



## 24-HOUR LIGHTING SCHEME FOR TRAIN DRIVERS

Effects of light on alertness

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## Lighting Research Center Rensselaer

The Lighting Research Center (LRC), as part of Rensselaer Polytechnic Institute, Troy, NY, is the leading university-based research center devoted to lighting since 1988.



Istanbul Ulaşım Co. is the subsidiary company of Istanbul Metropolitan Municipality, and internationally provides a comprehensive range of integrated planning, management, engineering services, and operates all the railway transportation modes in Istanbul, Turkey.



Blindness or no light perception is the condition of lacking visual perception due to physiological or neurological factors



By Edmond Castan







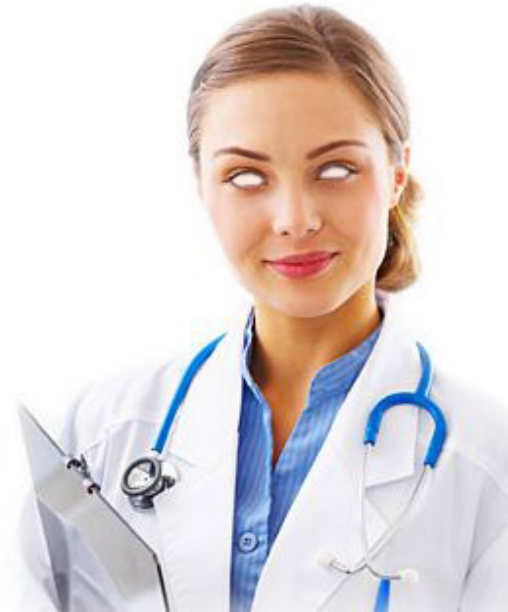
Fatigue is a physiological state of diminished mental capacity caused by acute or chronic sleep deprivation



[www.youtube.com](http://www.youtube.com)







[www.google.com/images](http://www.google.com/images) (Edited)



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## 24-Hour Lighting Scheme for Train Drivers: Effects of light on alertness

The **primary goal** of this study is to use light as a non-pharmacological treatment for increasing alertness of train drivers during operation by developing a lighting scheme in the cabin interior.

## 24-Hour Lighting Scheme for Train Drivers: Benefits

- Supporting accident prevention strategies
- Reducing the impact of human errors on train accidents
- Reducing the social and economical consequences of such incidents and accidents.
- Providing essential information on driver cab design
- Recommendations for lighting standards and practices to advance driver's performance by taking the non-visual effects of light into consideration
- Applicability of the findings to other transportation types such as airlines and roadways

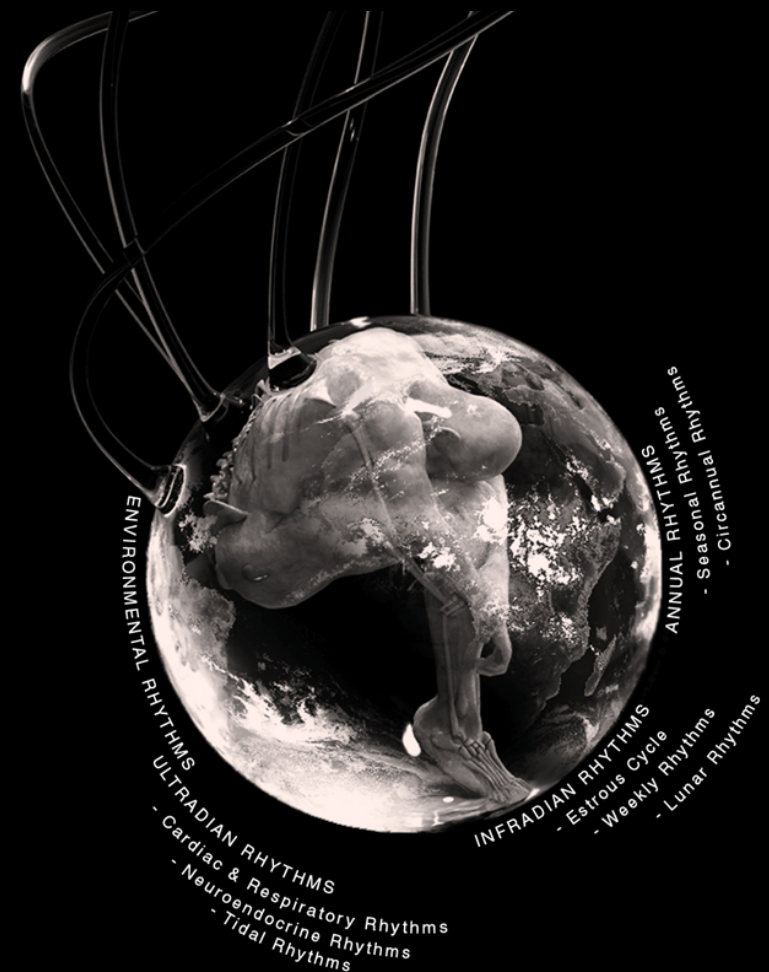
## The Nature of Us: Circadian System

Circadian means around (*circa*) a day (*dies*).

Circadian rhythms are biological daily rhythms that repeat themselves approximately every 24 hours.

- Sleep/wake cycle
- Hormone production
- Body temperature
- Heart rate
- Blood pressure
- Gene expression

If our behaviors are desynchronized from the light and dark patterns that the outside world provides, our circadian rhythms will become disrupted.

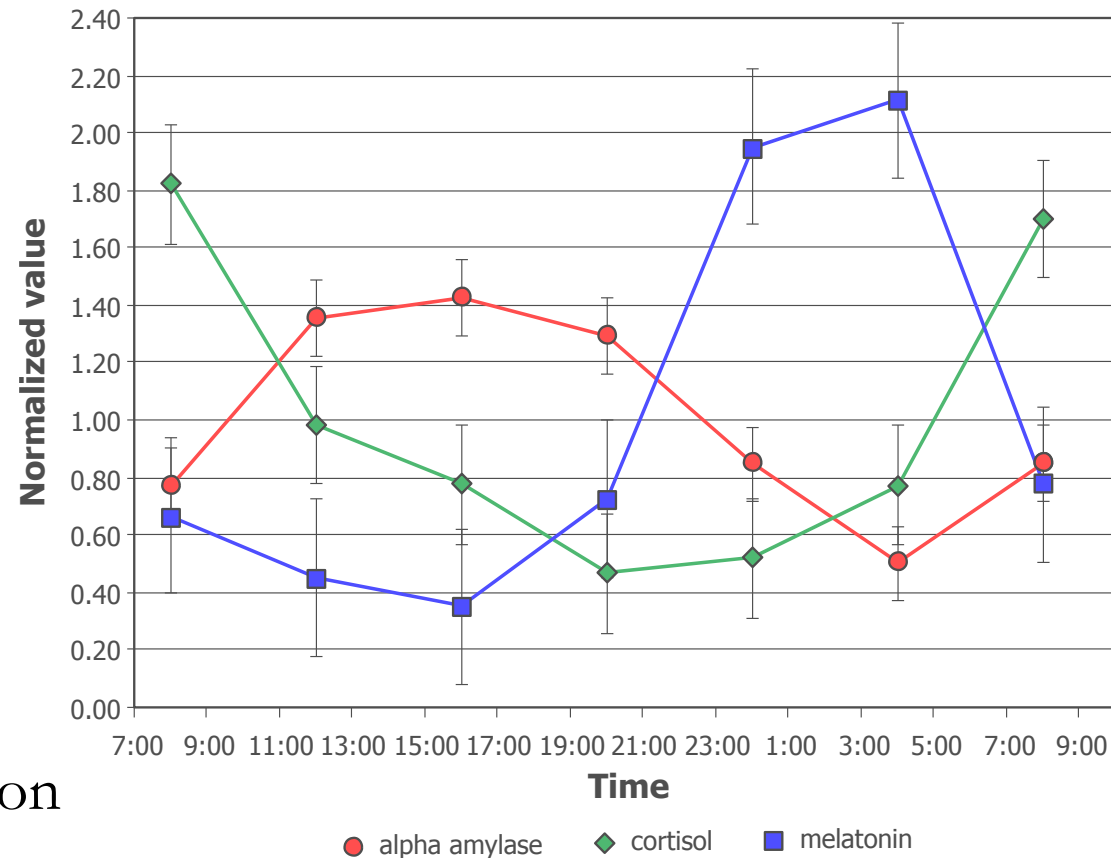




# The Nature of Us: Circadian System

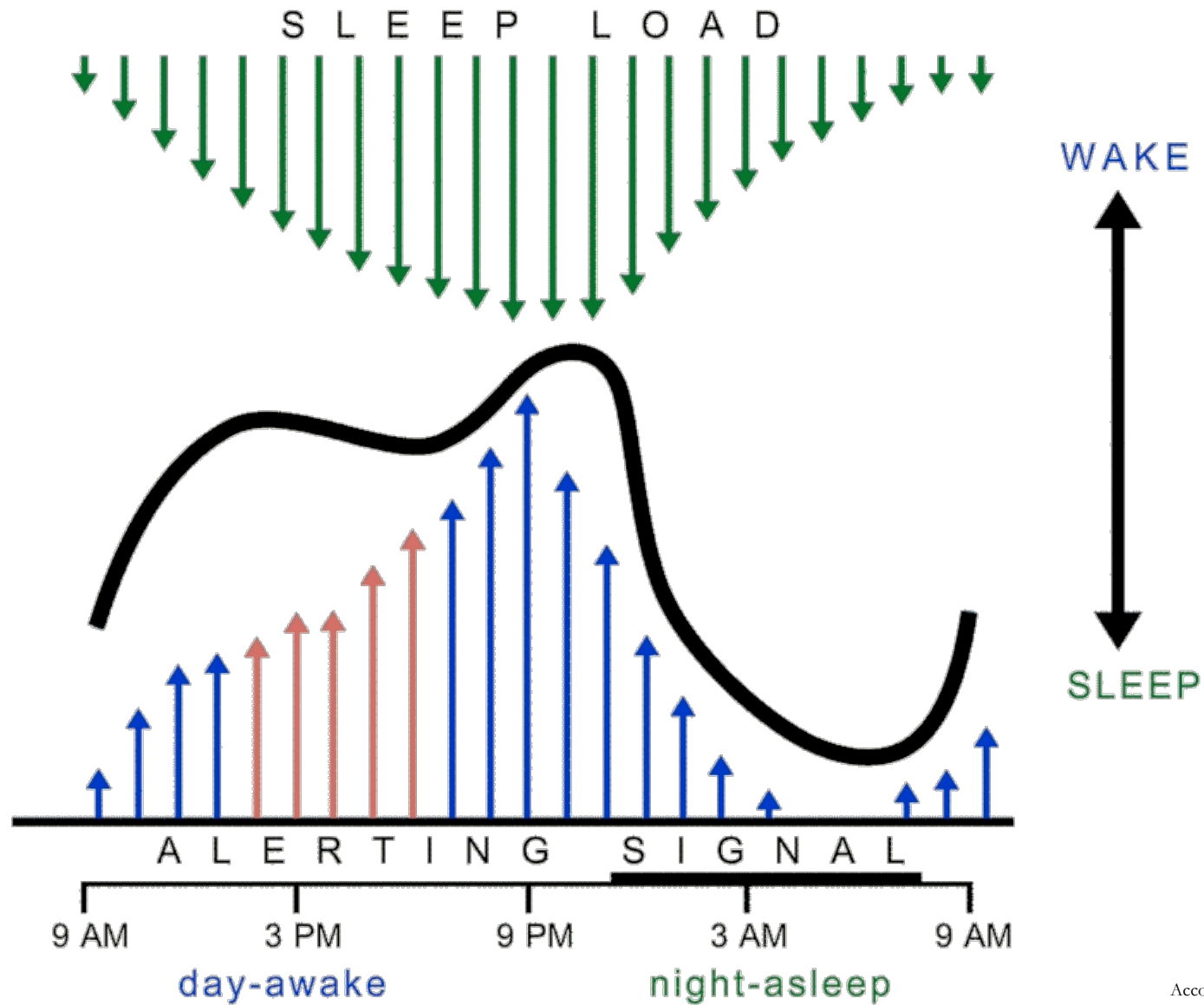
Biological (circadian) rhythms can be measured in several ways

- Sleep/wake cycle
- Core body temperature
- Melatonin concentration
- Cortisol concentration
- Alpha amylase concentration



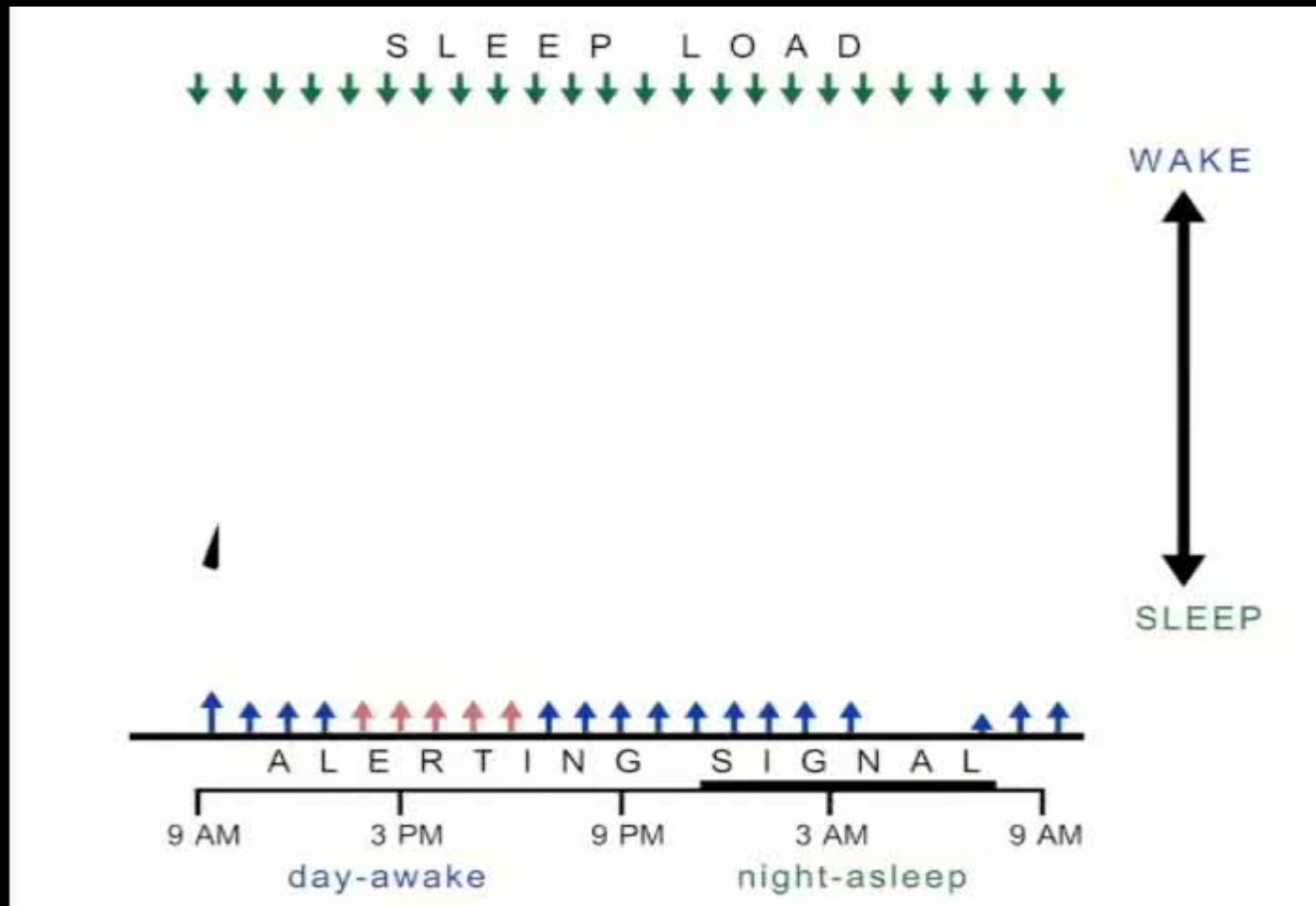
Figueiro et al., 2009  
Sponsor: Office of Naval Research

# The Nature of Us: Opponent Process Model of Sleep



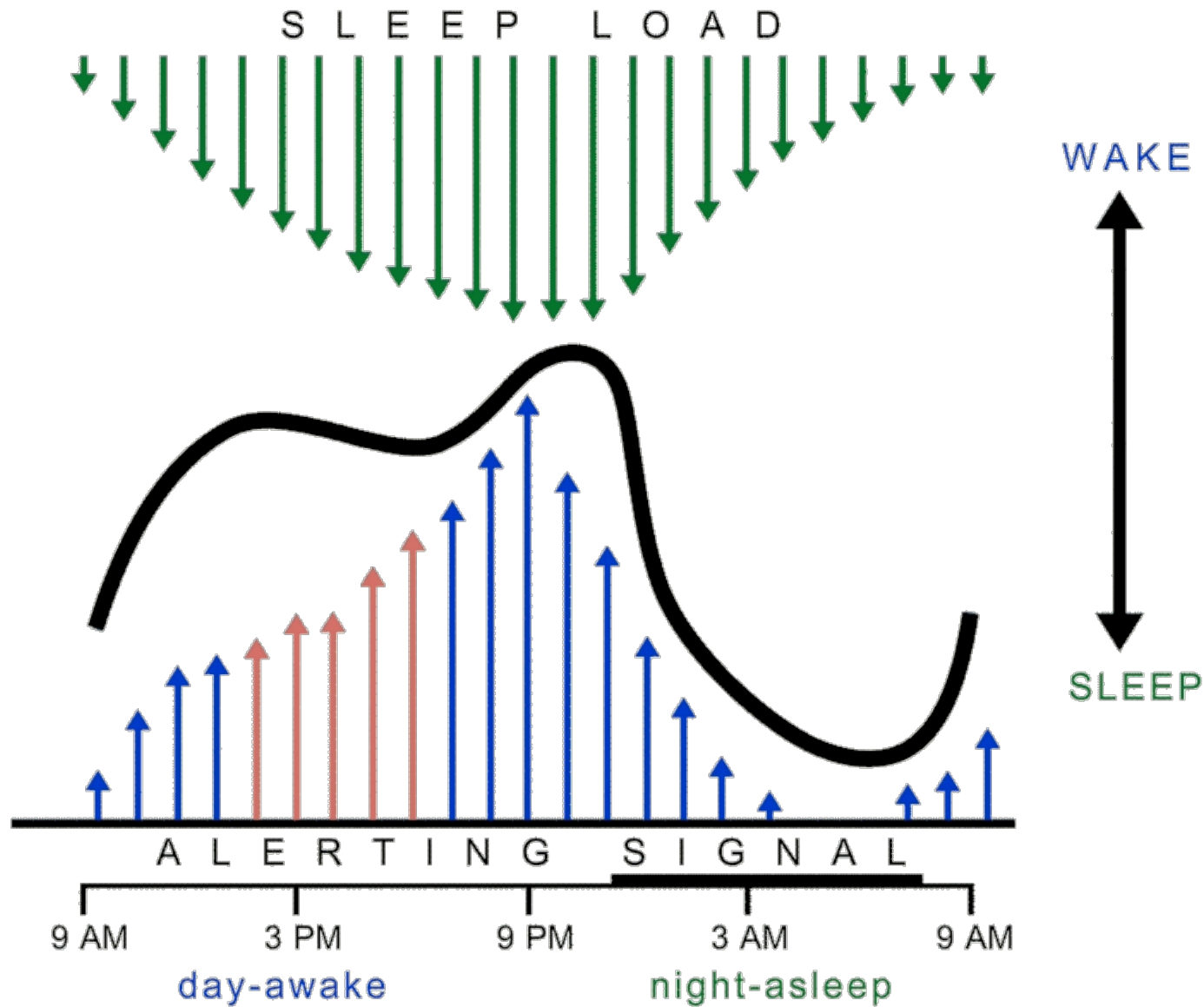
According to Edgar et al.

# The Nature of Us: Opponent Process Model of Sleep



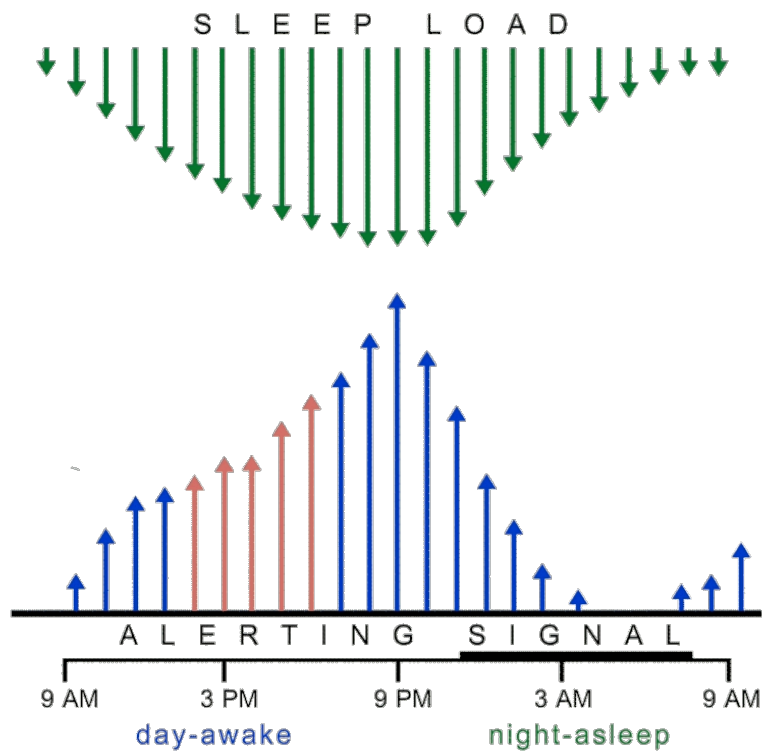


# The Nature of Us: Opponent Process Model of Sleep



According to Edgar et al.

# The Nature of Us: In case of Desynchronized Opponent Process Model



## 24-Hour Lighting Scheme for Train Drivers: Shift Work and Performance

- The risk for severe sleepiness was 6-14 times higher in the night shift and about twice as high in the morning shift compared with the day shift

>Harma et al. 2002

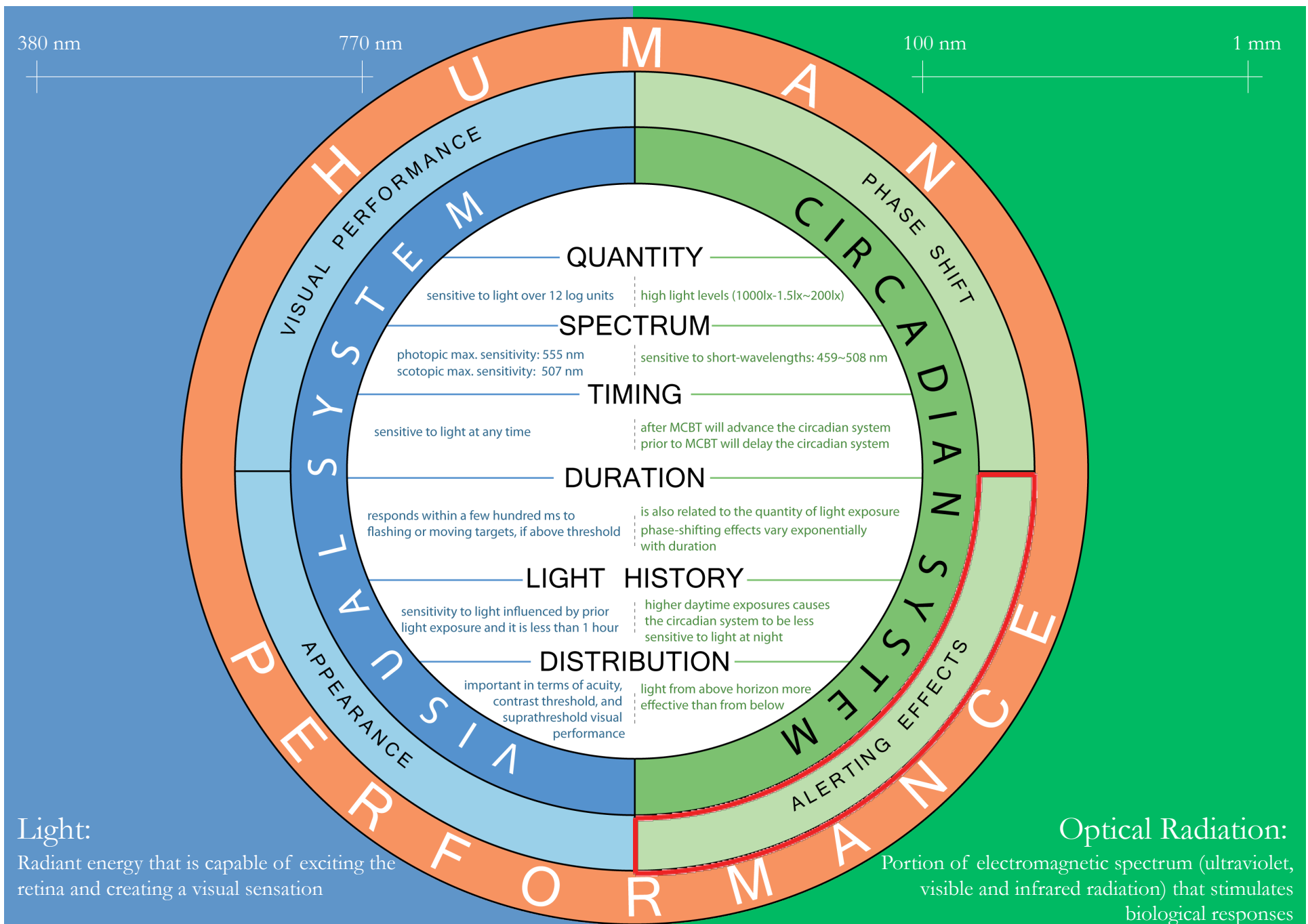
- About 25 % of train drivers dozed off while driving or waiting at the station

>Austin & Drummond 1986

- Drivers in the moderate fatigue group used 4% more, and drivers in the high group used 9% more fuel than drivers in the low fatigue group. High fatigue-group drivers used less throttle and dynamic brake and engaged in more heavy brake and maximum speed violations.

> Dorrian et al. (2006)





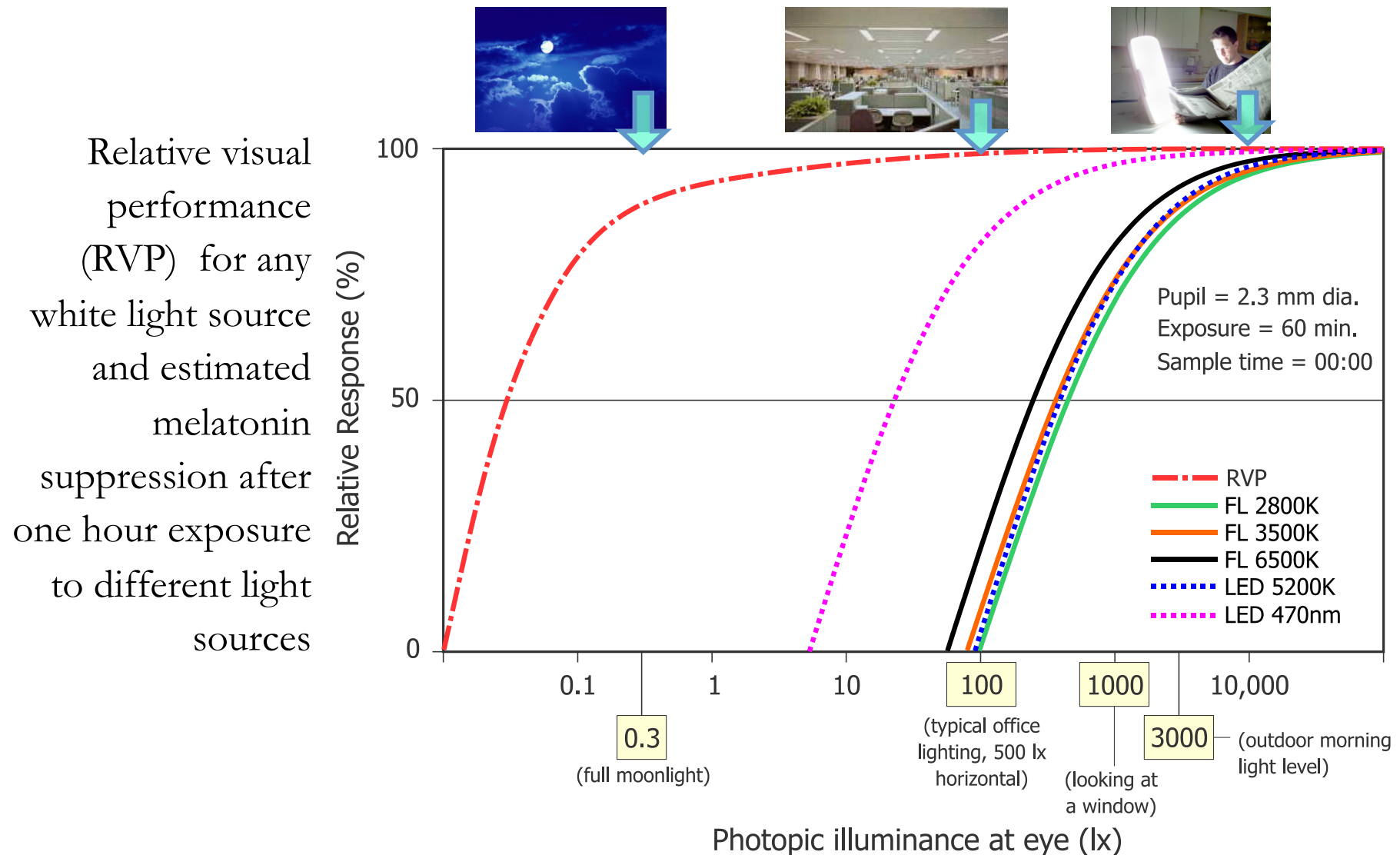
## Light:

Radiant energy that is capable of exciting the retina and creating a visual sensation

## Optical Radiation:

Portion of electromagnetic spectrum (ultraviolet, visible and infrared radiation) that stimulates biological responses

# 24-Hour Lighting Scheme for Train Drivers: Quantity & Spectrum



## 24-Hour Lighting Scheme for Train Drivers: What else do we know?

Light at night;

- reduces subjective sleepiness
- increases task performance
- increases body temperature and heart rate
- reduces low frequency and increases high frequency EEG activity
- reduces the incidence of slow-eye movements (SEMs)
- suppresses melatonin levels compared to control conditions

>Campbell and Dawson 1990; Badia et al. 1991; Thessing et al. 1994; Cajochen et al. 1998; Daurat et al. 2000; Cajochen 2000; Figueiro et al. 2001; Lowden et al. 2004



## 24-Hour Lighting Scheme for Train Drivers: What else do we know?

- Blue light enhances brain responses
- Monochromatic light can affect cognitive functions almost instantaneously. However dissipates swiftly.  
>Vandewalle et al. 2007
- Long wavelength light (red) also reduces alpha and increases beta activity in EEG  
>Figueiro et al. 2009

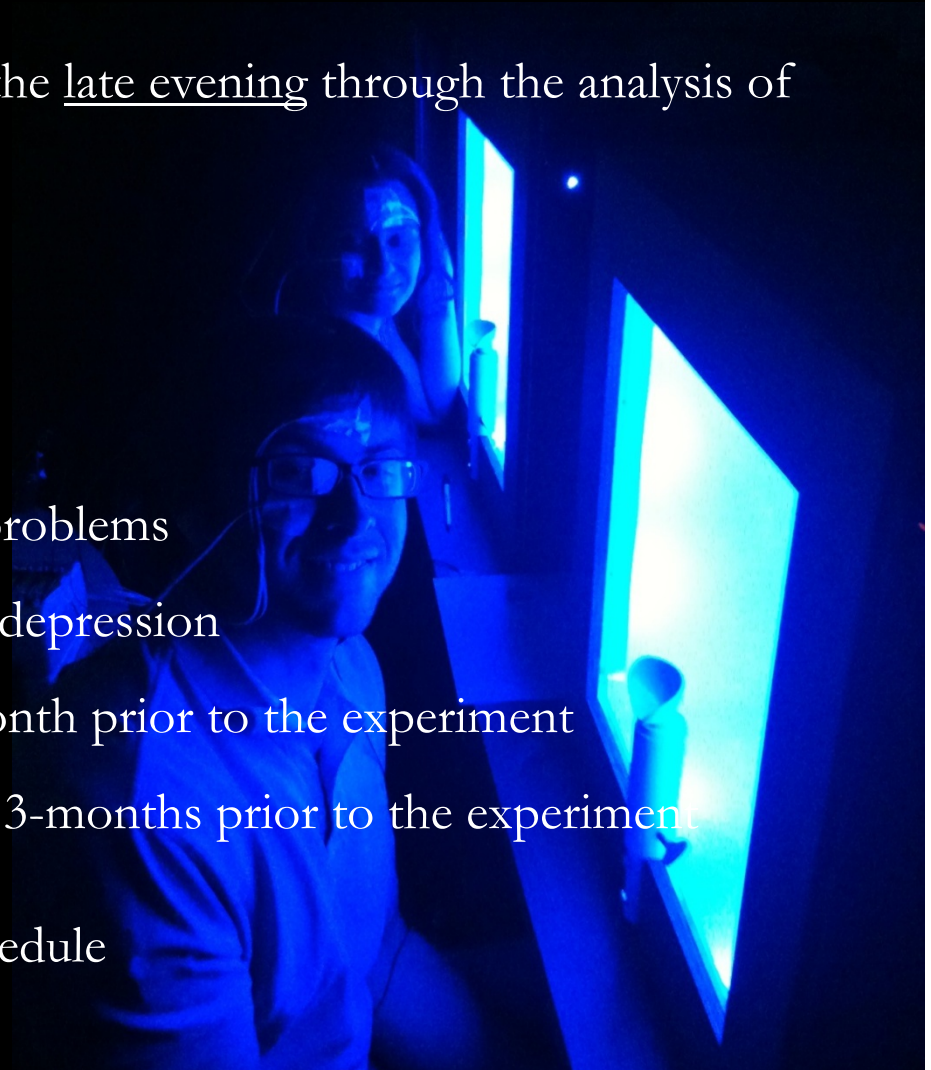
# Experiment: Acute effects of short and long wavelength light on alertness

## Purpose

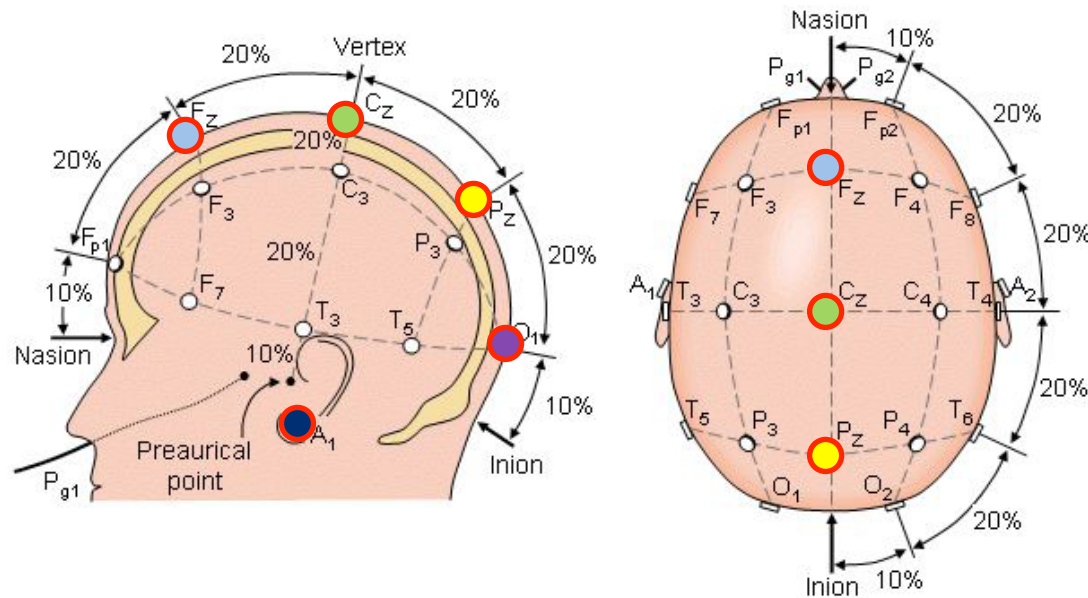
To investigate the alerting effects of light in the late evening through the analysis of EEG activity

## Participants

- 8 participants with normal color vision
- no report of any physical or mental health problems
- neither diagnosed with bipolar disorder nor depression
- no experience of shift work within the 3-month prior to the experiment
- no travel to a different time zone within the 3-months prior to the experiment
- participants kept their own regular sleep schedule



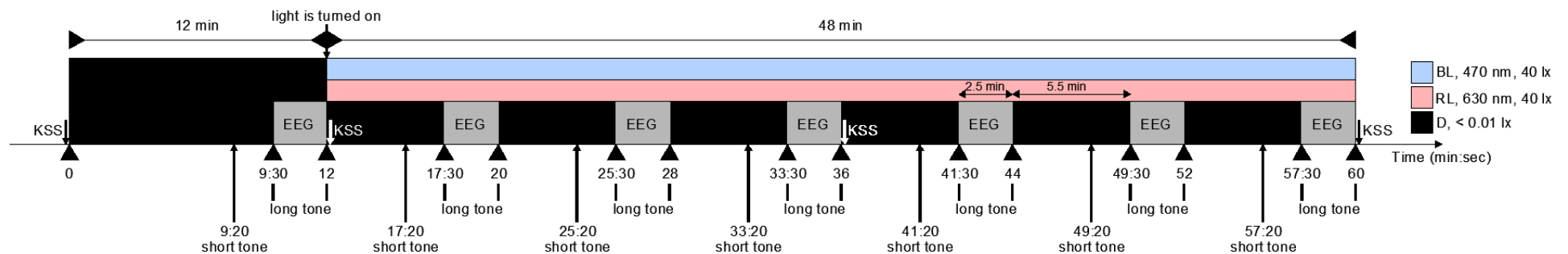
# EXPERIMENT: Protocol



EEG signals were recorded from 4 locations on the scalp: Fz, Cz, Pz and Oz

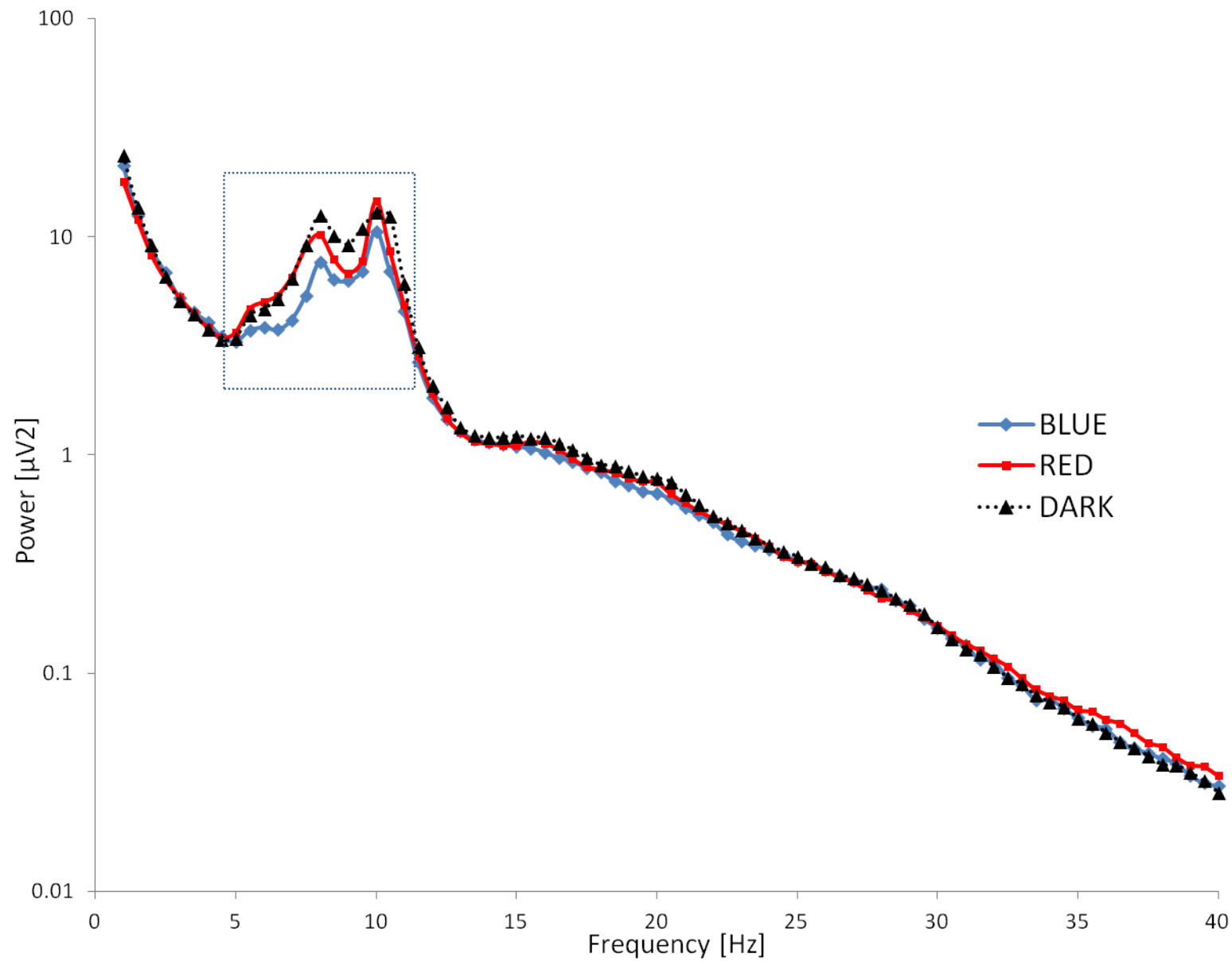
EOG was recorded from an electrode located directly below the right eye

Reference electrodes were attached at ear lobes

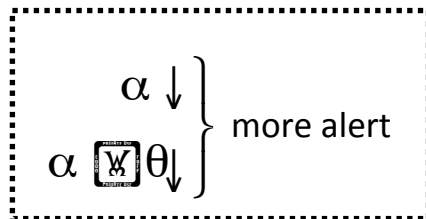
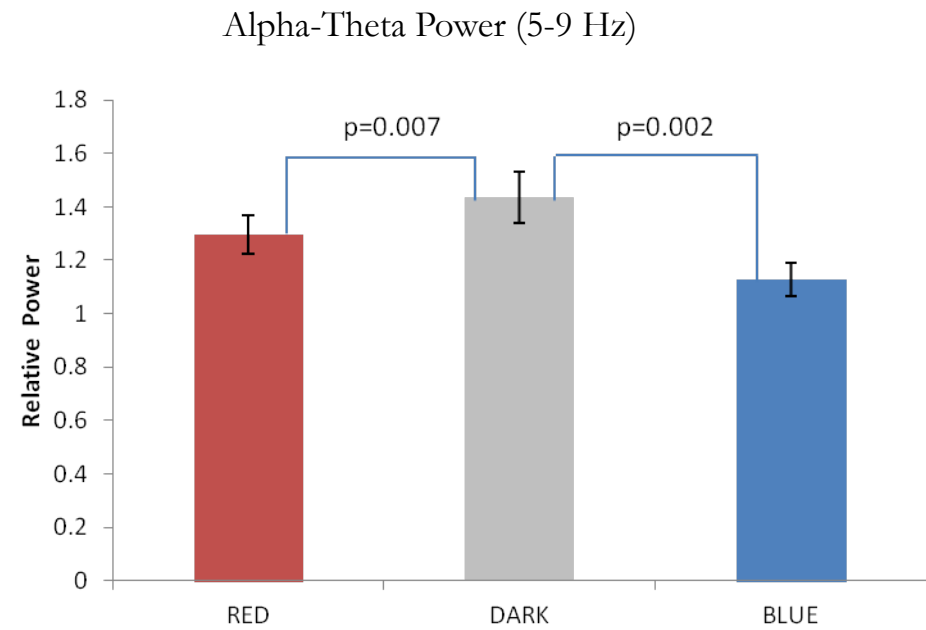
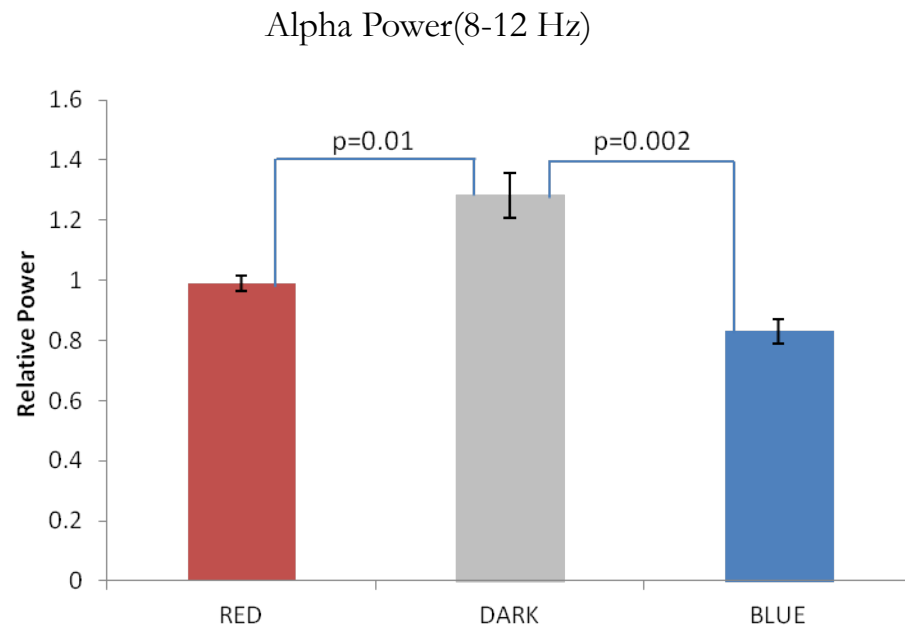




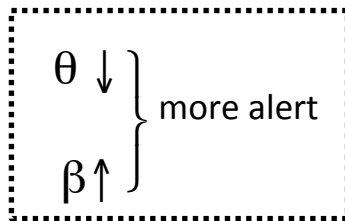
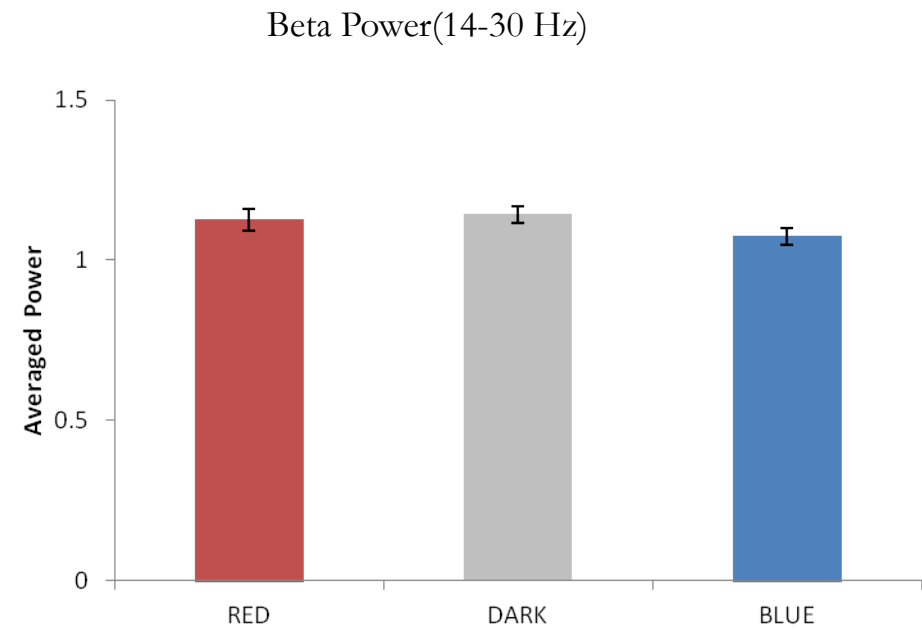
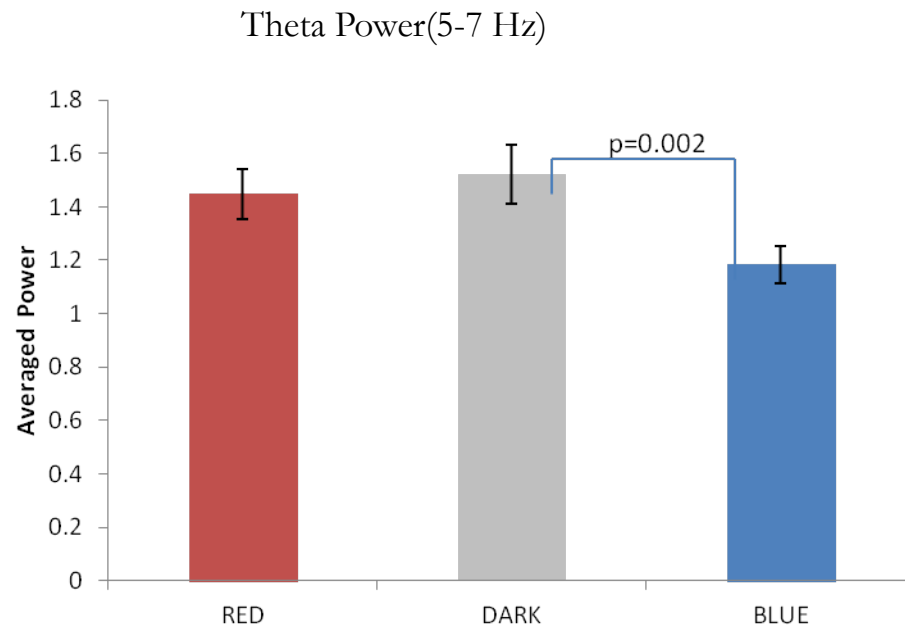
# EXPERIMENT: Results



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## EXPERIMENT: Discussion

Sleepiness is reduced by exposure to short and long wavelength light in the late evening among subjects who are not sleep deprived

Our results are consistent with other studies suggesting that exposure to long wavelength (red) light during the night also increases alertness

>Figueiro et al. 2009

These findings suggest that light can affect alertness not only by mechanisms dependent on melatonin suppression, which is sensitive to short wavelength light but also on melatonin suppression-independent mechanisms

## WHAT DO WE HAVE?: Standards & Culture

- According to EN 13272:2001 "Railway applications- Electrical lighting for rolling stock in public transport systems", it is required to have min 75 lx on the driver's desk in general
- On particular areas such as reading, the illuminance level has to be min 150 lx (EN, 2002)
- Istanbul Ulasim Co. requires having fluorescent lamps that provides min. **200 lx** on the driver's desk (IU, 2007)

## What do we have: Quick Example

The interior of the cabin is illuminated by 36 W T8 FLUORESCENT LAMP (6500 K)

According to the measurements done in the company, the illumination level on the driver's desk is **384 lux** in average. Might be high enough to affect circadian system of a driver.



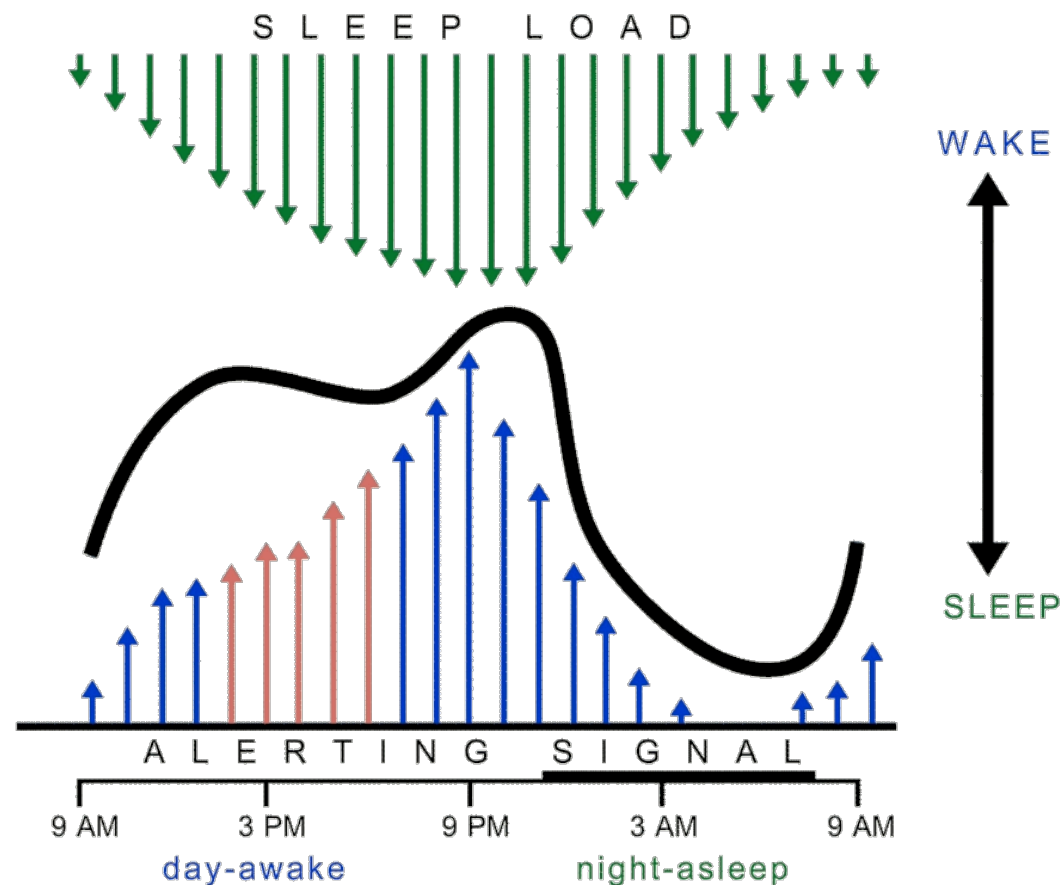


## SUMMARY: Key Points

- Safety is inevitable and foremost quality indicator of any railway system, and fatigue is one of the leading causes of accidents in the work place
- Our circadian system works as a “blue sky detector”
- Disrupted circadian rhythm affects human performance
- Light at night suppresses “melatonin” also known as “darkness hormone”
- Not only short wavelength (blue) light but also long wavelength (red) light exposure increases alertness at night
- Advancing drivers’ alertness can be obtained through effective use of light without disrupting circadian rhythm

## WHAT IS NEXT?: More research is needed 😊

Investigation of the alerting effects of light around the middle of the day (post-lunch dip hours), where circadian drive for wakefulness is low



## WHAT IS NEXT?: Questions & Challenges

- What is the relationship between the spectral characteristics of light that stimulates alertness and the time of day in simulated train driving condition under real working schedules?
- What is the best way to deliver alerting light stimulus to driver's eye without compromising the visual performance of the driver?
- If light stimulus will be provided in periods, what is the optimum duration for the light intervention to keep drivers alert?
- How long the alerting effects of light remain after the removal of the stimulus?

## Acknowledgements

➤ Dr. Mariana Figueiro

LRC, NY USA

➤ Dr. Yosuke Okamoto

Health Research Institute, Osaka, Japan

➤ Istanbul Ulasim Co.

Istanbul, Turkey





**Thank You!**