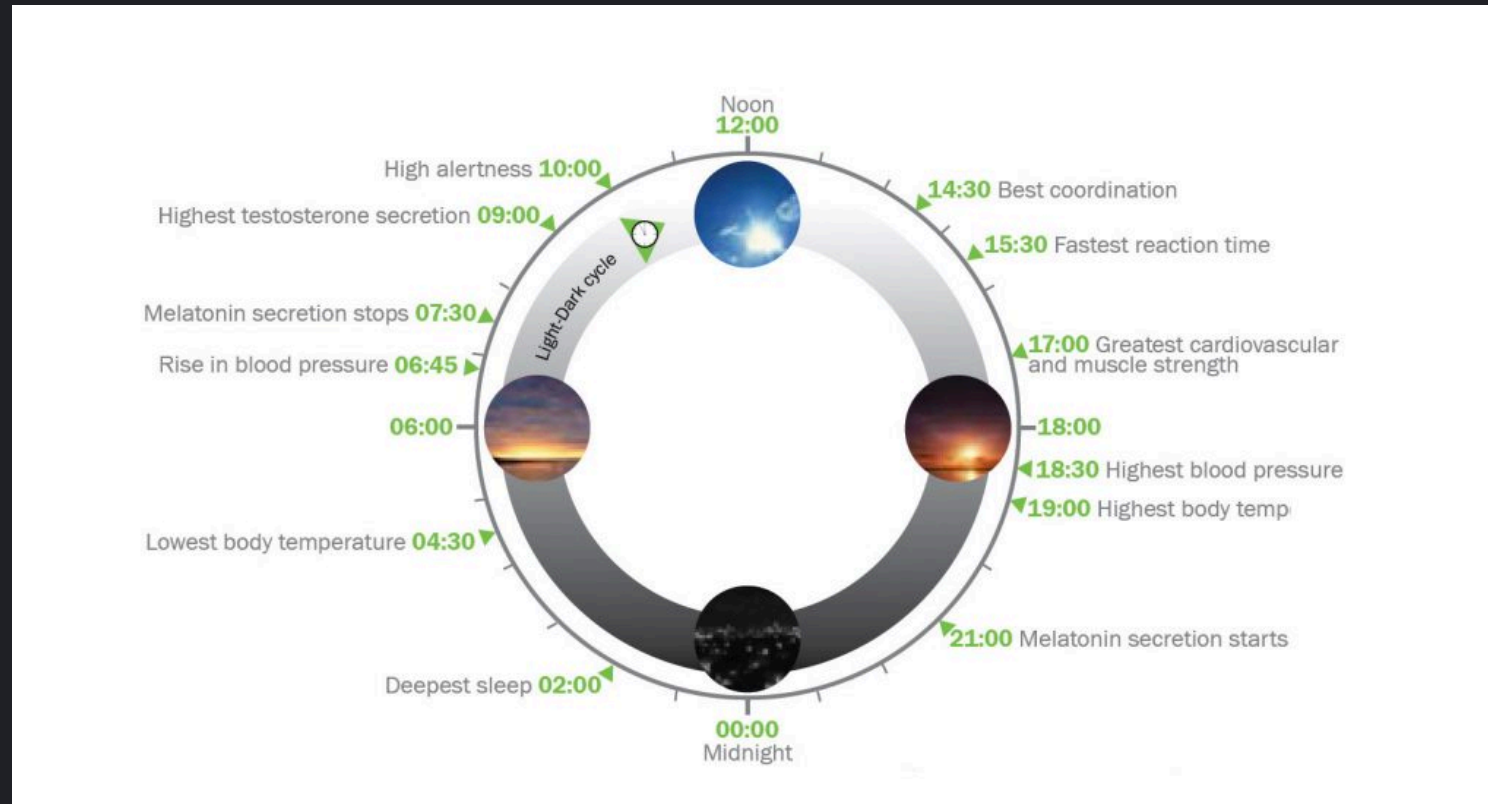② Signal relayed in roundabout fashion to pineal gland



Figure 17.21.

# Circadian Rhythms – 24 hour light and dark cycle

"built in clocks" regulate the timing of biological processes and daily behavior.



The photoreceptors are ensitive to different wavelenght
Blue light - alertness in the morning
Decreasing light warm light in the evening (3000-8000 kelvin)

# Simple general circadian lighting plan

**Morning:**
- A smooth transition from dark to warm white
- Bright light with colour temperature around 4,000K after approximately 2 hours after waking

**Noon:**
- The brightest light (12:00-14:00)
- Color temperature around that time tops at 5,500 K approximately correlating to the color temperature of daylight from a clear sky around noon

**Evening**
- The colour temperature is down to normal indoor levels around 3,000 K and the illuminance levels is reduced to 30%

**Night**
- Darkness or orange/red light of low illuminance level

# Circadian Lighting

- Improves sleep [1,4]
- Drives natural eating times, reduces night waking [1]
- Faster recovery times [4,5]
- Energizing during the day [6]
- Relaxation at evening/night [1,4,6]
- Promotes healthy activity [4,5]
- Increases productivity [7]
- Improves learning [7]
- Improves concentration [7]
- Improves mood & behavior [6]
- Reduces hyperactivity/ADHD [7]
- Reduces errors and accidents [7]
- Increase in memory [8]
- Faster cognitive processing speed [8]
- Reduces dementia symptoms [2,3]
- Reduces cardiovascular disease [4,5,9]
- Reduces obesity/diabetes [4,5,9]

**Circadian lighting seems to positively influence age-related needs, mood, cognition, alertness, sleep and improve well-being in general**

1 Figuieiro and Read, 2005; Roberts, 2008
2 Gehrmann, 2005
3 Torrington , 2006
4 (Roberts, 2000; Vetch et al., 2004; Cutolo M et al., 2005; Heschong and Roberts, 2009).
5 (Wilson, 1972; Stevens et al., 2007; Rea et al., 2008; Erren and Reiter, 2008; Arendt, 2010)
6 (Santillo et al., 2006; Musio and Santillo, 2009; Gaddy et al., Roberts 1995; Czeisler et al., 1995)
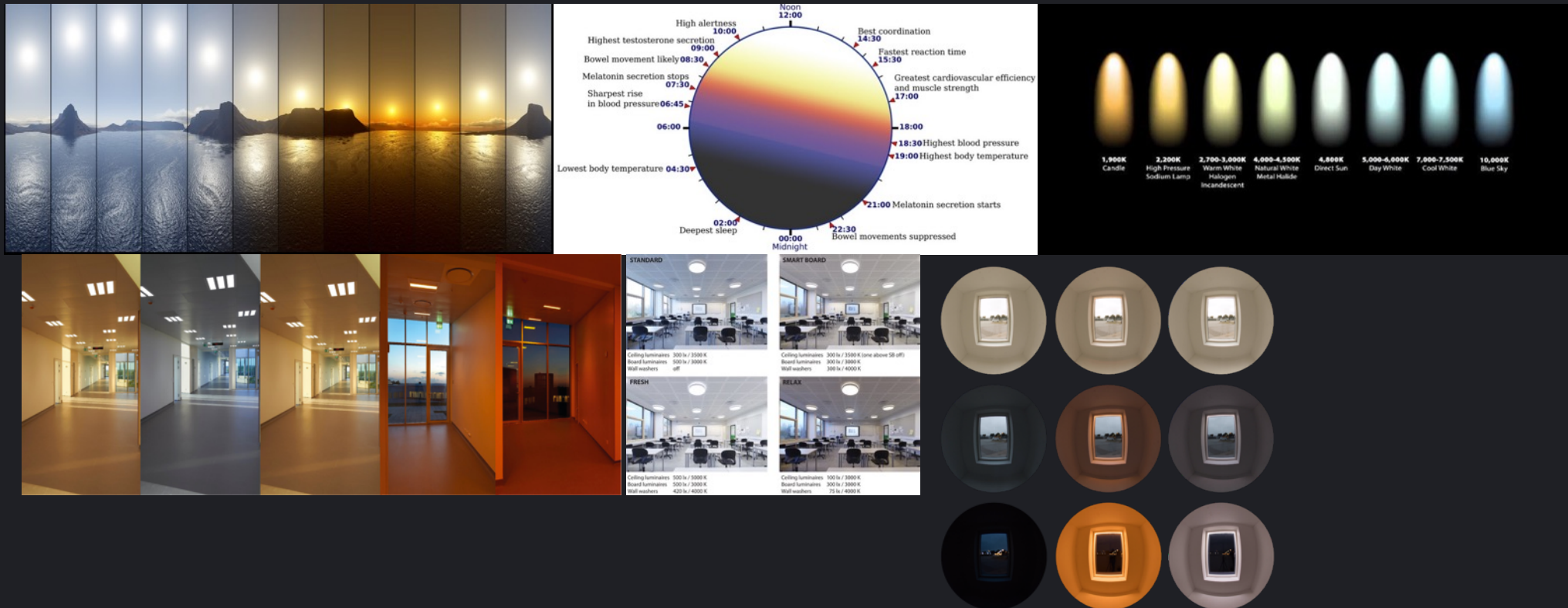7 (Schulte 2010)
8 (Helbig 2013)
9 Fonken et al., 2010

Source: http://www.photonstarlighting.co.uk/technology/circadian_lighting/

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# The interaction of the dynamic coloured light, intensity, distribution in relation to a circadian rythm – Non static light

/ dynamic daylight

/ dynamism of the circadian rhythm

/ dynamic artificial light

# 1. The effects of artificial lighting on symptoms of eating disorder

**Clinical Investigator: Jan Magnus Sjögren, MD, PhD, Associate Professor, Region Hovedstadens Psykiatri and Copenhagen University**
**Technical Investigator: Michael Mullins, MAA, PhD, Associate Professor, Aalborg University**
**Technical co-Investigator: Georgios Triantafyllidis, PhD, Associate Professor, Aalborg University**

*Jitka Stilund Hansen, PhD, Pernille Bech-Larsen, Research Assistant, Emilie Vangsgaard Rosager, Research Assistant*
*Katharina Collin Hasselbalch, Research Assistant, Staff at the department 14, Eating Disorders, Psychiatric Center Ballerup*

*Lighting Metropolis Partners: Region Hovedstaden, Zumtobel and Aalborg University*

The objective of this pilot study is to explore if and **how artificial lighting affects symptoms of eating disorders** (ED).

The study will provide information on **how to improve light exposure to ED patients** in psychiatric treatment units.

In addition, the outcomes may help identify a **better system for measurement and adjustment** of the specific light variables of colour temperature and light intensity.

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# Study design



Lux change:
Recreation and connecting corridor

CL (dynamic lux and Kelvin):
Private rooms and dining

Lux and some kelvin change:
Internal corridors

Study design:
Single-blind, internal control, four -stages, pilot intervention study

Planned number of subjects:
16 patients with a ICD-10 diagnosis of Anorexia Nervosa

Place:
24-hour ED facility in Ballerup with controllable light
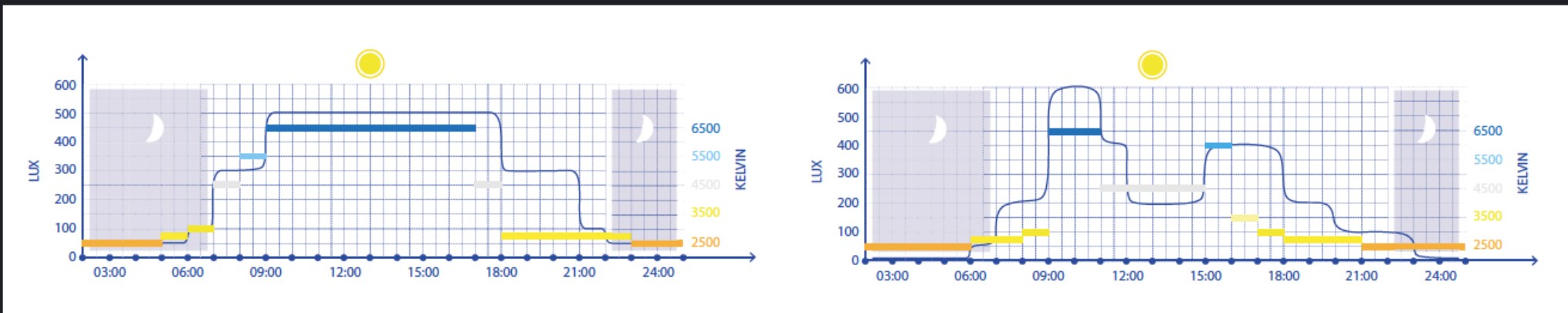
Reasoning:
Several lines of evidence, albeit from hypothesis generation studies, suggest that artificial lighting may have a positive effect on well-being, mental health and affective symptoms in ED

# Circadian lighting plan

**Research period: March 15th – July 31st (4,5 months)**
**4 x 3 week exposure to two different circadian rhythms, L1-L2-L1-L2**



L1: High mid day intensity
(high kelvin in one long peak) (April + June)

L2: Lower intensity and mid day drop
(changing kelvin in two shorter peaks) (May + July)

Mixed methods: Clinical (blood, urin etc.) and technical data (Thermal sensors and actiGraphy etc.) will be gathered during this period, as well as occupancy, humidity, weather conditions, lux and decibel levels. Qualitative measures, such as questionaires and observations will also be gathered for the entire research period.

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# Psychiatric Center Ballerup, Eating Disorder Facility



Natural light in recreational area



Typical patient room



Connecting glass corridor

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# Light distribution and fixture placement



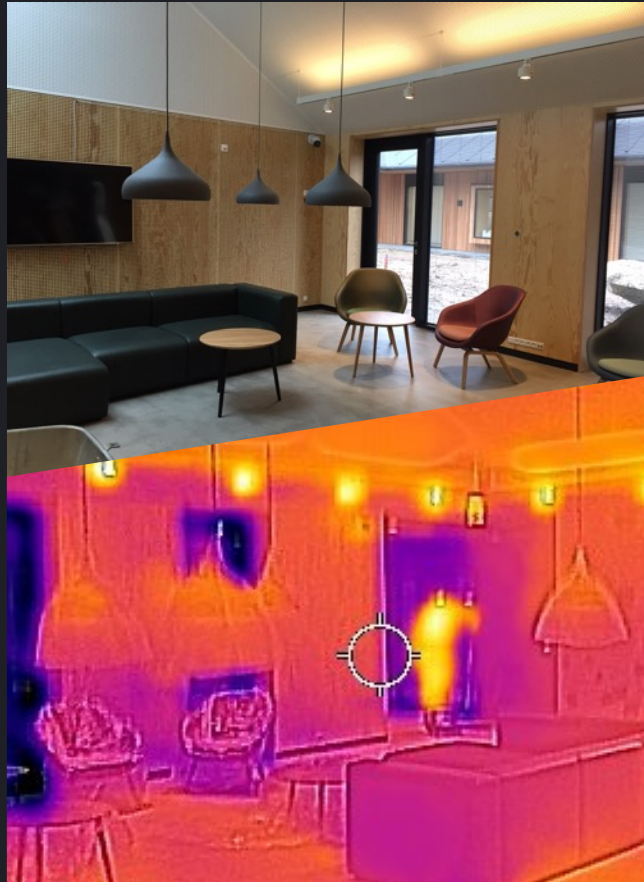Dining        Corridor        Recreation        Patient room

# Initial Results

**Clinical results**

- Results has not been published

**Technical results**

- Focus on comparing the activity levels in the two different circadian rhythms (L1-L2)

- Early results indicates that the heat sensors has detected higher activity levels in the dining room in the L1 period (high peak)

# 2. Dynamic lighting, a tool for teaching

Partners: AAU, Albertslund Municipalicy, Zumtobel. Consultant: Sweco, AI,

A field study on the use of lighting as a tool to structure and support teaching and learning activities by teachers.

1. Analyze dynamic lighting in learning environment **holistically** using **mixed methods**

2. Create knowledge on the **users needs** that is translated into a design concept and **design parameters for dynamic lighting in classrooms**

3. Conduct a **post-occupancy evaluation** on the teachers use of lighting scenarios and understanding their motivations

Hansen, E. K., Nielsen, S. M. L., Georgieva D., Schledermann K. M.: **The Impact of Dynamic Lighting in Classrooms. A Review on Methods**, EAI International Conference on Design, Learning & Innovation, October 2017, Heraklion, Greece

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# Result: Pre-Study

Analysis of the relationship between students' behavior and the lighting condition in classrooms with different orientations

- **Glare** on the smartboard is an issue

- **Random use of the light**

- They pay attention to the light only when there is an issue

- The teachers are the **center of attention** but are in the dark

- There is **lack of structure and patterns** from an observer perspective

- **Noise** is perceived as an issue by the students and the teachers (81% above 60 dB)

- Overheating



26.10. - Brightness & Behaviour, whole day

Brightness ——— Behaviour
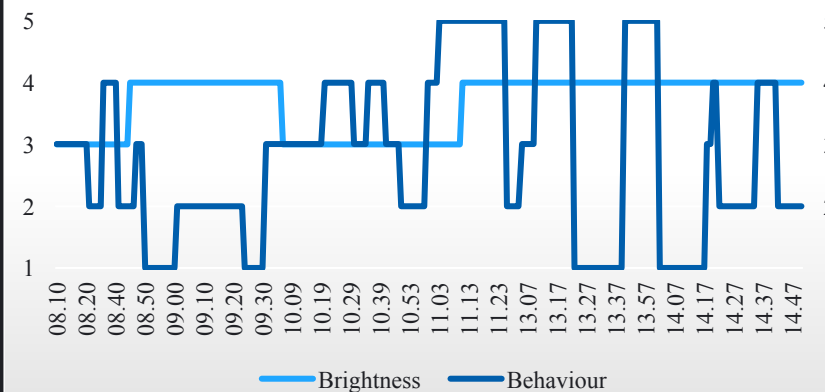
Rating scale:1 calm behavior and 5 noisy and disruptive behavior
Illustration and photo: Kathrine Schledermann

Investigate whether there is a correlation between **brightness and students behavior**, using sound as measurable parameter

Georgieva D., Schledermann K. M., Nielsen, S. M. L., Hansen, E.K.: **Designing User Centred Intelligent Classroom Lighting**, EAI International Conference on Design, Learning & Innovation, October 2017, Heraklion, Greece

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Photos: Sweco

# Post-occupancy evaluation

Partners: AAU, Albertslund Municipalicy, Zumtobel. Consultant: Sweco

A field study on the use of lighting 4 scenario as a tool to structure and support teaching and learning activities.

Research questions:
*1. Is there a relationship between the **teachers' usage of lighting and the classroom activities**? Moreover, what motivations are indicated for using the lighting scenarios?*
- *Analysis of qualitative data (interviews and observations)*
- *Comparison with quantitative data of lighting control data log*

*2. Is there a relationship between the **use of scenarios and the varying daylight availability** due to the season, time of day and the orientation of the classroom?*
- *Statistical analysis of quantitative data (lighting control data log) using simple and multiple linear regression models*

# Results of post-occupancy evaluation

**Relation to activities**

- The teachers used lighting scenarios as a **tool to both support activities and structure lessons through changes in lighting.**
- The manner in which the lighting scenarios were used i.e. which scenario for which activity, was **individual and teacher specific, based on their own pedagogical approaches.**

Illustration can not be shared her. The findings will be published as:

Schledermann K. M., Pihlajaniemi H., Sen S., Hansen, E. K.: Dynamic Lighting in Classrooms: A new interactive tool for teaching in EAI International Conference on Design, Learning & Innovation, October 2018, Braga, Portugal **[accepted]**

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# Results of post-occupancy evaluation

**Motivations**

Db / t.

Illustration can not be shared her. The findings will be published as:

**Five motivations for using lighting as a tool to support teaching** were identified:

- Supporting and structuring learning activities
- Communicating with lighting and involving students
- Affecting students' activity level and behavior
- Creating atmosphere
- Supporting visual task and visual comfort

Schledermann K. M., Pihlajaniemi H., Sen S., Hansen, E. K.: Dynamic Lighting in Classrooms: A new interactive tool for teaching in EAI International Conference on Design, Learning & Innovation, October 2018, Braga, Portugal **[accepted]**

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# Results of post-occupancy evaluation

**Relation to season and orientation**

- The statistical analysis of the use of scenarios in the case study classrooms during the period from September to December indicates that **there is a relation between the choice of scenario and the seasonal daylight availability**.

- There was found also **difference in the scenario use between east and west classrooms**.

Illustration can not be shared her. The findings will be published as:

Pihlajaniemi H., Sen, S., Schledermann K. M., Hansen, E.K.,: Choosing right light for learning – effect of season, time of day and class room orientation
**[work in progress]**

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# Dynamic lighting, a tool for teaching

The results show that lighting scenarios become an important element in setting the scene when teaching, and they support the lessons and create variability throughout the day.

The study:
- demonstrates how mixed methods can be applied in complex field study settings
- emphasize how qualitative methods can bring new perspectives to quantitative data.
- supports the need for doing research holistically

While designing future schools and classrooms, designers should integrate dynamic lighting scenarios in the design according to the users' needs.

Pihlajaniemi H., Sen, S., Schledermann K. M., Hansen, E.K.,: Choosing right light for learning – effect of season, time of day and class room orientation **[work in progress]**

Schledermann K. M., Pihlajanieni H., Sen S., Hansen, E. K.: Dynamic Lighting in Classrooms: A new interactive tool for teaching in **[accepted]**
EAI International Conference on Design, Learning & Innovation, October 2018, Braga, Portugal

Hansen, E.K., Nielsen, S. M. L., Georgieva D., Schledermann K. M, Mullins, M. F.: **Dynamic Lighting in Classrooms, A mixed method approach combining light, behavior and noise**, Digital Poster presentation, PLDC 2017, Professional Lighting Designers Convention, November 2017, Paris

Hansen, E. K., Nielsen, S. M. L., Georgieva D., Schledermann K. M.: **The Impact of Dynamic Lighting in Classrooms. A Review on Methods**, EAI International Conference on Design, Learning & Innovation, October 2017, Heraklion, Greece

Georgieva D., Schledermann K. M., Nielsen, S. M. L., Hansen, E.K.: **Designing User Centred Intelligent Classroom Lighting**, EAI International Conference on Design, Learning & Innovation, October 2017, Heraklion, Greece

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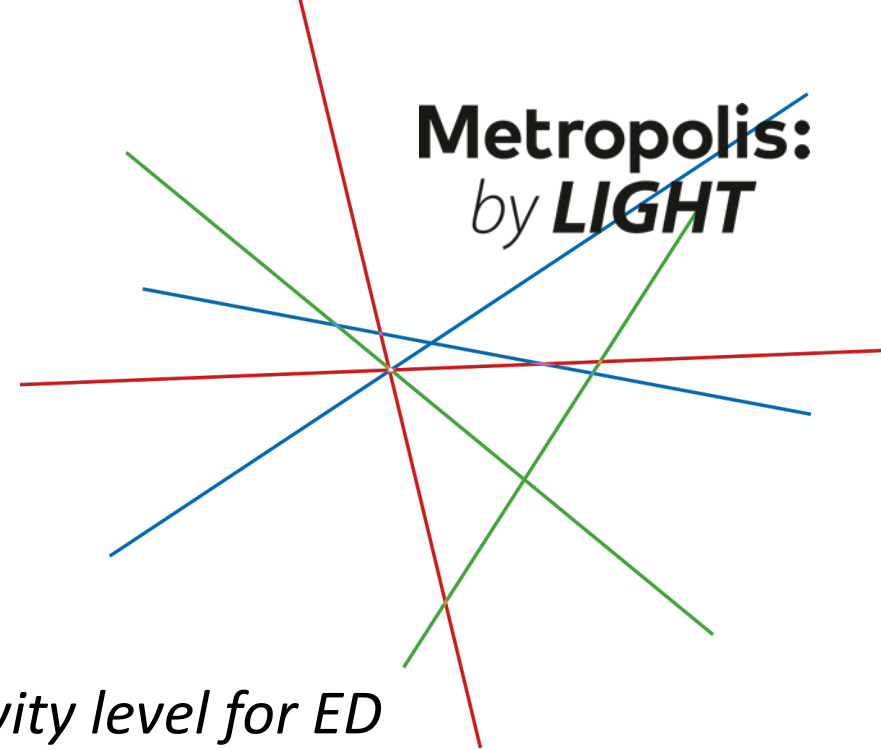
**Key takeaways case 1 and 2 -**

- *Dynamic artificial lighting might change the activity level for ED pations*

- *Dynamic Light can be used as a tool for teaching, new design criteria*

- *Mixed methods are useful for investigating the impact of dynamic lighting*