Beyond our eyes: the non-visual impact of light

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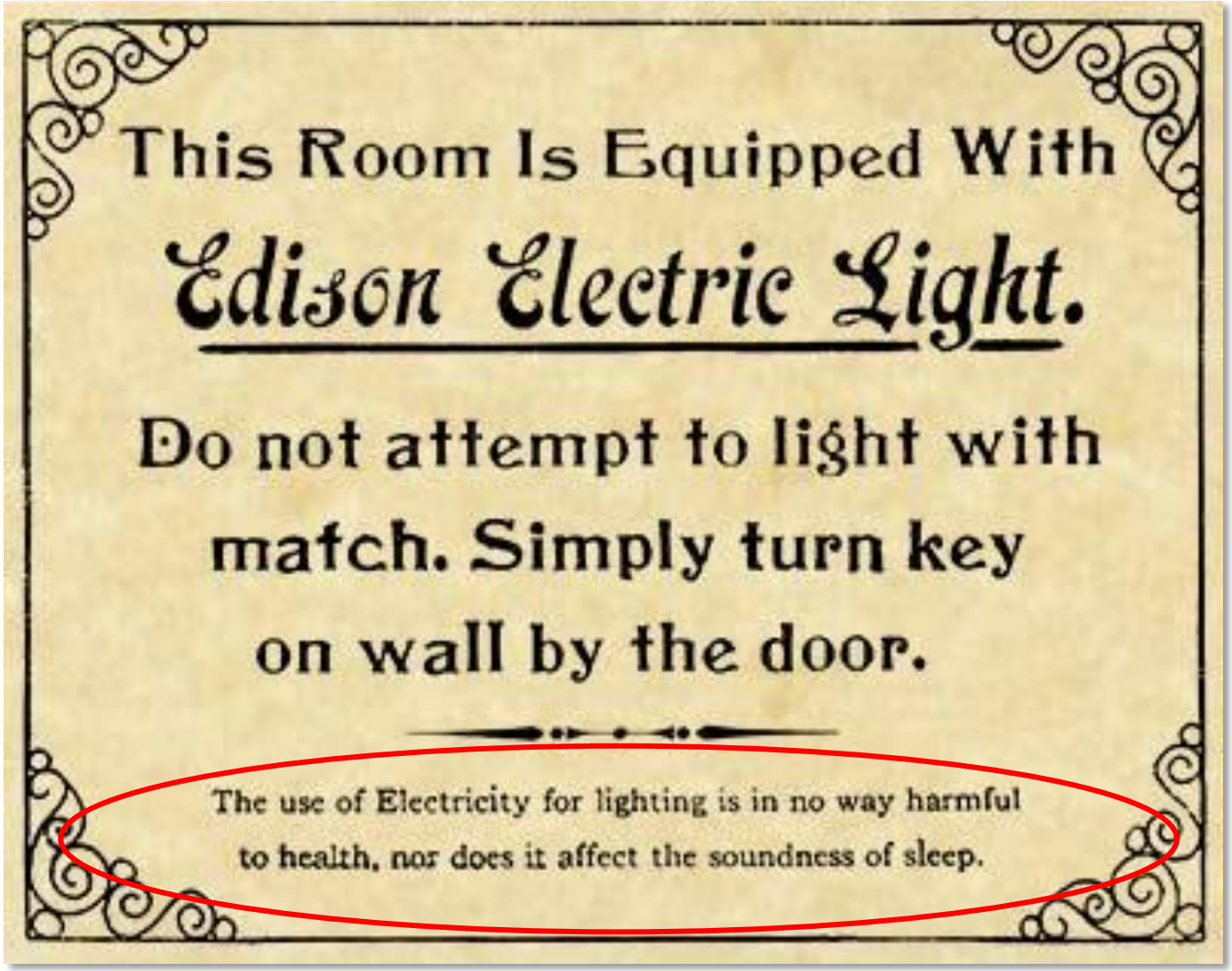
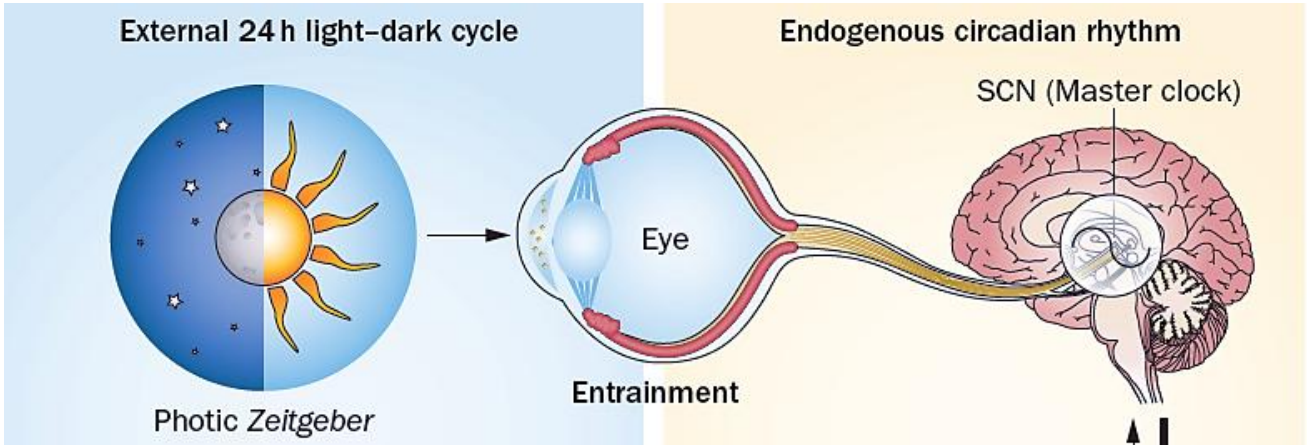
Workshop Intelligent Efficient Human Centric Lighting
Muttenz/Basel
12.. December 2016

Thomas Edison was maybe wrong !



Light is the most important Zeitgeber !

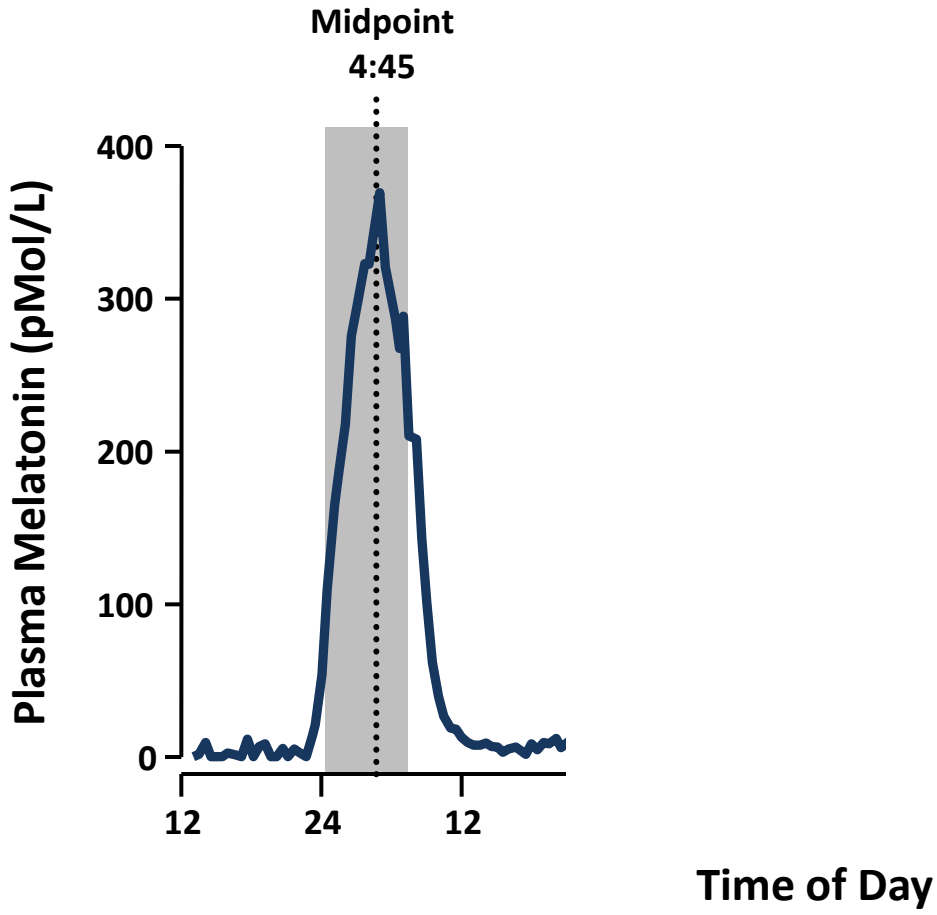


Buttgereit, Smolen, Coogan, Cajochen, Nat Rev Rheumatol, 2015

Light and human circadian rhythms

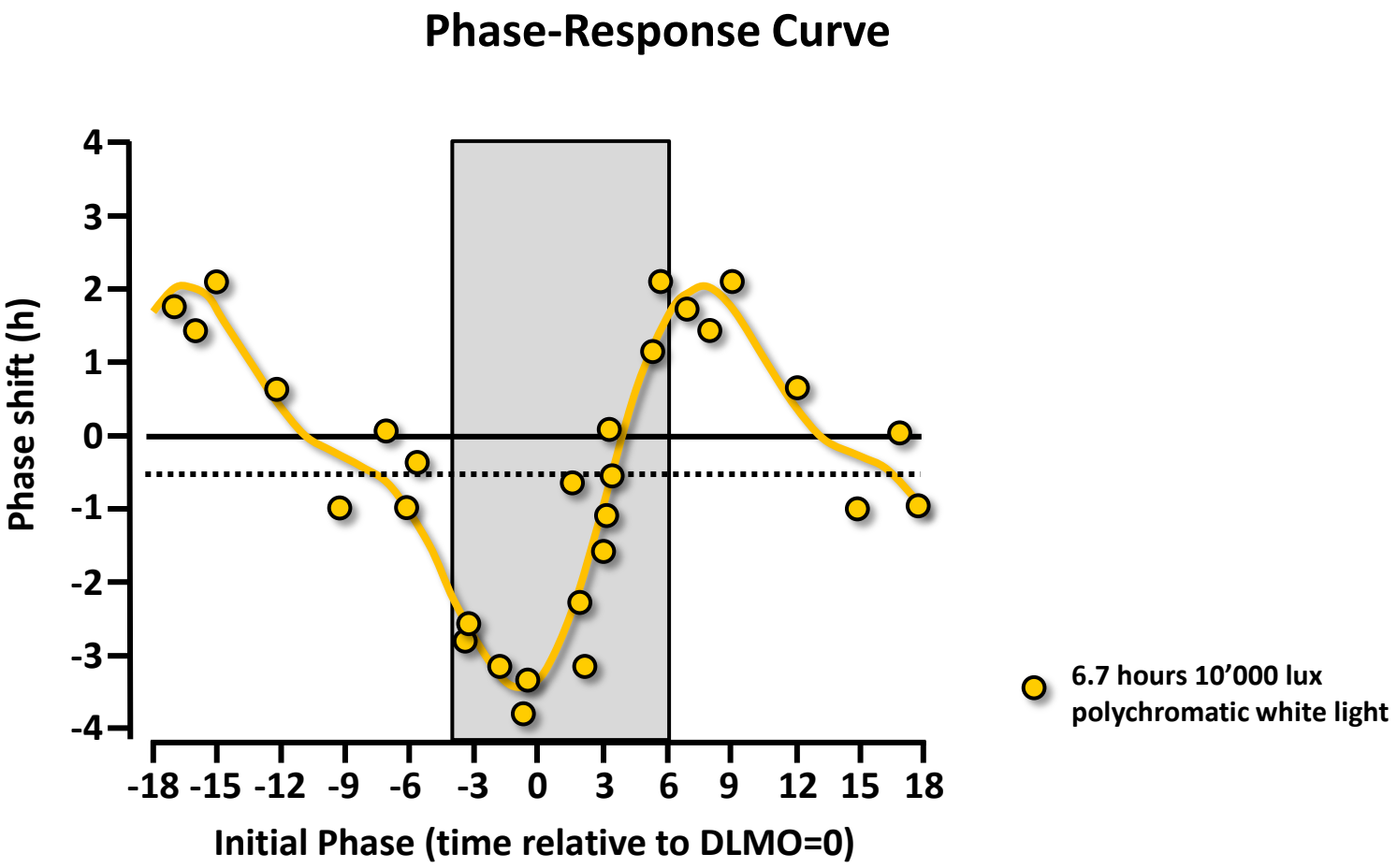
Melatonin as the best circadian marker in humans

Induction of a Phase Delay in the Human Circadian Melatonin Rhythm by Light (10’000 lux for 6.5 h)



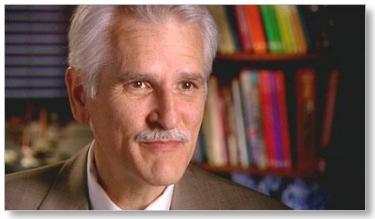
Khalsa et al., J Physiol (London) 2003

Light and circadian phase



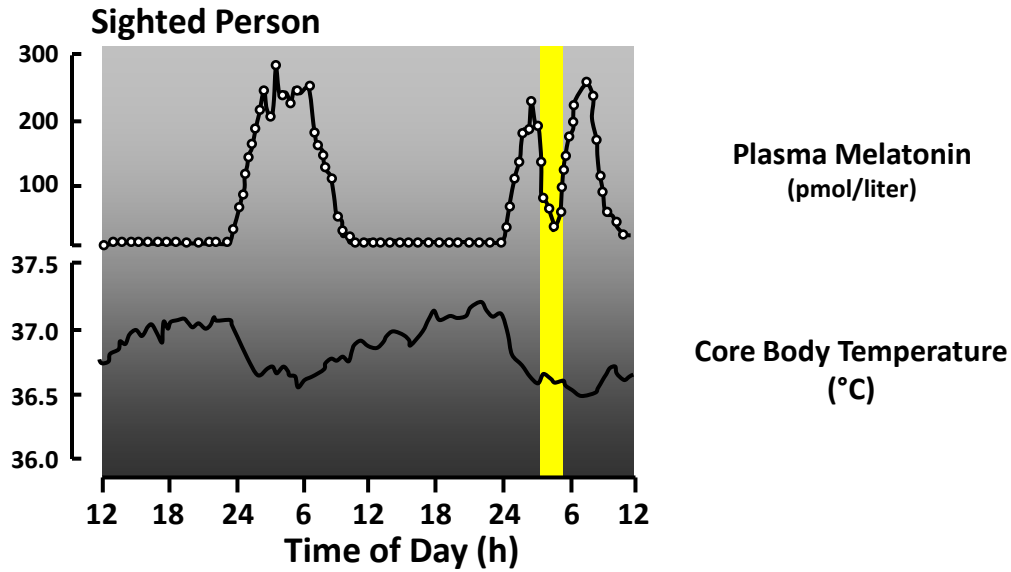
Khalsa, et al., J Physiol (London) 2003

«Light impacts on our circadian rhythms more powerfully than any drug»



Charles Czeisler «Casting light on sleep deficiency»
Nature, 2013

Suppression of melatonin in a totally blind person with bright light



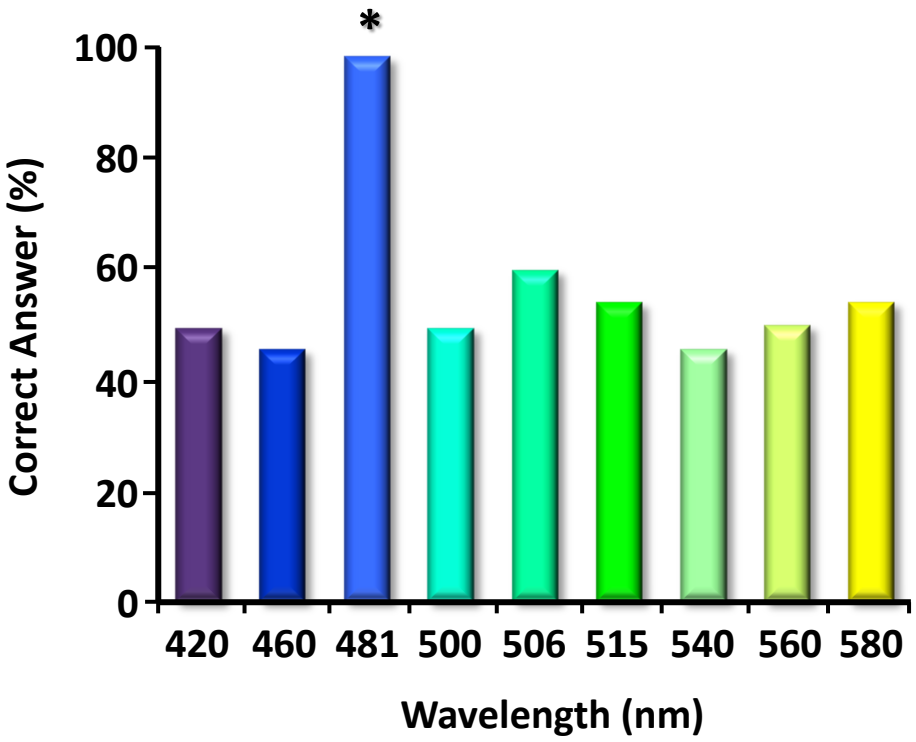
Czeisler et al., New Engl Med 1995

Light is more than vision

non-visual / non-image forming light effects

Light can be «seen» without conscious vision

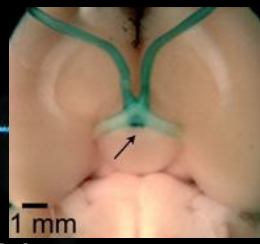
«Forced choice» test in a totally blind person



Nach Zaidi et al., Curr Biol, 2007

Non-classical Photoreceptor

intrinsic photosensitive retinal ganglion cells (iPRGs, Melanopsin)

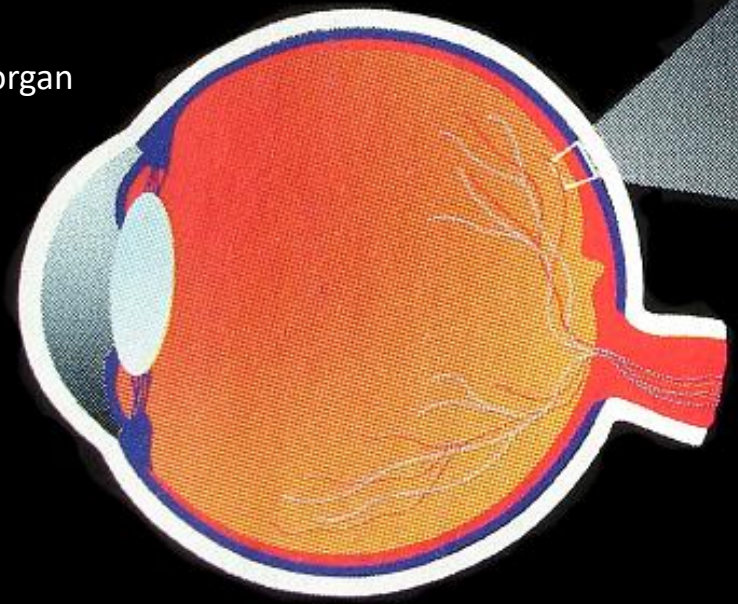


SCN

(circadian Pacemaker)

Eye

A dual sensory organ



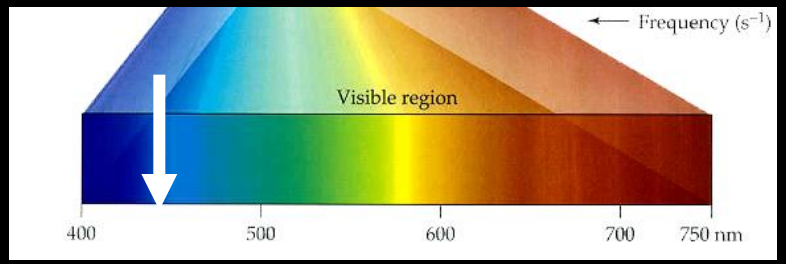
Retina

Rods

Cones

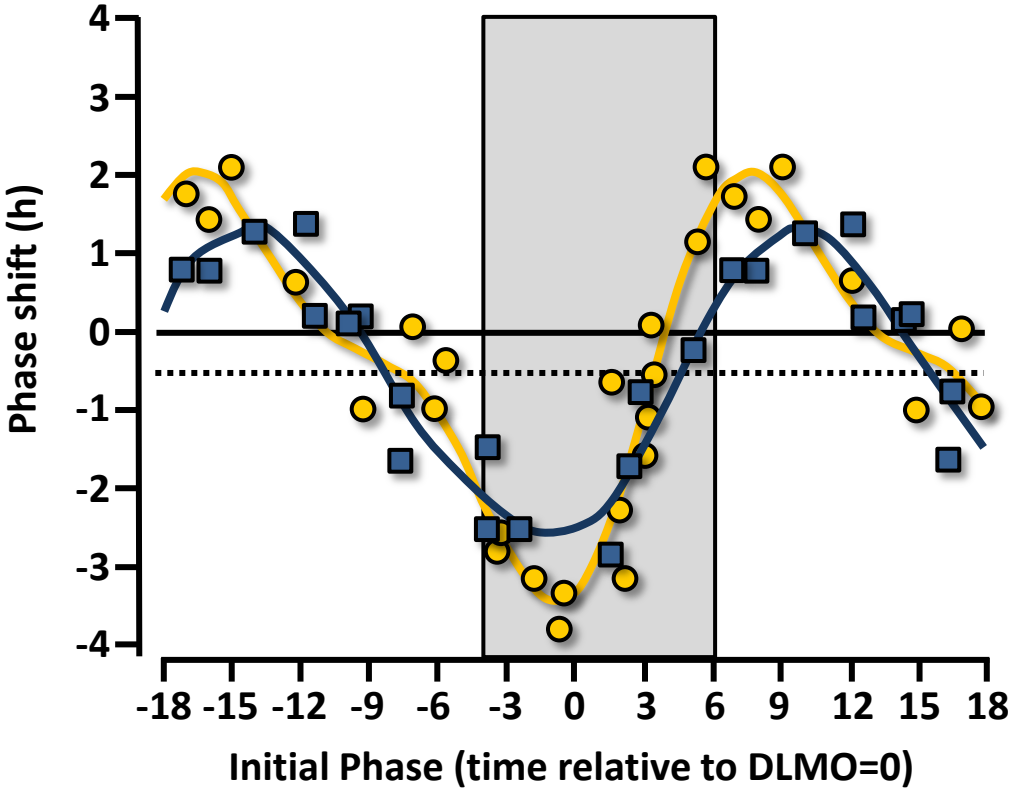
Hattar et al. Science, 2002

Berson et al. Science, 2002



Light and circadian phase

Phase-Response Curve



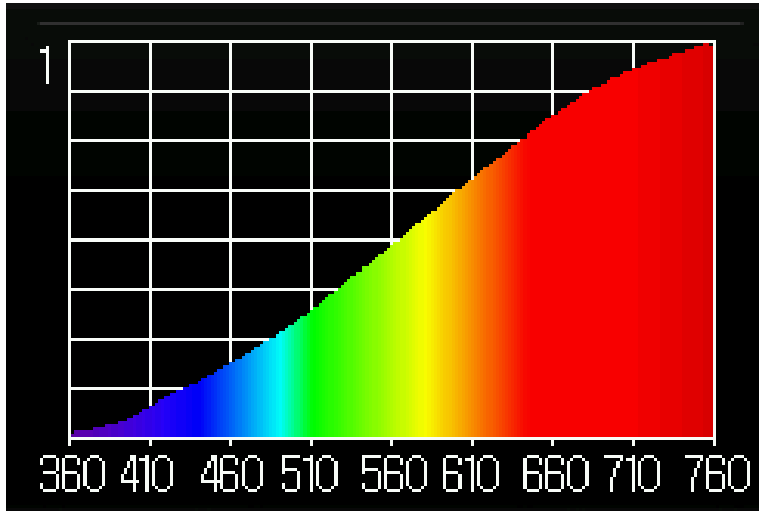
75 % of the resetting response

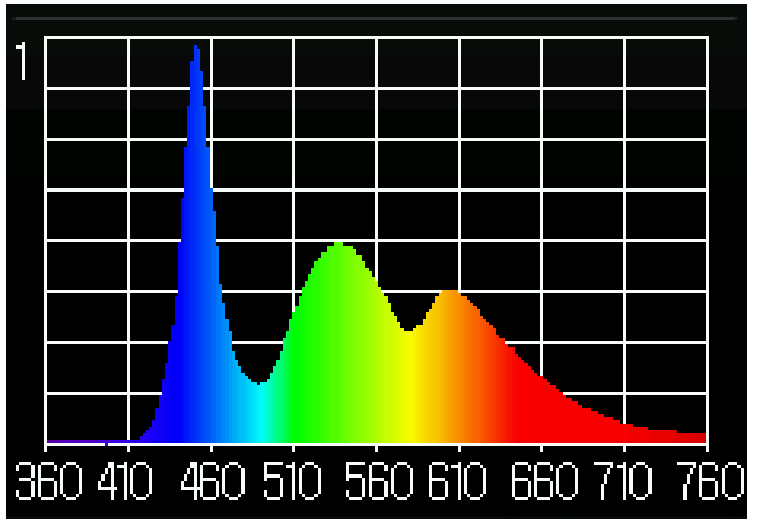
- 6.7 hours 10’000 lux polychromatic white light
- 6.5 hours blue light (480 nm) 11.8 μWcm^{-2}, 11.2 lux)

Khalsa, et al., J Physiol (London) 2003

Rüger, et al., J Physiol (London) 2013

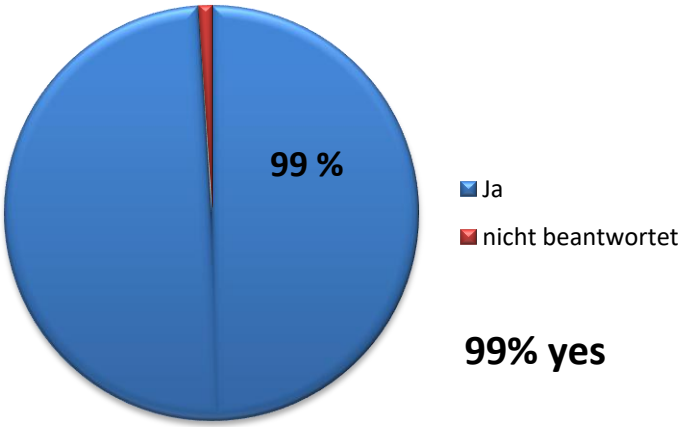
Why is this relevant: Light bulb versus LED





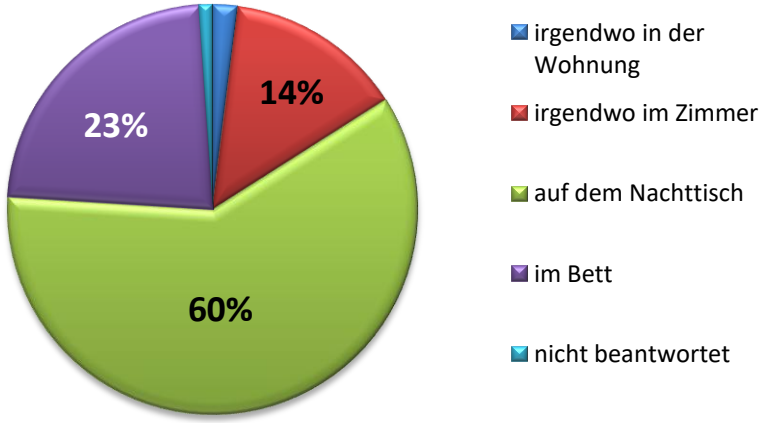
Smartphone use in adolescents (14-20 years)

Use of smartphones
1 hour prior bedtime



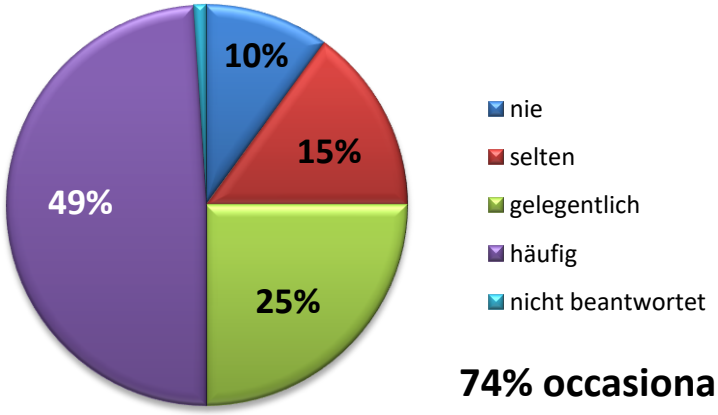
99% yes

Where do you keep your smartphone during night?



97% in bedroom

How often do you use your smartphone after «Lights off»



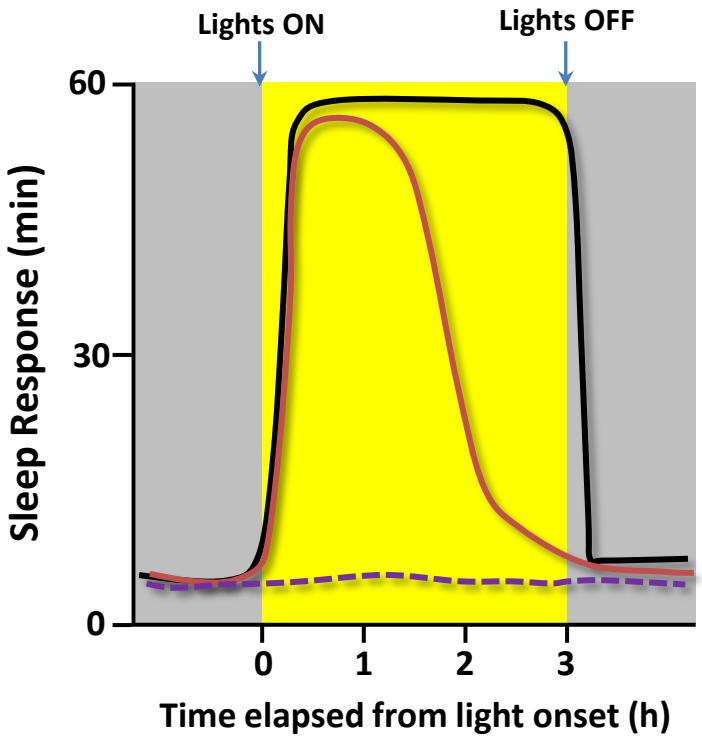
74% occasionally-often

Strube et al. Somnologie, 2016

Light has also «non-circadian» acute effects

- **Light suppresses the soporific hormone melatonin within minutes (Gronfier et al., 2002)**
- **Light inhibits sleep-promoting GABA neurons in the ventrolateral preoptic area in the hypothalamus (VLPO, Tsai et al., 2009)**
- **Light activates wake-promoting orexin neurons in the lateral hypothalamus (McGregor et al., 2011)**

Acute sleep induction by light in nocturnal mice



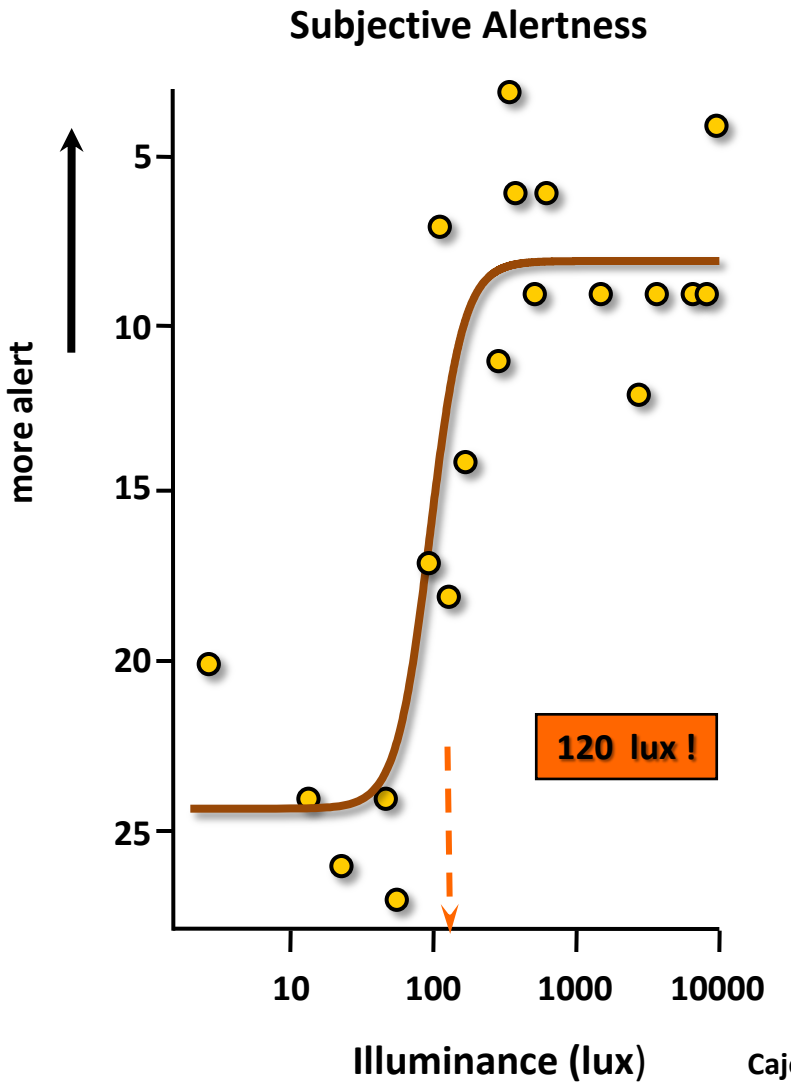
Wildtype

Melanopsin knockout

Melanopsin aDTA

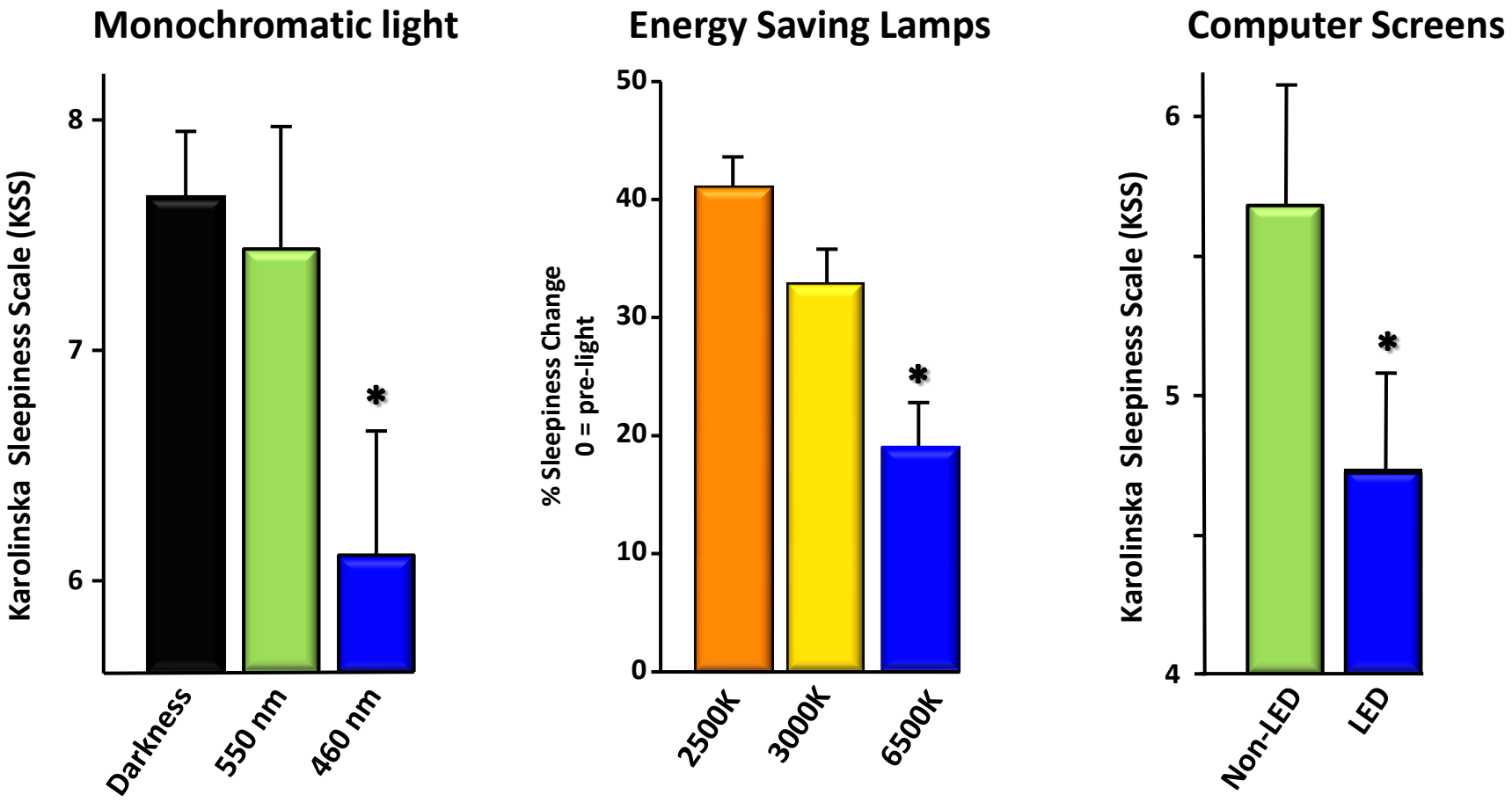
According to Muindi et al., Front Syst Neurosci, 2014

Acute alerting effects of light in diurnal humans



Cajochen et al., Beh Brain Res. 2000

The human alerting response to light is blue-shifted

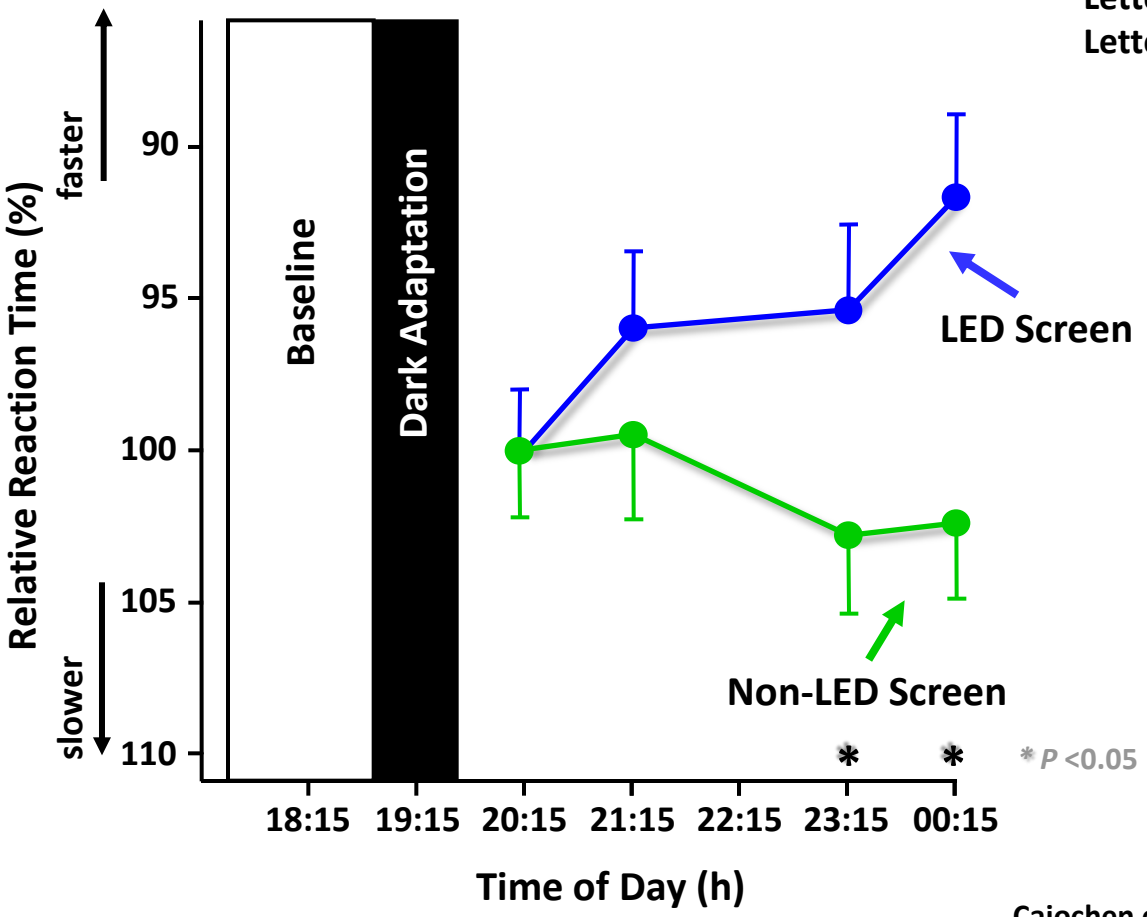


Cajochen et al., Sleepiness and human impact assessment
Book chapter, Springer, 2014

Sustained Attention and Response Control

(Go/noGo Task)

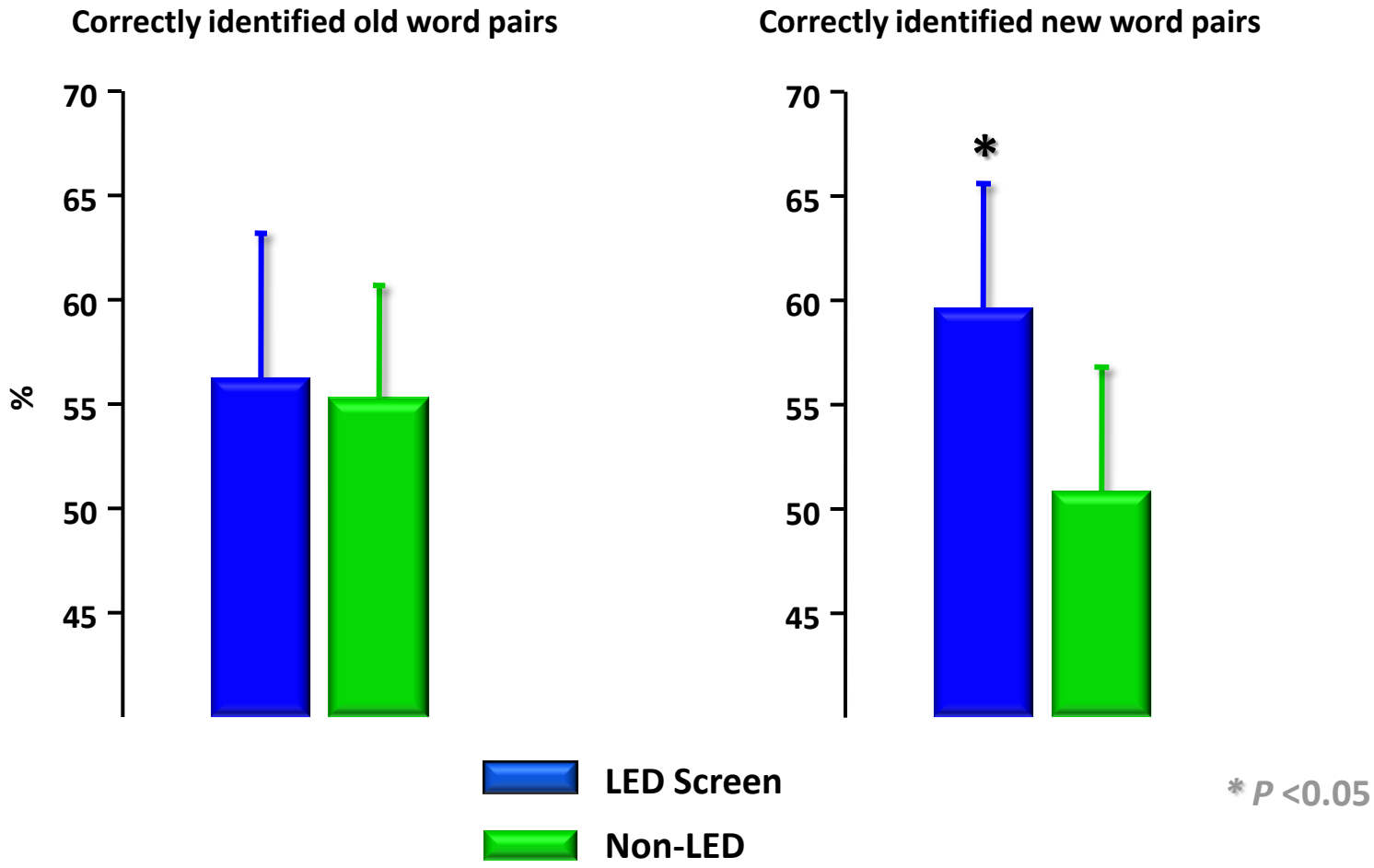
Letter „W“: go
Letter „M“ : no-go



Monitor: $F_{1,11}$=12.2; p<0.04
Time of day: $F_{11,44}$=7.8; p<0.02
Monitor x Time: $F_{12,132}$=3.0; p=0.041

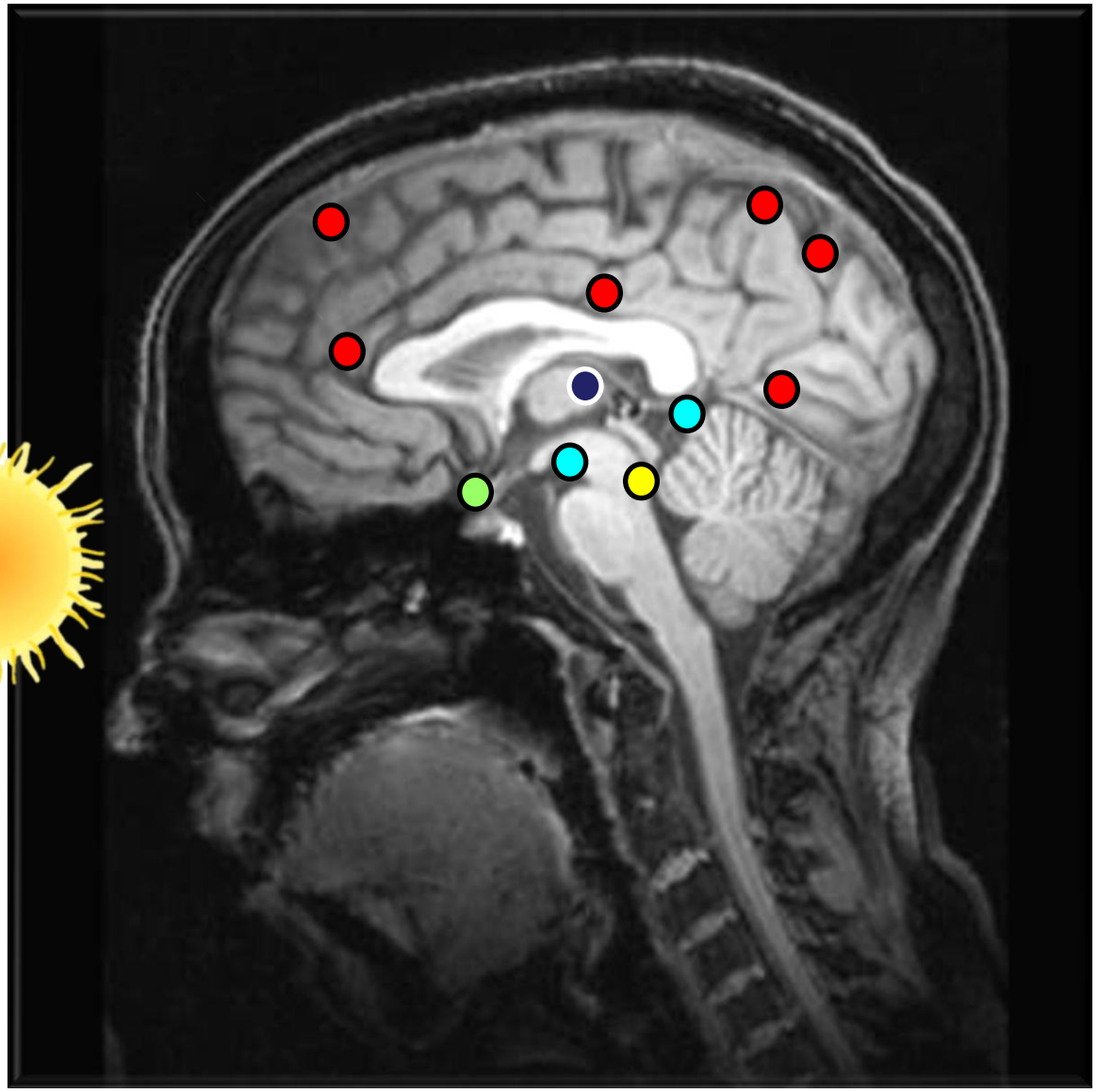
Cajochen et al., J Appl Physiol. 2011

Declarative Learning
(Word pairs)



Cajochen et al., J Appl Physiol. 2011

Light is not just for vision



- Cortex
- Thalamus
- Hypothalamus
- Brainstem
  - Locus coeruleus
- Limbic system
  - Amygdala
  - Hippocampus

Modified from Vandewalle et al. Trends Cogn Sci, 2009

Light has many non-visual biological effects in humans (only peer reviewed data)

- Synchronization of circadian rhythms
- Suppression of the «darkness hormone» melatonin
- Alerting and enhancing of cognitive performance
- Regulation of pupil size
- Enhancing mood (antidepressant)
- Enhancing physical performance in top athletes
- Light color modulates mental effort

Conclusion

- **Light rules our body via its non-visual effects**
- **Blue wavelengths -- which are beneficial during daylight hours because they boost attention, reaction times, mood, and physical performance -- are most disruptive at night**
- **The proliferation of electronics with screens, as well as energy-efficient lighting, is increasing our exposure to blue wavelengths, especially after sundown**

Non-visual lighting solutions should be:

Dynamic

- Intensity and duration
- Spectral composition
- According to time of day

Individual

- Age
- Gender
- Chronotype (early *vs*.late people)

Wanted

Intelligent human centric lighting to adapt our illuminated surroundings such that we do not jeopardize quality of life and health but positively influence our sleep, circadian physiology, cognition and well-being

Acknowledgements

Centre for Chronobiology

www.chronobiology.ch

- Antoine Viola, PhD
- Christina Schmidt, PhD
- Mirjam Münch, PhD
- Sarah Chellappa, PhD
- Vivien Bromundt, PhD
- Jakub Späti, PhD
- Sylvia Frey, PhD
- Virginie Gabel
- Micheline Maire
- Carolin Reichert
- Stephanie van der Lely

PHILIPS

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Swiss Federal Office for Public Health

FNSNF
Swiss National Science Foundation

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