



# Beyond our eyes: the non-visual impact of light

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Centre for Chronobiology

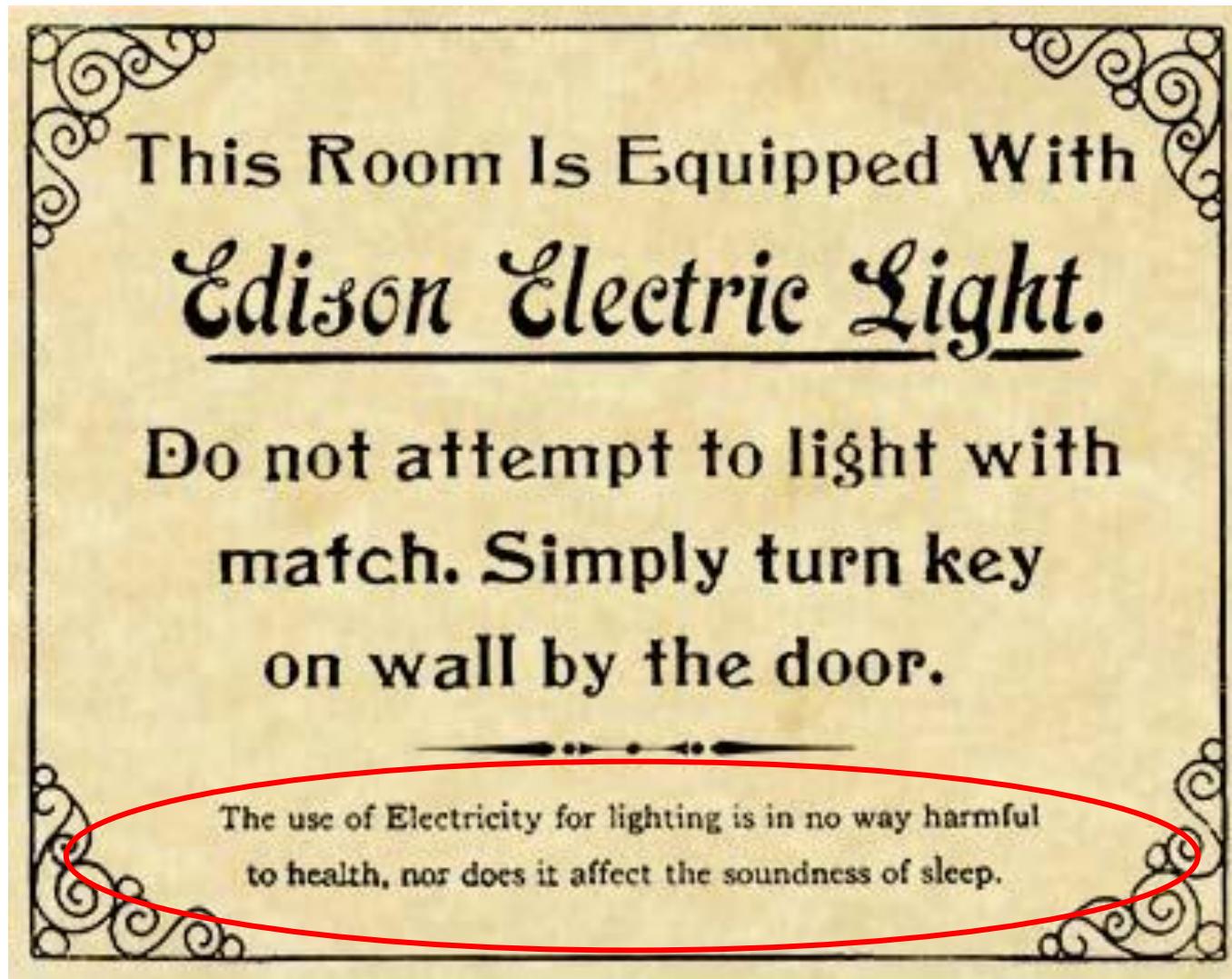
Psychiatric Hospital of the University of Basel, Switzerland



SLL-erate final event  
October 13, 2016, Brussels

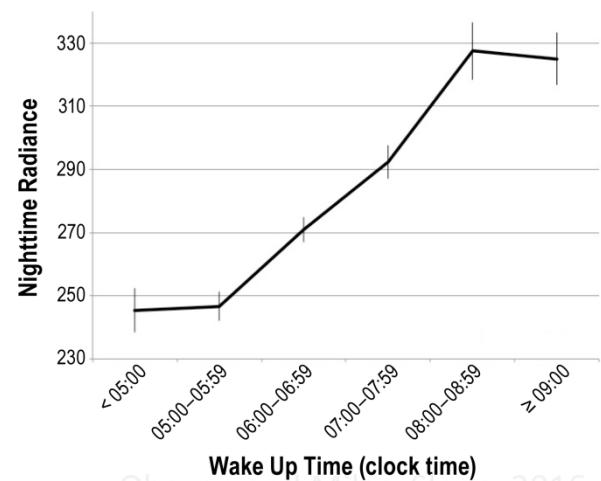
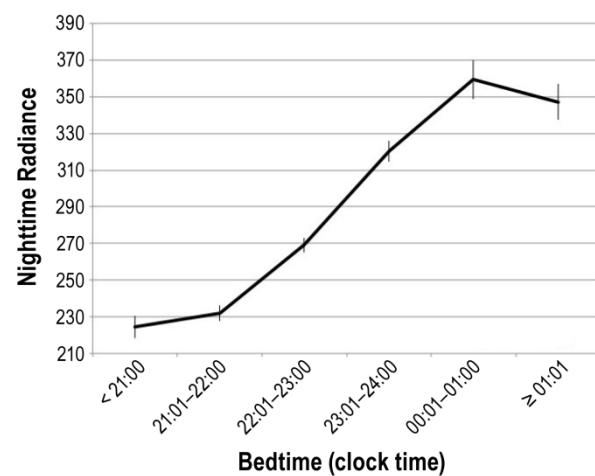
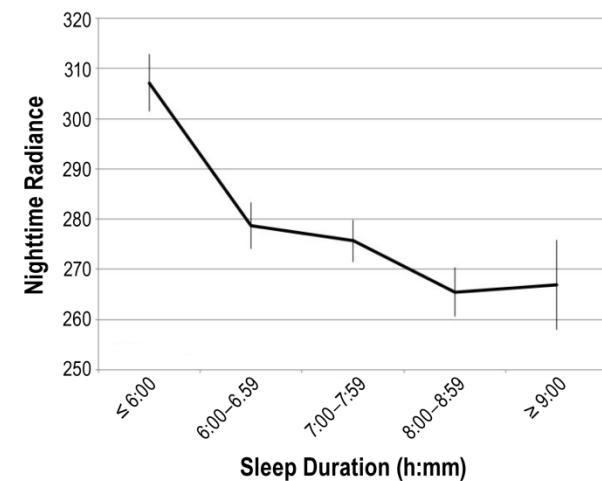


# Thomas Edison was maybe wrong !

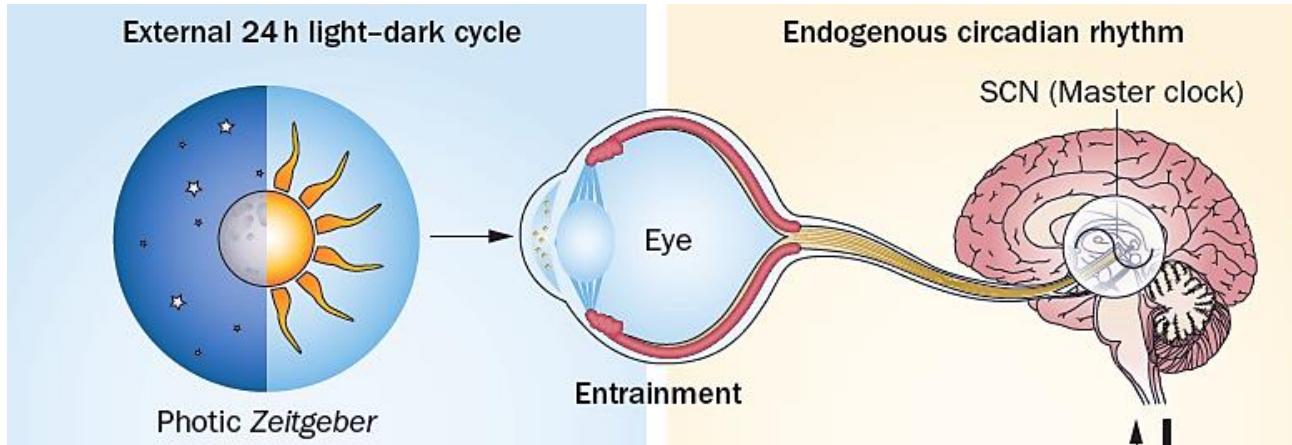


# Artificial outdoor nighttime lights associate with altered sleep behavior in the American general population (n=19'136)

Distribution of nighttime radiance calibrated lights



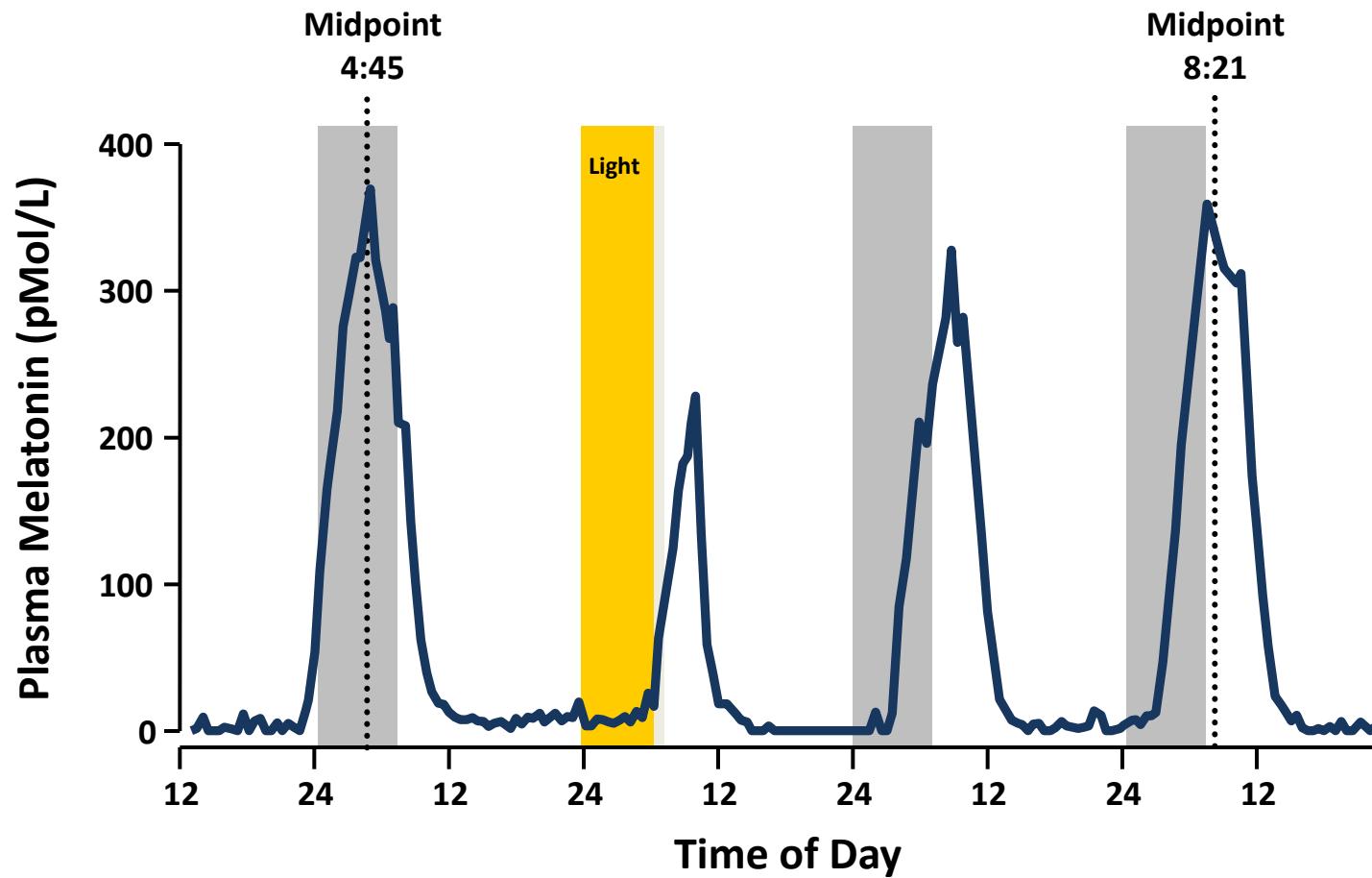
# Light is the most important Zeitgeber !



# 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)**

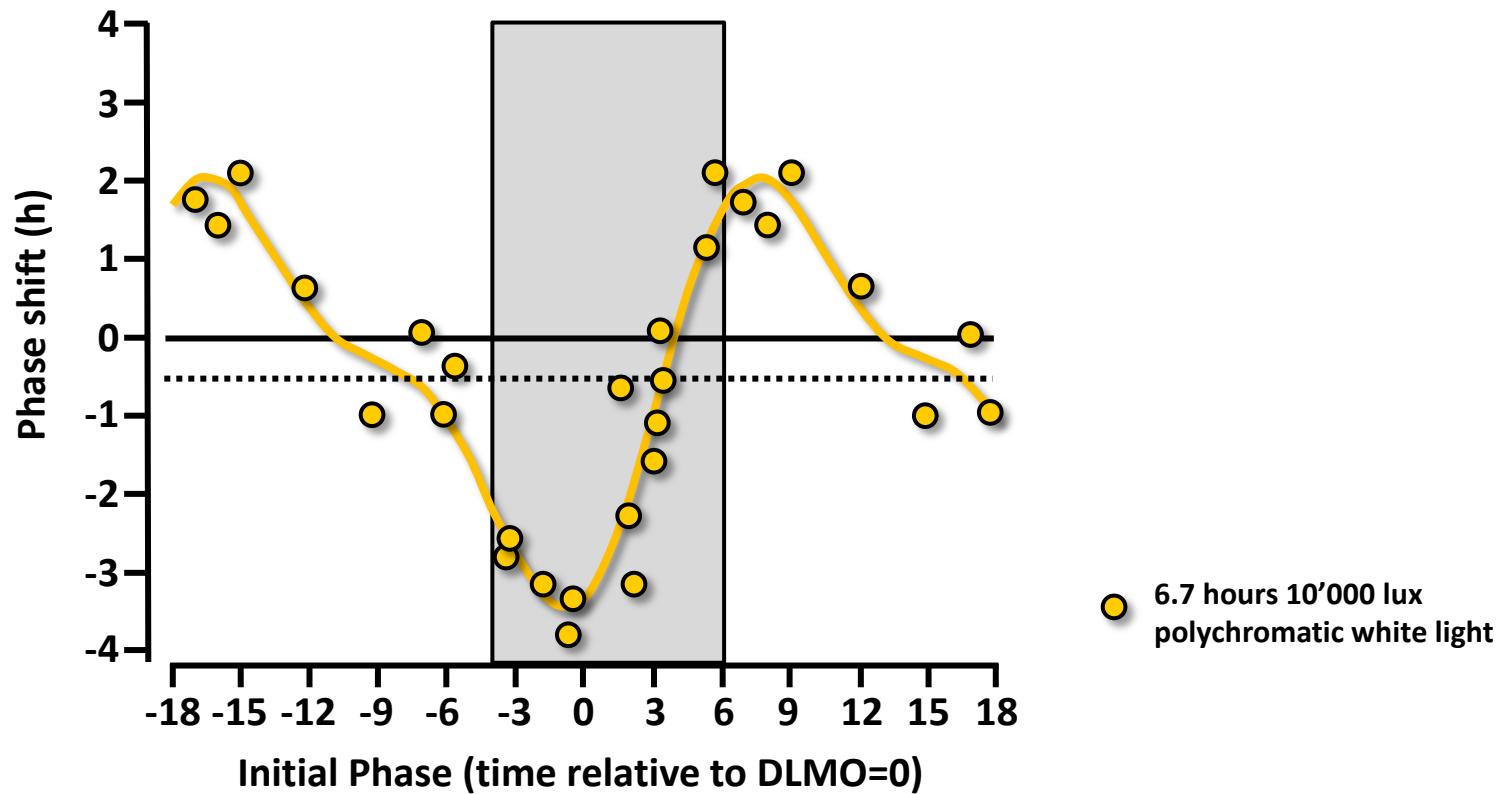


## Sleep period

Khalsa et al., J Physiol (London) 2003

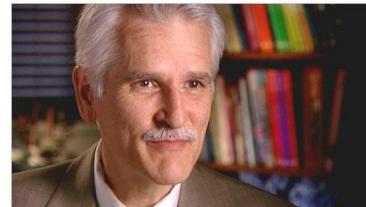
# Light and circadian phase

Phase-Response Curve



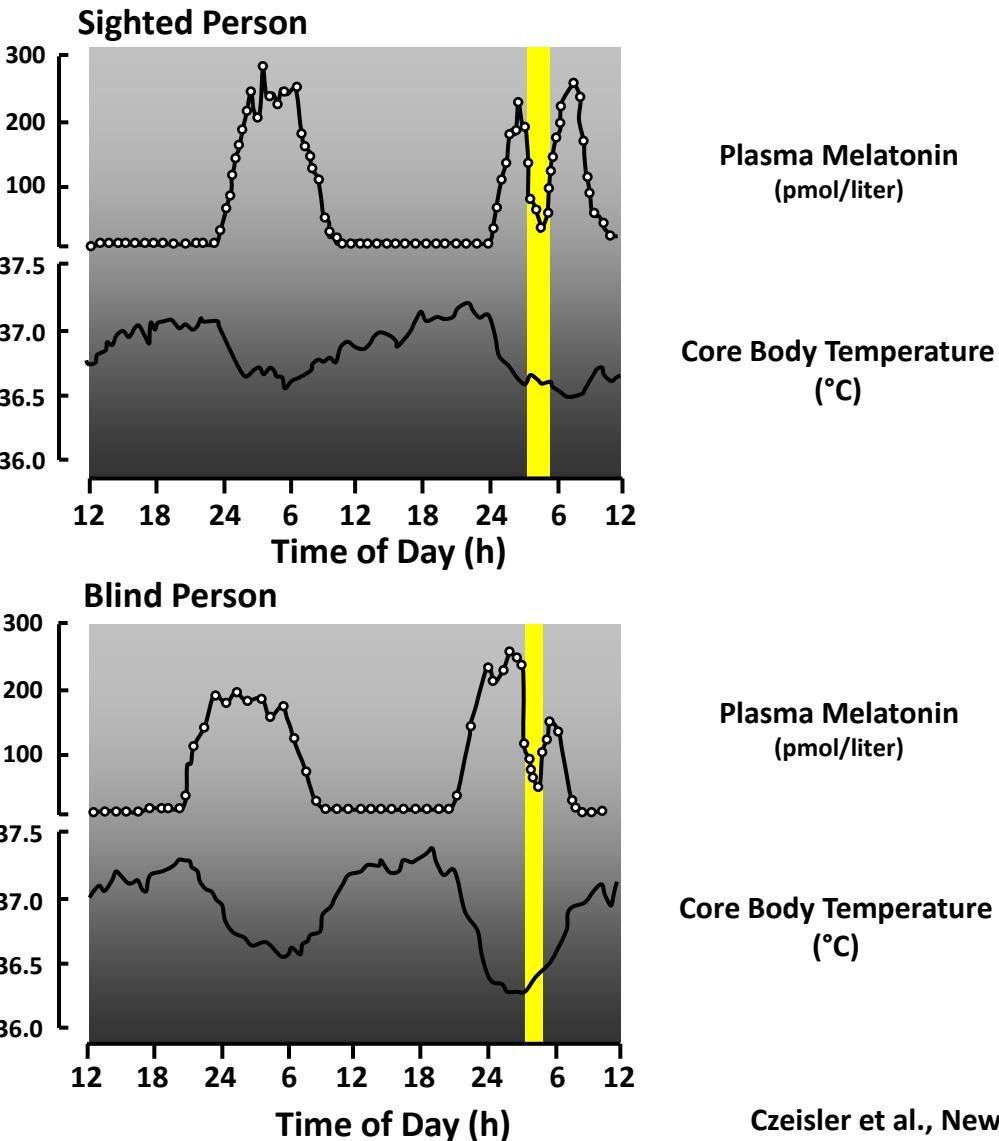
● 6.7 hours 10'000 lux  
polychromatic white light

«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

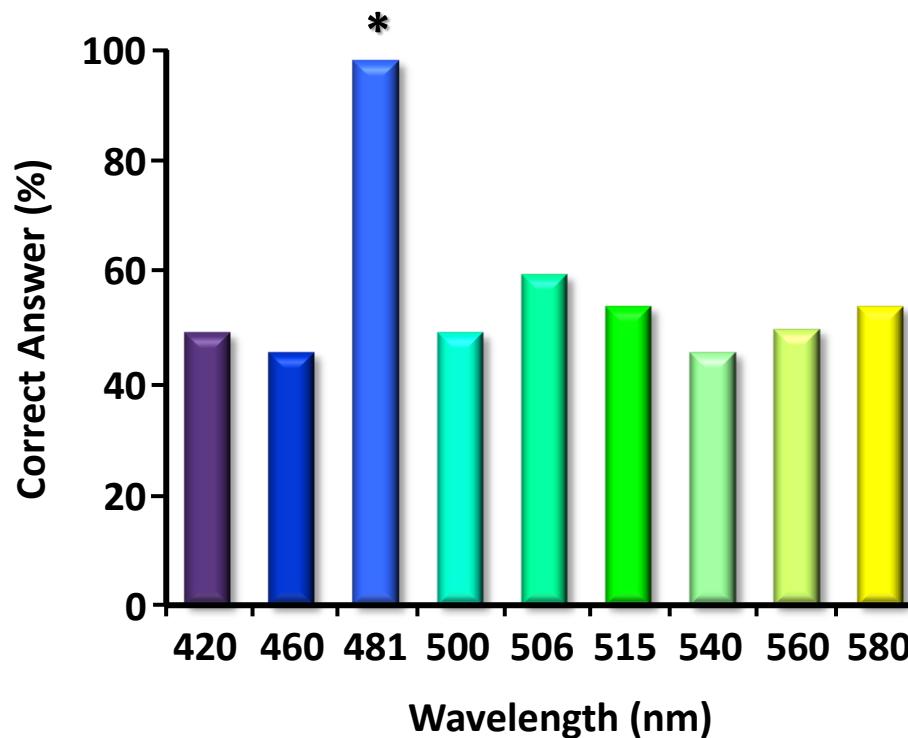


# **Light is more than vision**

**non-visual / non-image forming light effects**

**Light can be «seen» without conscious vision**

**«Forced choice» test in a totally blind person**



# Eye

A dual sensory organ



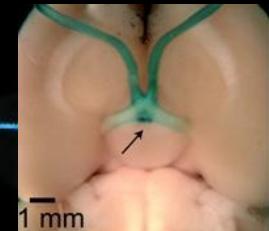
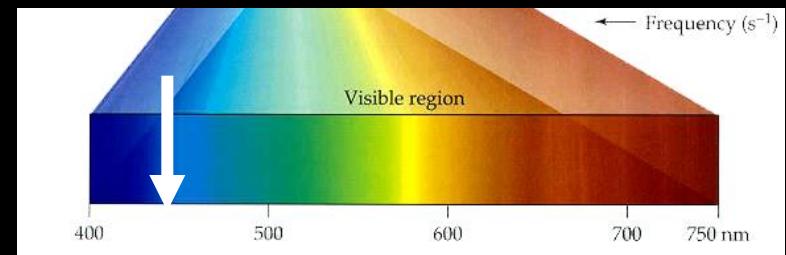
## Non-classical Photoreceptor

intrinsic photosensitive retinal ganglion  
cells (iPRGs, Melanopsin)

Retina

Rods  
Cones

Hattar et al. Science, 2002  
Berson et al. Science, 2002

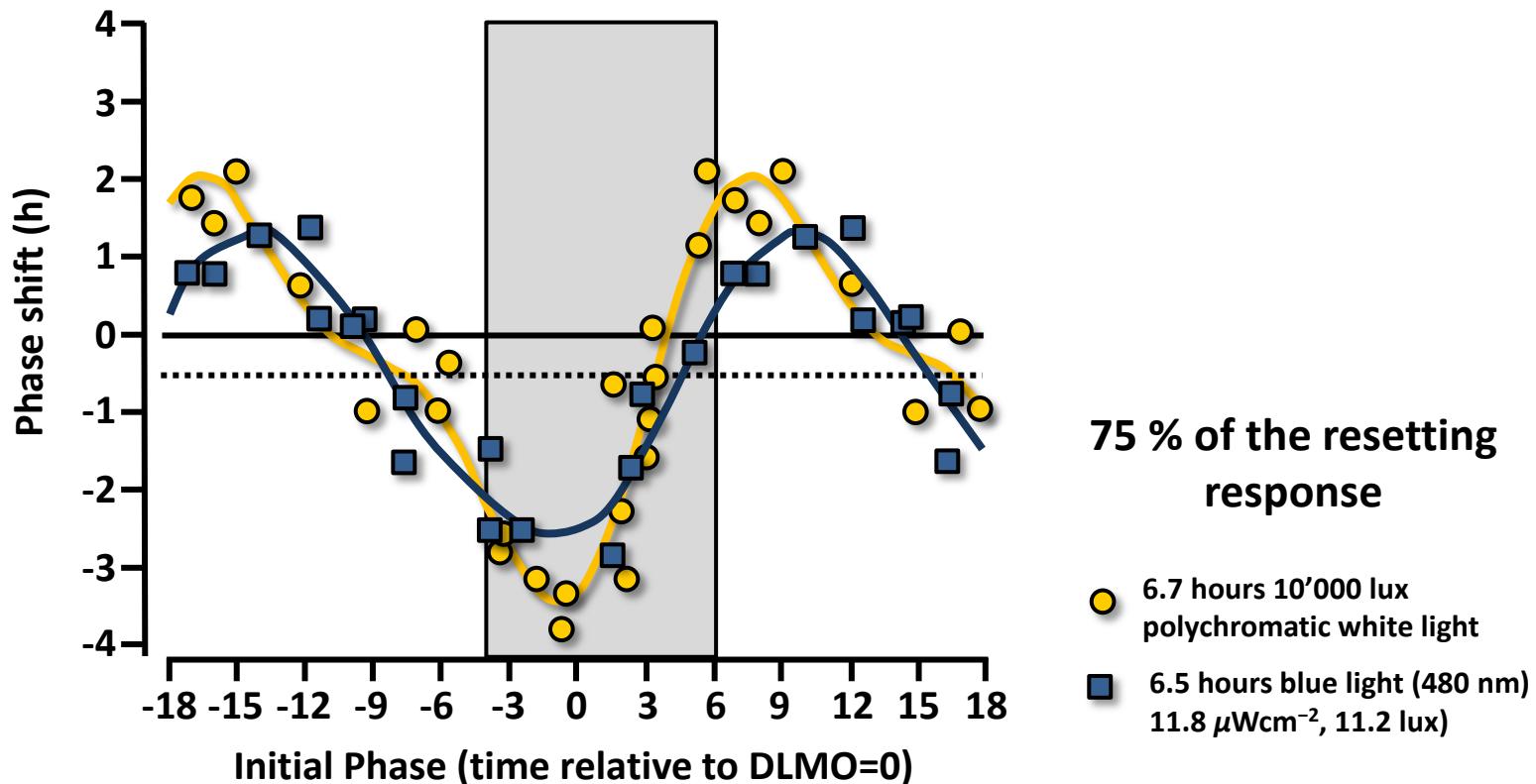


SCN

(circadian Pacemaker)

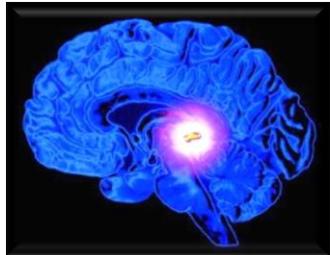
# Light and circadian phase

## Phase-Response Curve



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

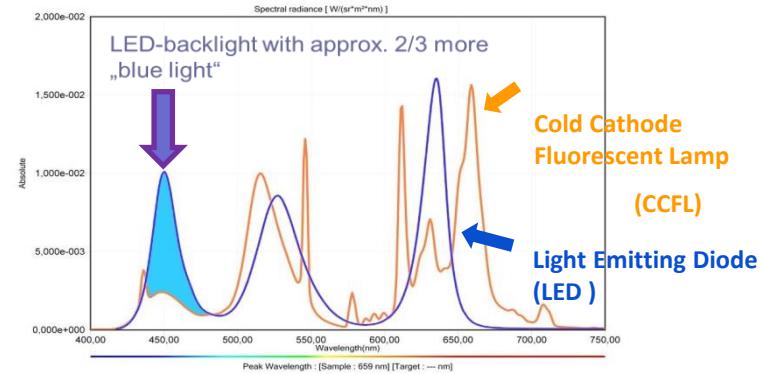
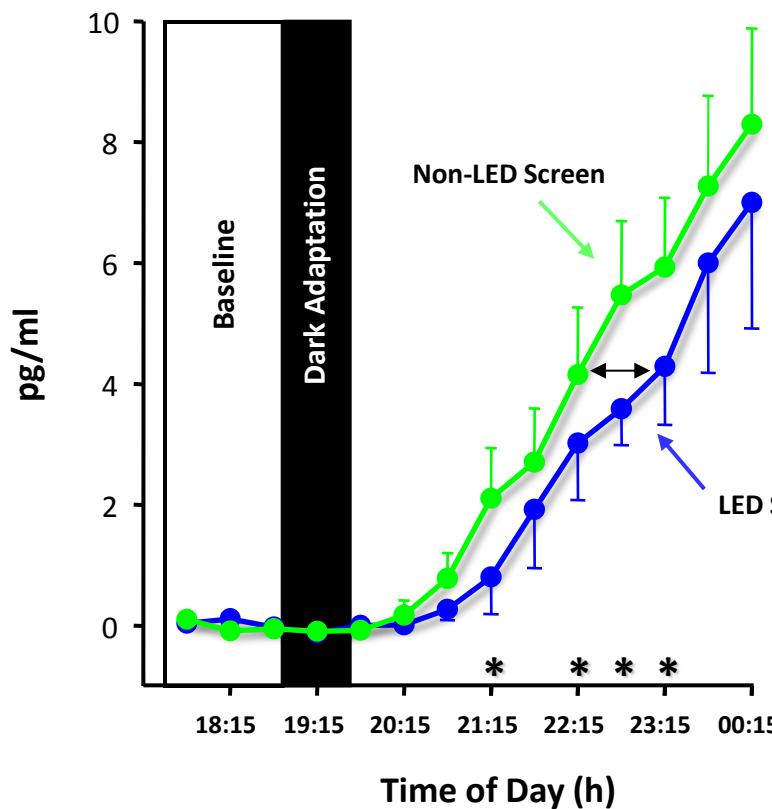
Rüger, et al., J Physiol (London) 2013



## Effects of LED-backlit computer screens on salivary melatonin, alertness and cognitive performance in the evening



### Salivary Melatonin

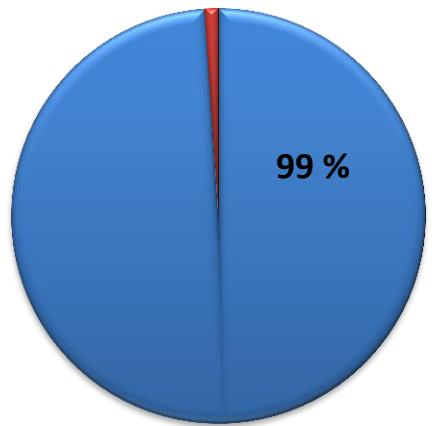


$\Delta\phi \sim 60 \text{ min}$

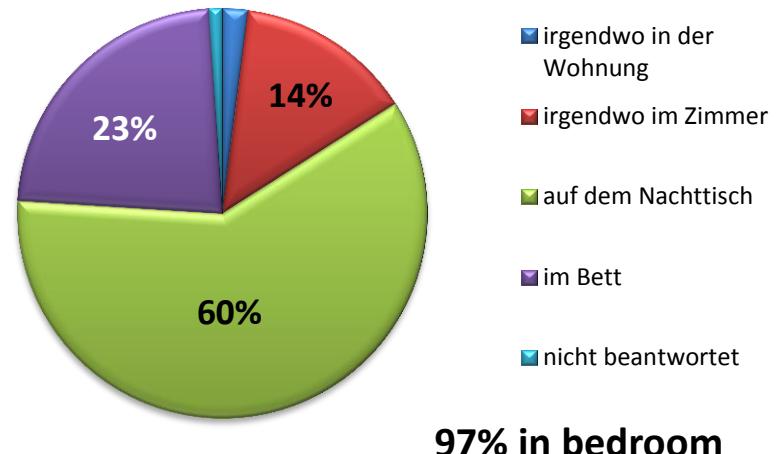
Cajochen et al., J Appl Physiol. 2011

# Smartphone use in adolescents (14-20 years)

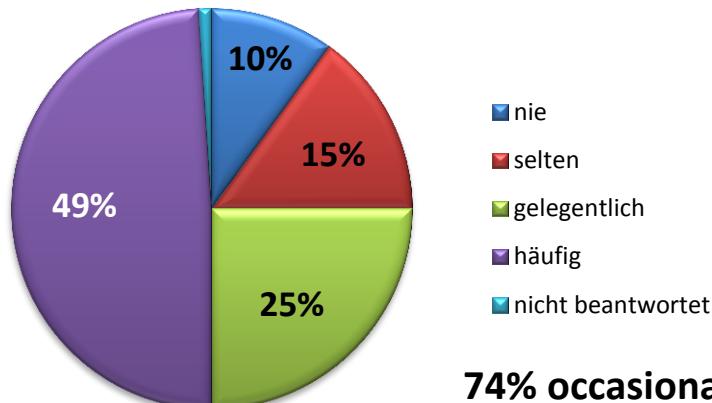
Use of smartphones  
1 hour prior bedtime



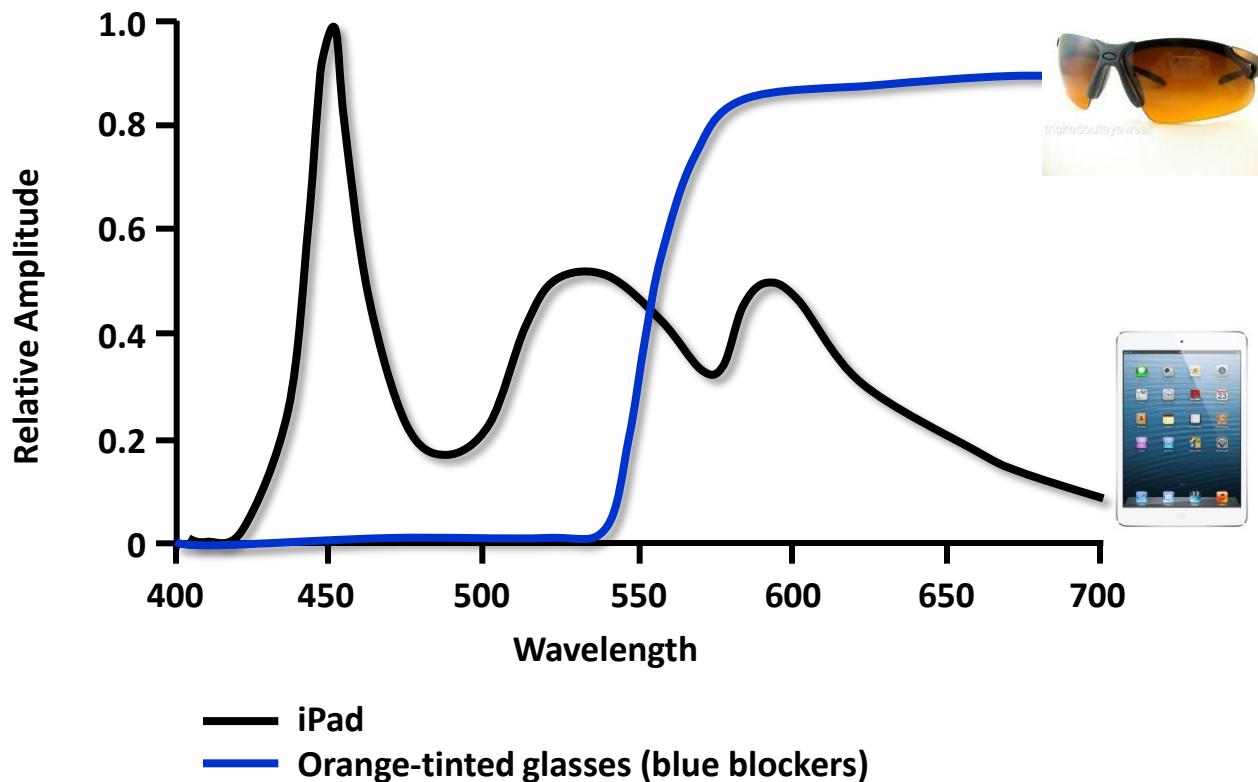
Where do you keep your smartphone during night?



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

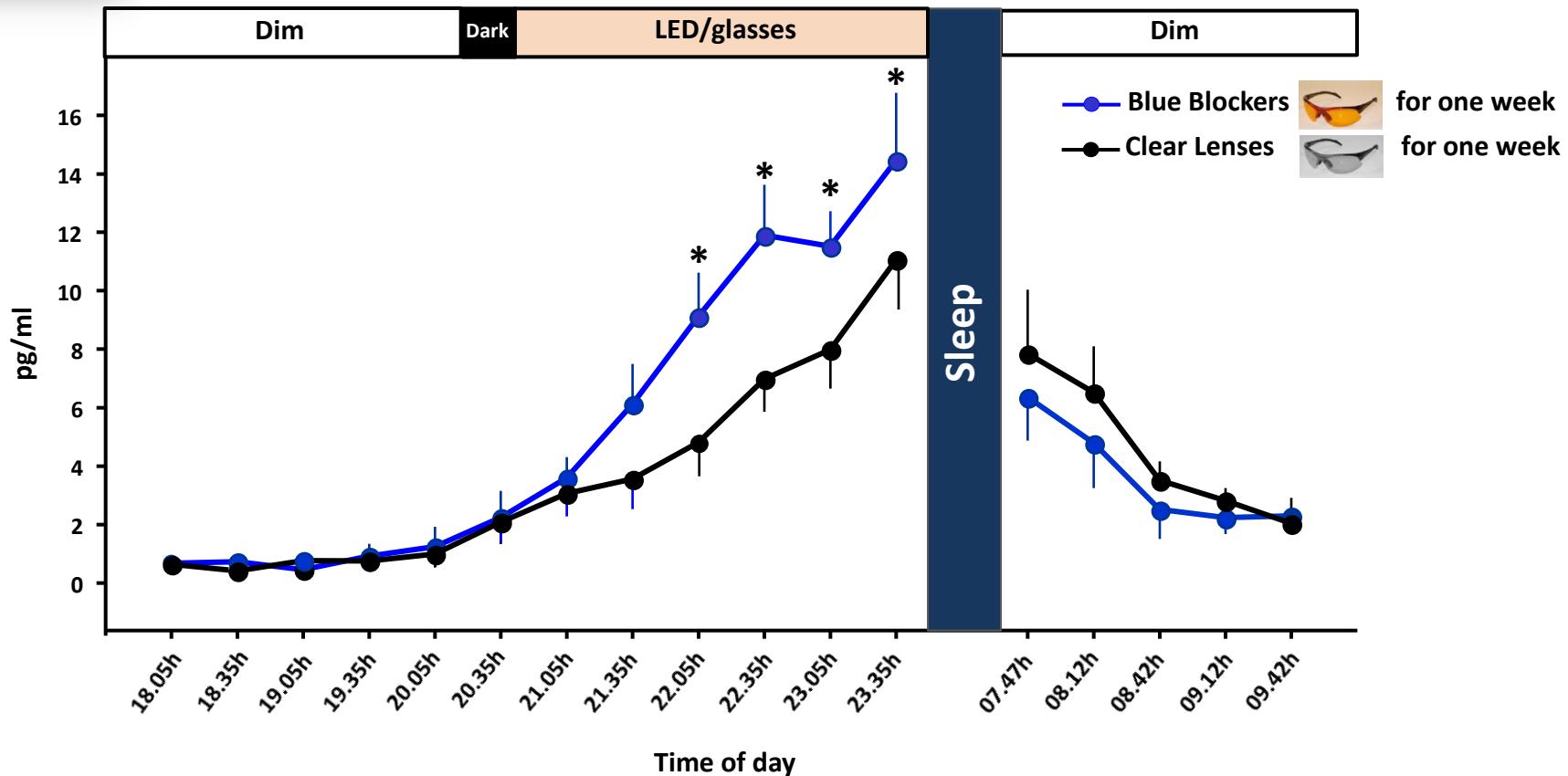


# “Ipad” versus “Blue-blockers” Transmission Spectra





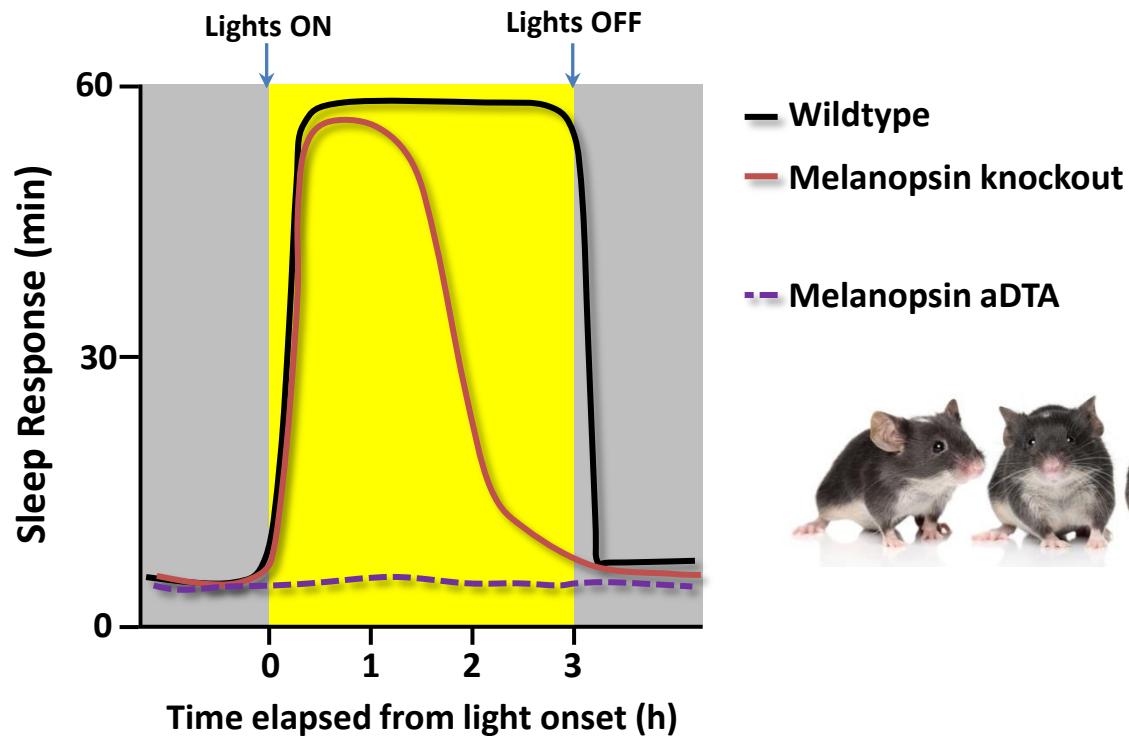
## Evening Melatonin Levels in Adolescents



# Light has also «non-circadian» acute effects

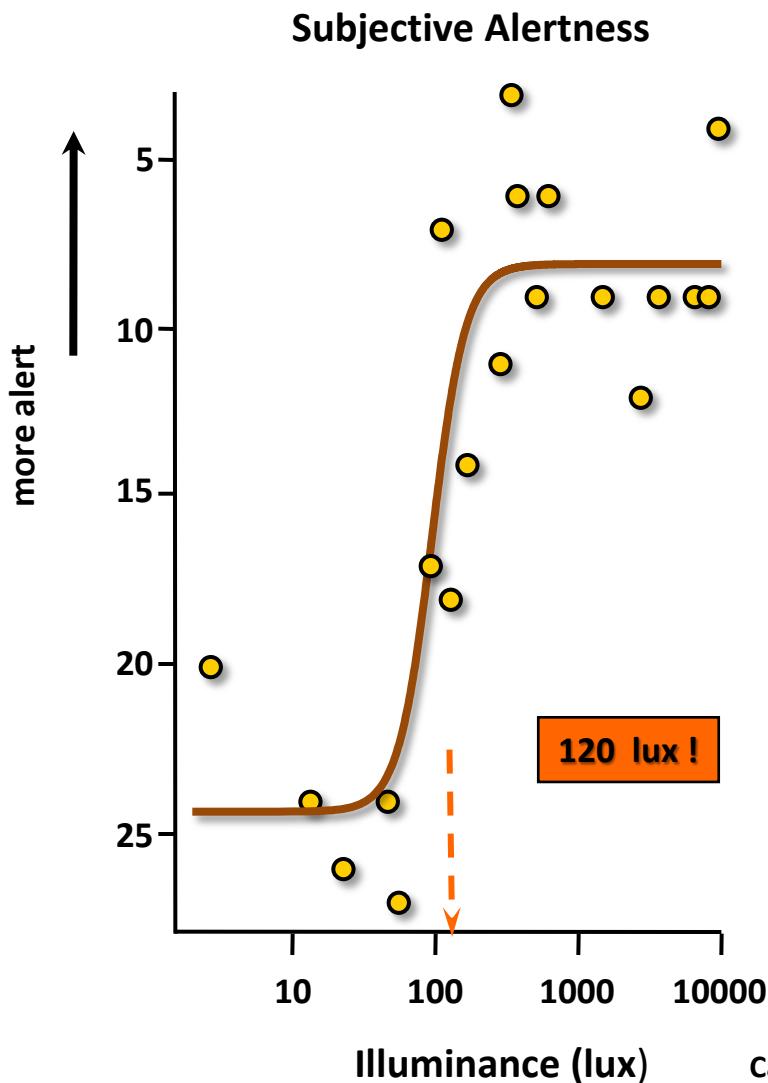
- Light suppresses the soporific hormone melatonin within minutes (Gronfier et al., 2002)
- Light inhibits sleep-promoting GABA neurons in the ventrolateral preoptic area in the hypothalamus (VLPO, Tsai et al., 2009)
- Light activates wake-promoting orexin neurons in the lateral hypothalamus (McGregor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

# Acute sleep induction by light in nocturnal mice



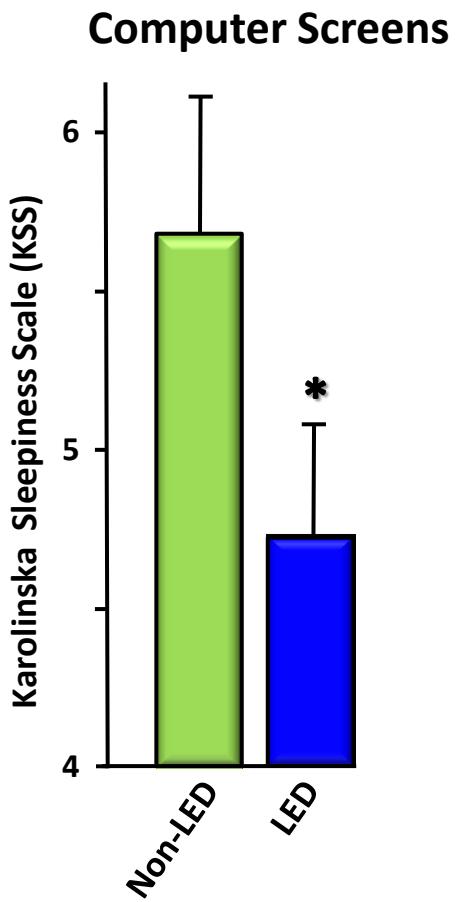
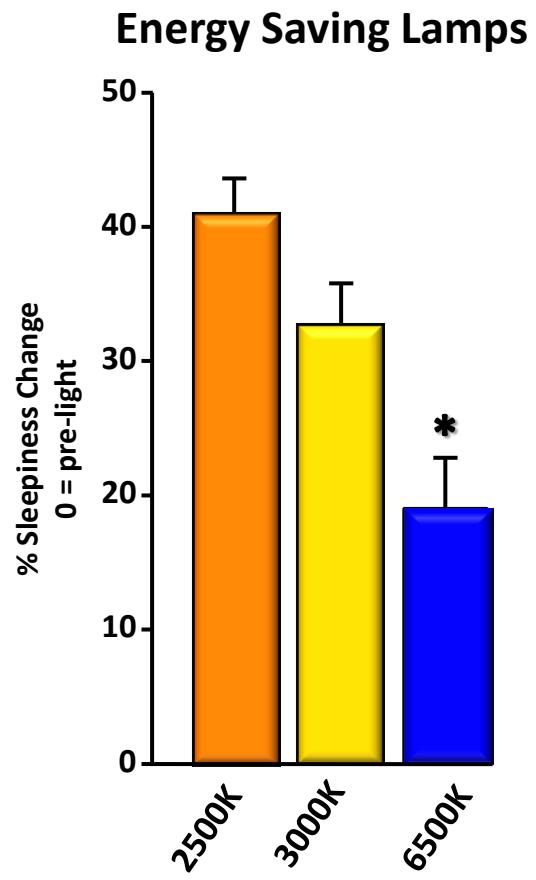
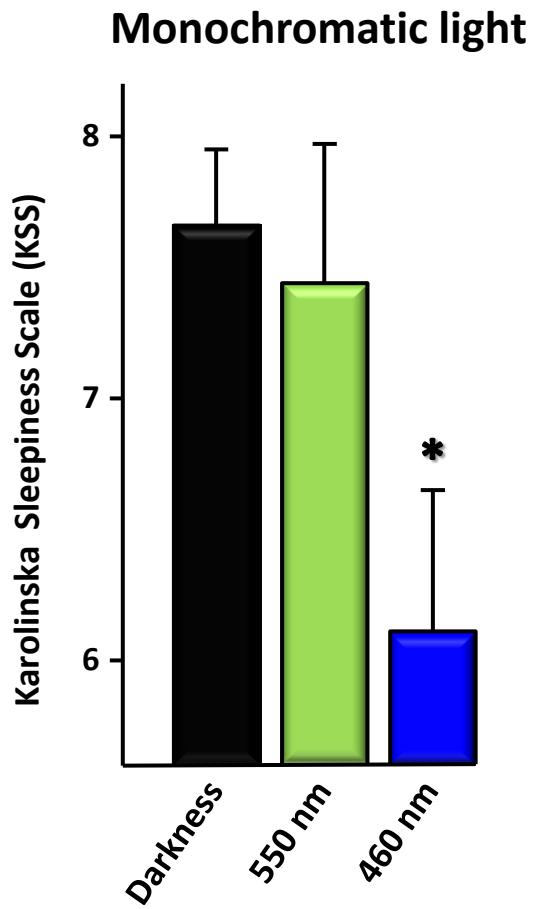
According to Muindi et al., Front Syst Neurosci, 2014

# Acute alerting effects of light in diurnal humans



Cajochen et al., Beh Brain Res. 2000

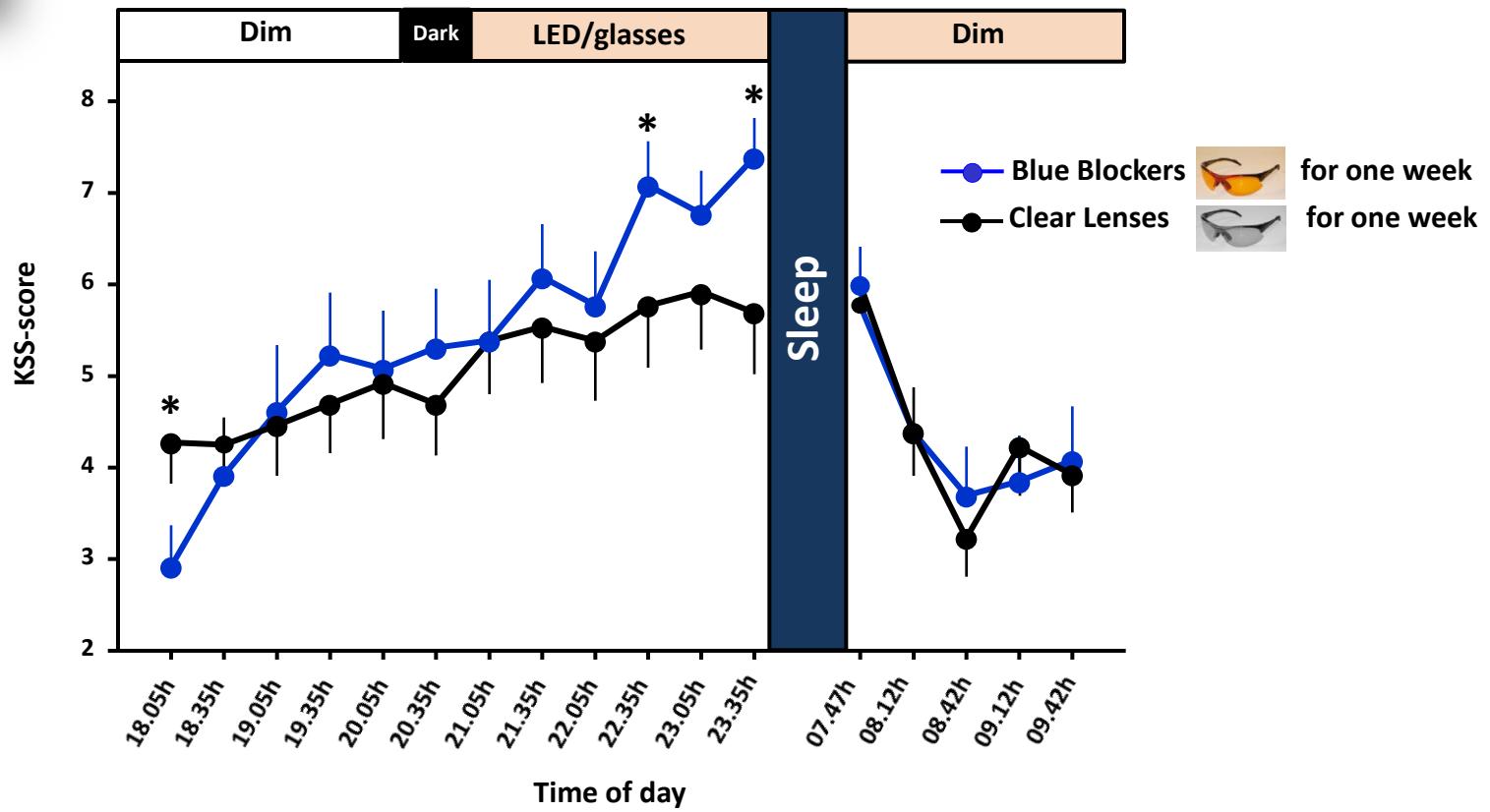
# The human alerting response to light is blue-shifted





# Blocking blue light in the evening

## Subjective Sleepiness in Adolescents



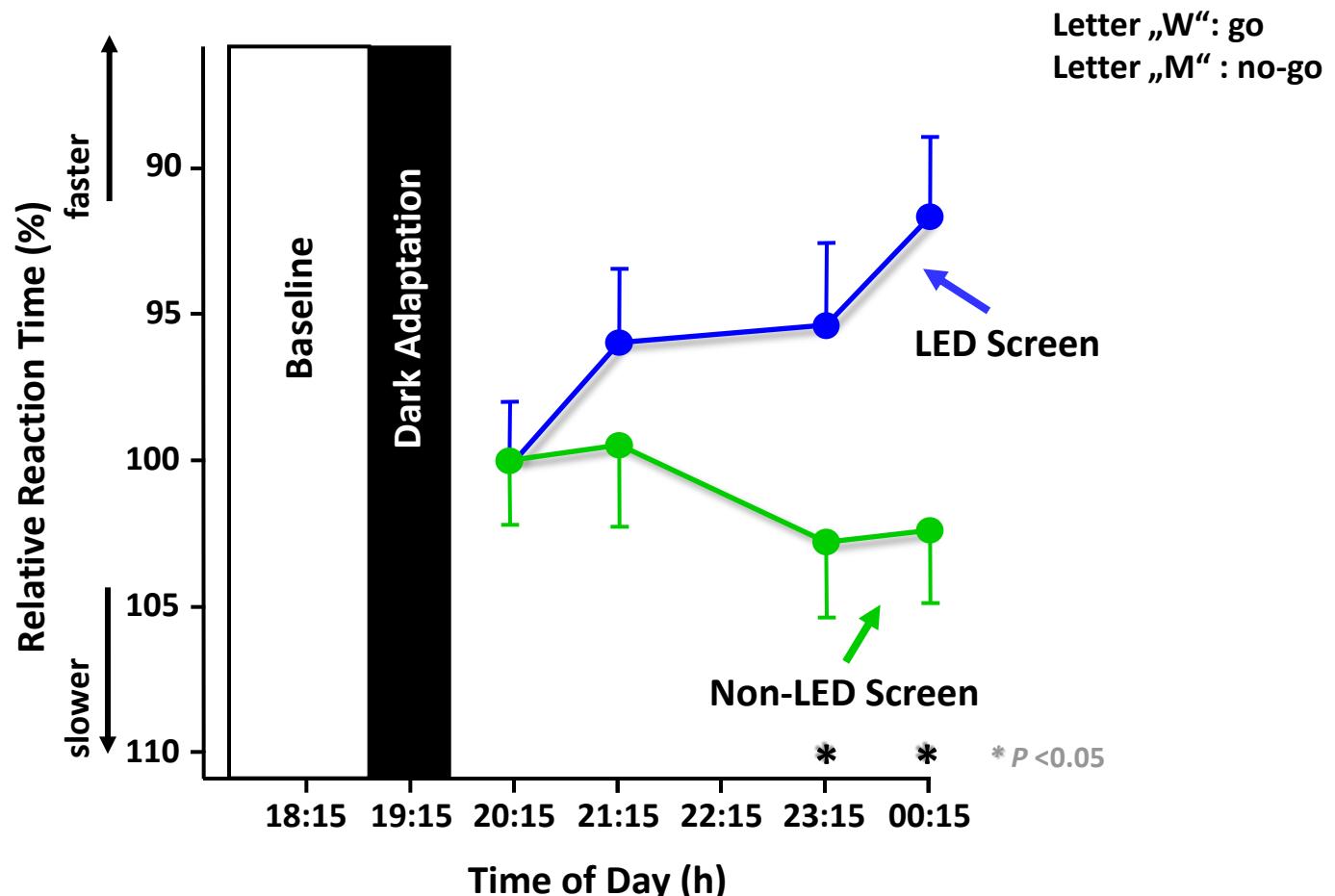
# **Does light affect higher cognitive functions ?**



**Does light make you bright?**



## Sustained Attention and Response Control (Go/noGo Task)



Monitor:  $F_{1,11}=12.2$ ;  $p<0.04$

Time of day:  $F_{11,44}=7.8$ ;  $p<0.02$

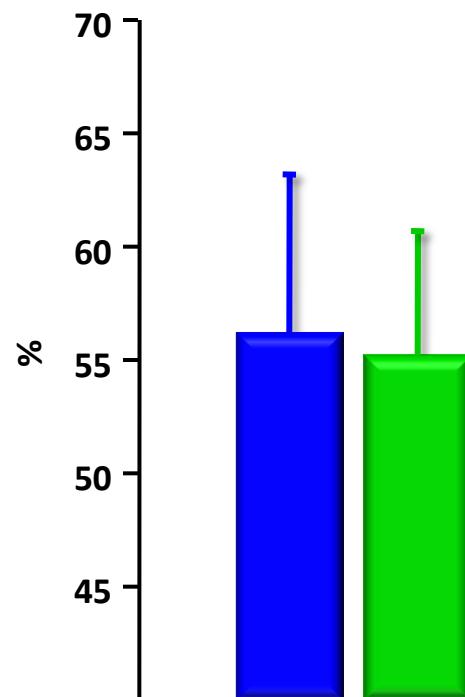
Monitor x Time:  $F_{12,132}=3.0$ ;  $p=0.041$

Cajochen et al., J Appl Physiol. 2011

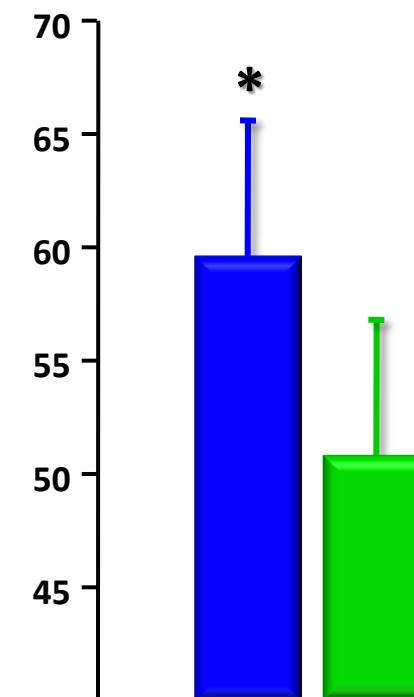


## Declarative Learning (Word pairs)

Correctly identified word pairs



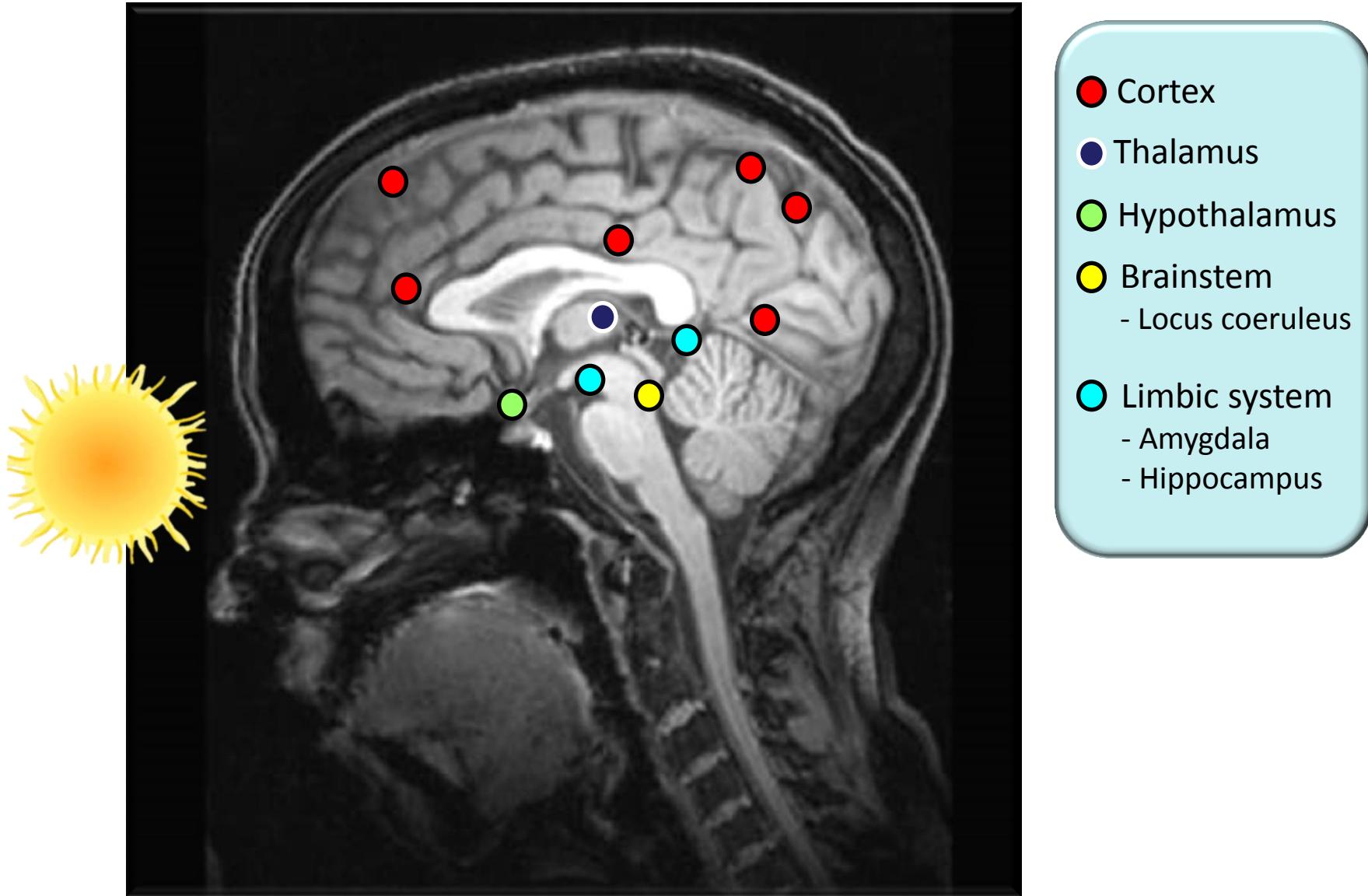
Correctly identified new word pairs



■ LED Screen  
■ Non-LED

\*  $P < 0.05$

# Light is not just for vision



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](http://www.chronobiology.ch)

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Confederazione Svizzera  
Confederaziun svizra

Swiss Federal Office for Public Health

**FNSF**  
SWISS NATIONAL SCIENCE FOUNDATION



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