

# The importance of considering the effects of light on human performance in military and shipyard environments

NSRP

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CIRCADIAN POSITIONING  
SYSTEMS

# Outline

- What is light?
  - Non-visual photoreception
- Why do we care about non-visual photoreception?
  - Circadian rhythms
  - Human performance, alertness, sleep
  - Real world consequences
- How does light work?
- Current recommendations for non-visual photoreception

## What is light?

- "Light is radiant energy of those wavelengths that are capable of affecting the eye to produce vision."
  - DOD-HDBK-289 (SH), 1986
- Light also affects photoreceptors in the eye to "drive biological effects that powerfully regulate human health, performance and well-being."
  - CIE Position Statement on Non-Visual Effects of Light, 2019

# Photoreceptors

- Classical photoreceptors
  - Rods – dim light
  - Cones – color
- Intrinsically photosensitive retinal ganglion cells (ipRGCs) - late 1990's
  - Photopigment melanopsin
  - Peak spectral sensitivity ~ 480nm

# Circadian Rhythms

- Earth's daily axial rotation in orbit around the sun
  - Light/Dark cycle
  - Temperature cycle
- Most organisms demonstrate internal timing system with a period of ~ 24 hours
- When sleep/wake schedule is out of alignment (synch) with your internal circadian clock
  - Shift work
  - Jet lag
- Circadian misalignment results in:
  - Negative consequences to/during sleep
  - Negative consequences during waking

# Sleep Loss & Circadian Misalignment: Consequences

- Performance
- Attention
- Alertness
- Mood
- Impulsivity
- Decision-making
- Learning
- Memory
- Overall physical and mental health

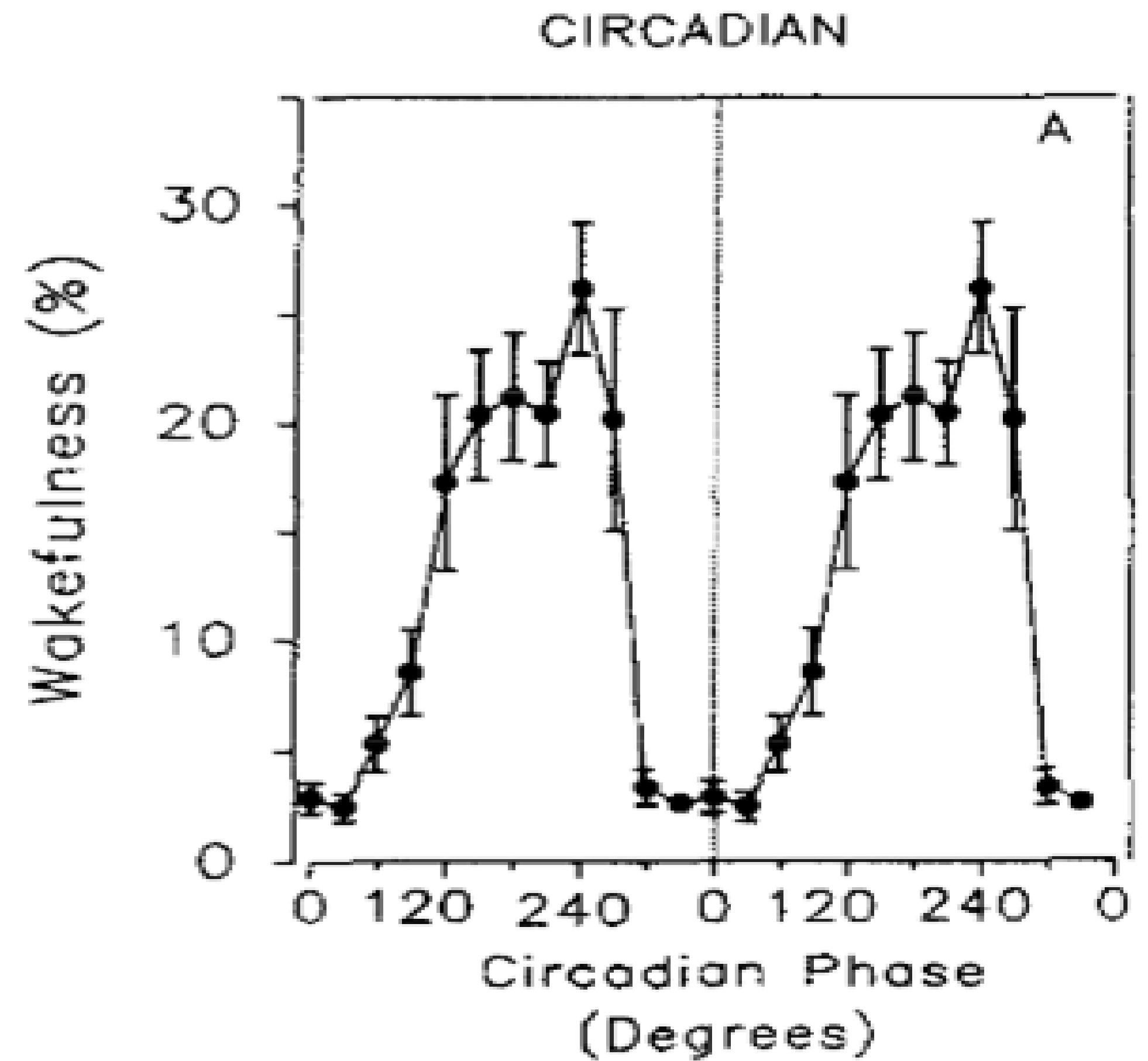
# Sleep Loss & Circadian Misalignment: Consequences

- Adverse circadian phase and inadequate sleep have resulted in some of the world's most devastating disasters
- All industries where performance is critical around the clock are at risk

# Circadian Rhythms

affect sleep

(Dijk and Czeisler, *Neuroscience Letters*, 1994)

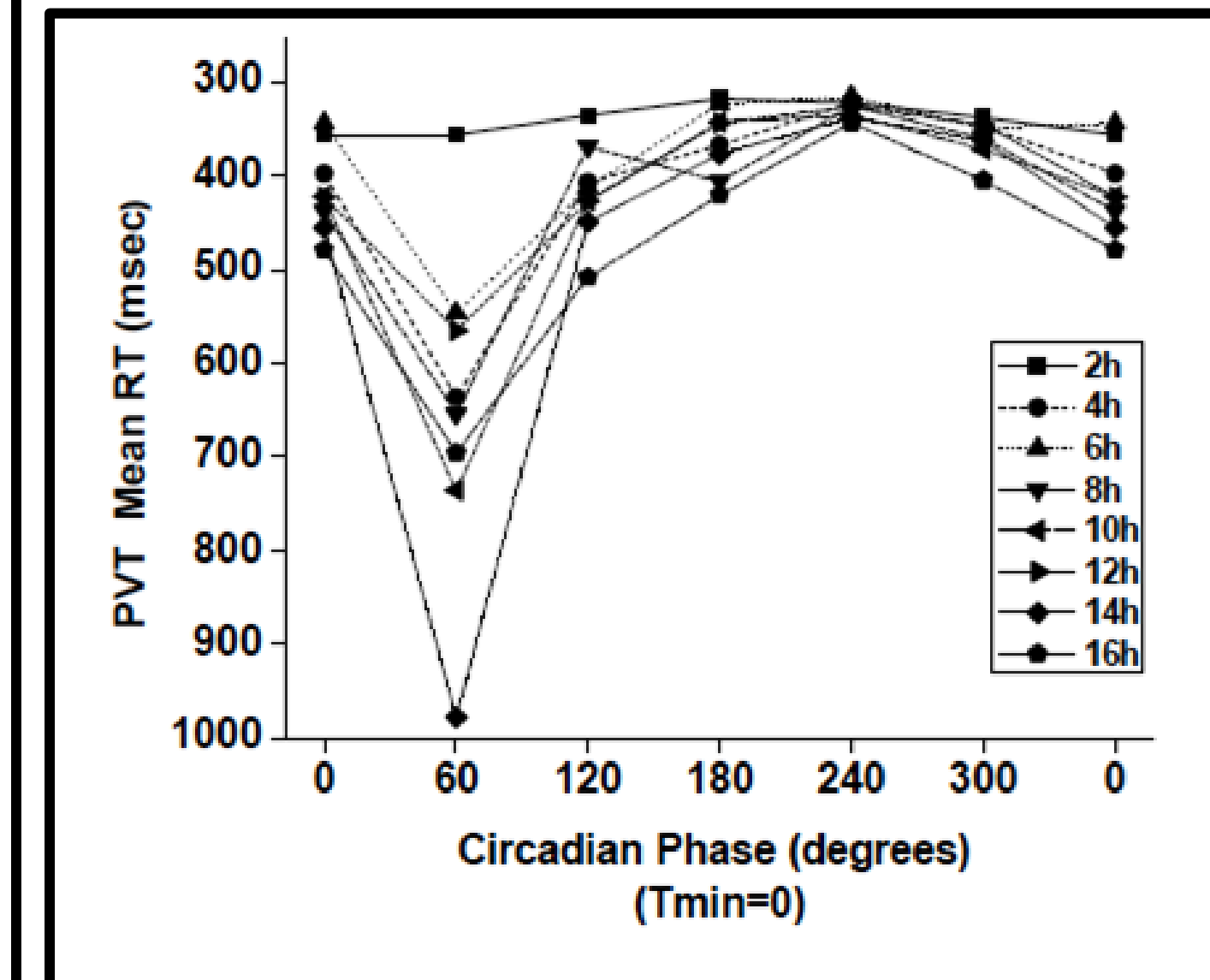
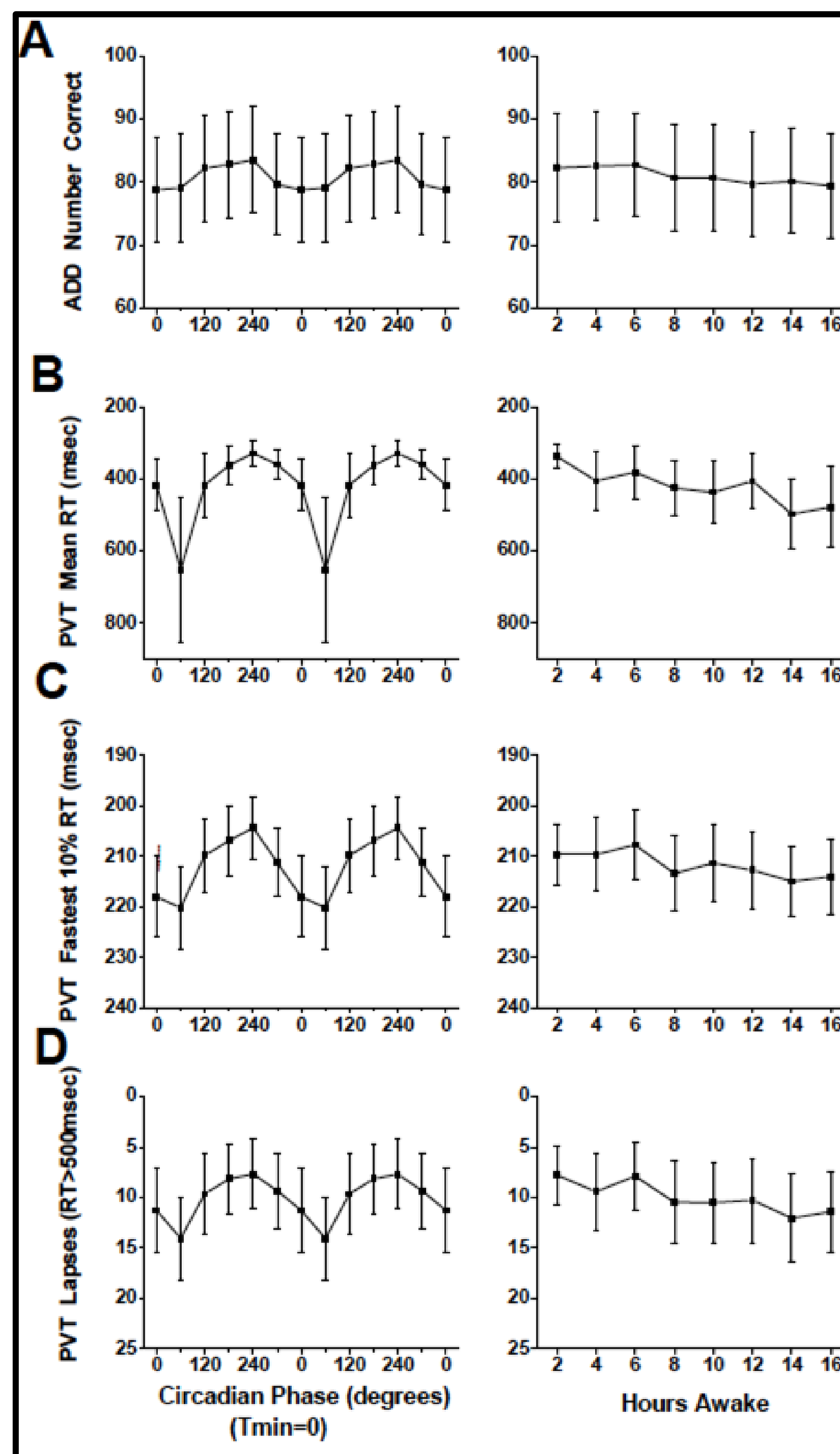


Sleep consolidation varies as a function of circadian data



Performance is affected by circadian phase, time awake, and the interaction of circadian phase and time awake

(Lee et al., 2009)



Performance varies as a function of circadian phase and time awake

# The Problem:

## Fatigue (Inadequate Sleep and Circadian Rhythm Misalignment) Is a Major Contributing Factor to Collisions Resulting in Loss of Life and Property



U.S. Marines F/A-18 fighter collided with a KC-130

### U.S.S. John McCain

#### Stories of 10 Sailors Who Died in Navy Collision

DOCK AUG. 27, 2017



Top left: Kenneth Aaron Smith, 22, from New Jersey; Logan Stephen Palmer, 23, from Texas; Ryan Hoagland III, 20, from Texas; Dustin Louis Doyon, 26, from Connecticut; Jacob



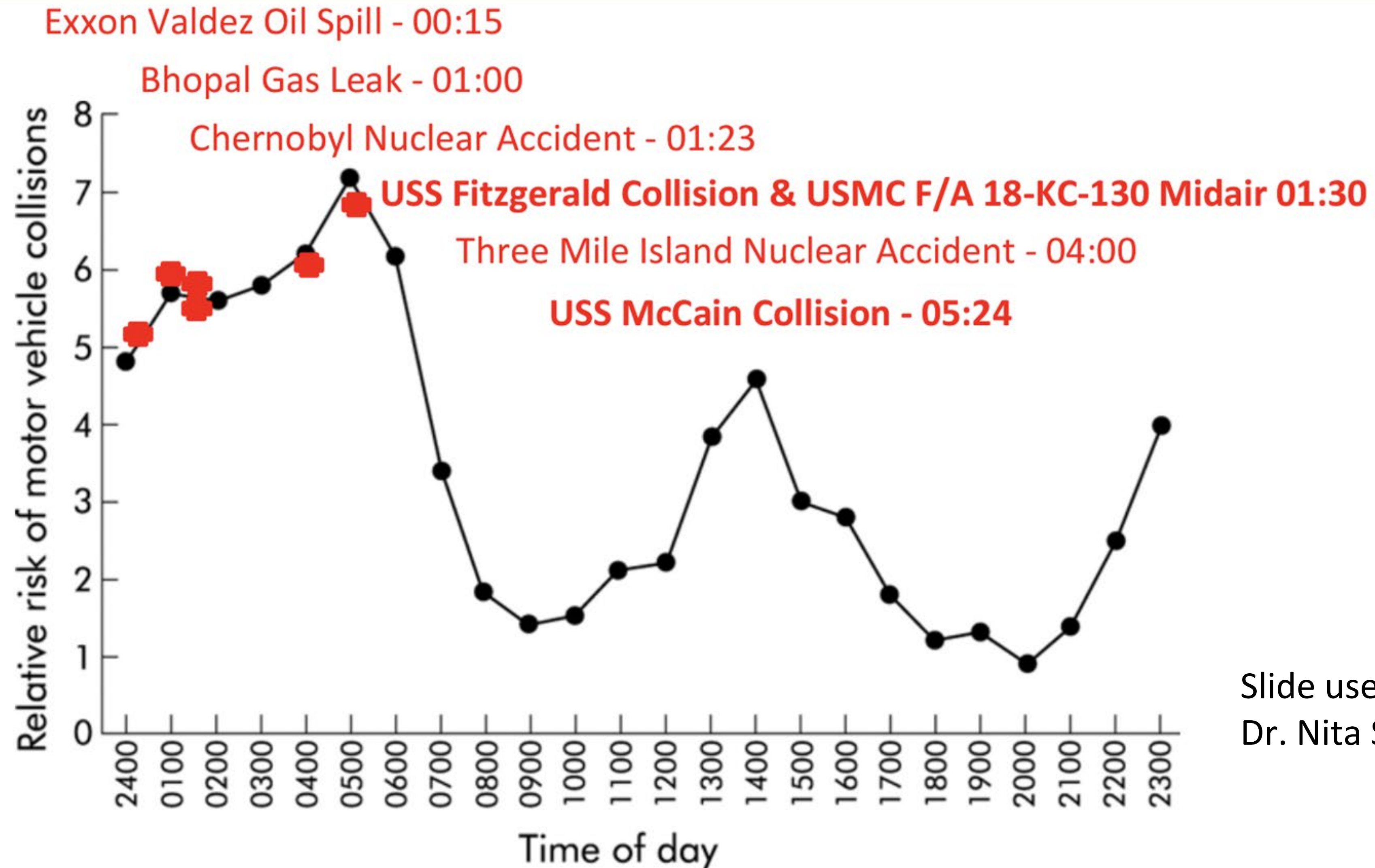
### USS Fitzgerald

#### 7 sailors died aboard the USS Fitzgerald. Here are their stories.

By Avi Selk June 19, 2017 [Email the author](#)



# The Problem: Real-World Accidents Happen at Adverse Circadian Phases (i.e., Biological Night)



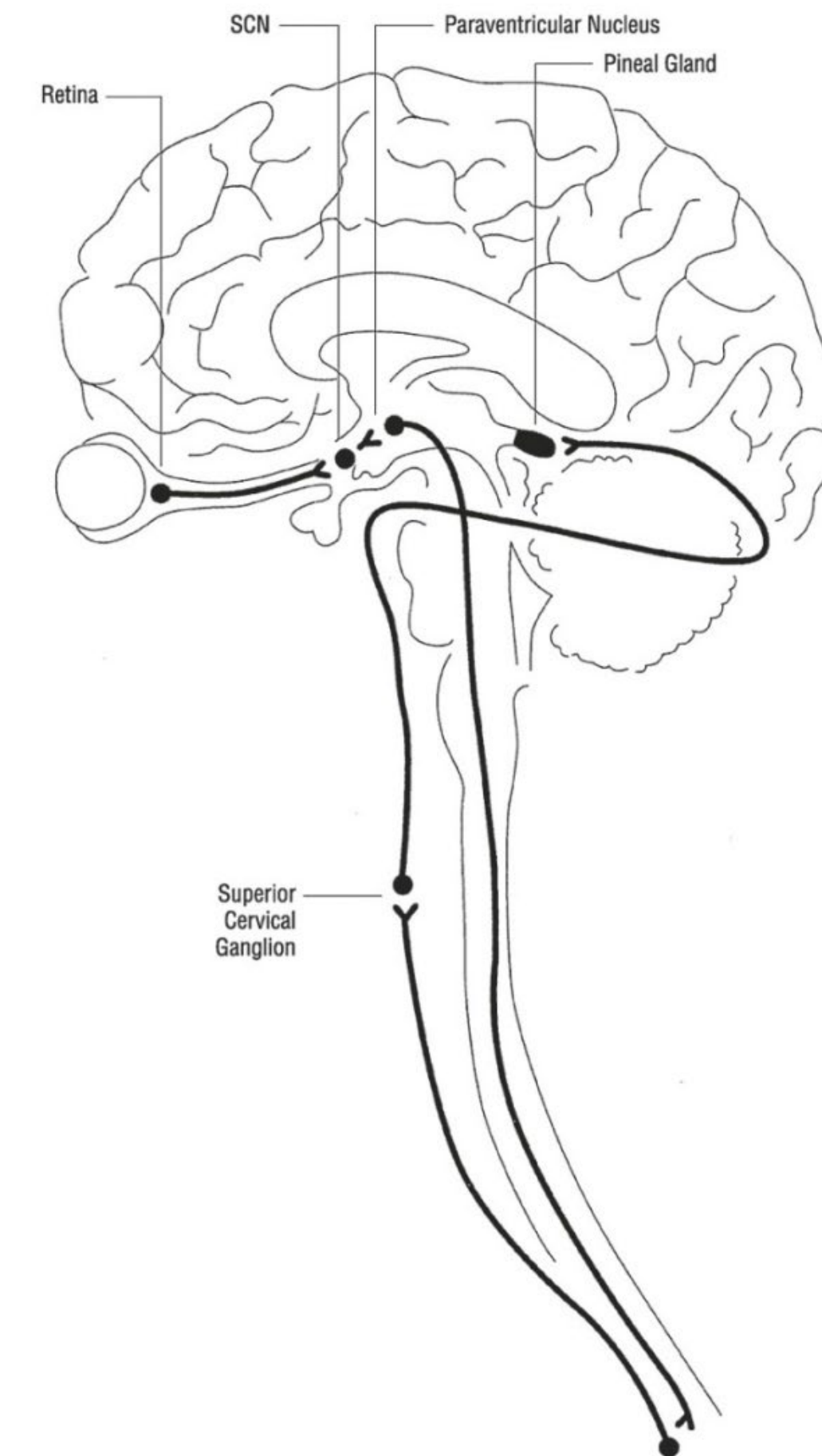
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Dr. Nita Shattuck

# Light and Circadian Rhythms

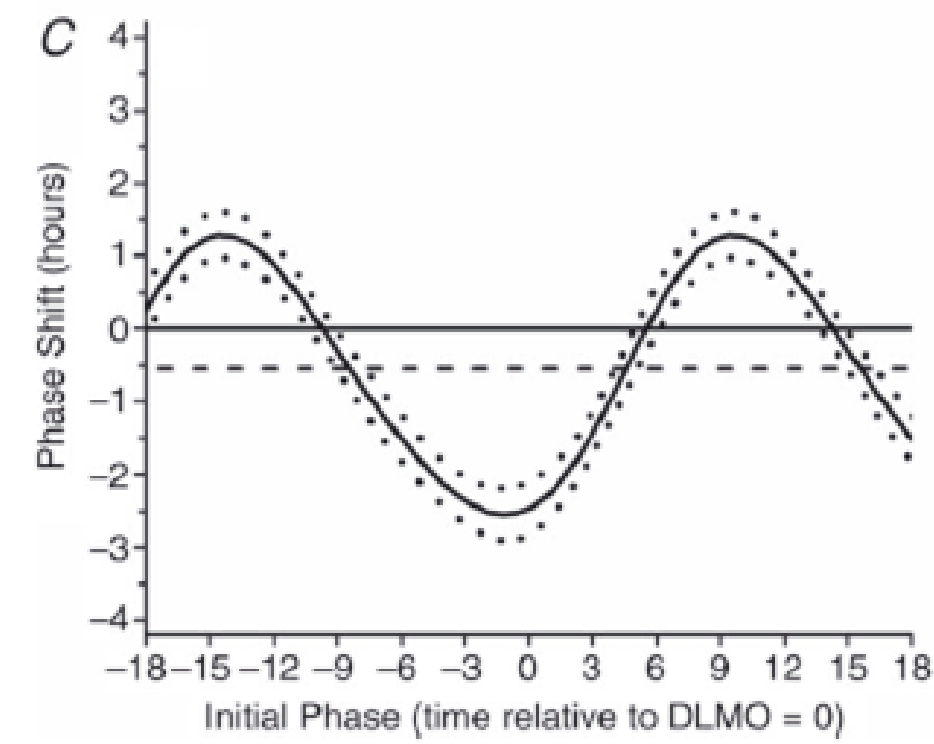
- Align circadian rhythms to meet work demands using light
- Ocular exposure to light
  - Entrain endogenous rhythms
  - Suppresses melatonin
  - Enhances alertness
  - Constricts the pupil
  - Increases heart rate
- How does light work?
- What type of light works best?

# How Does Light Work to Entrain Circadian Rhythms?

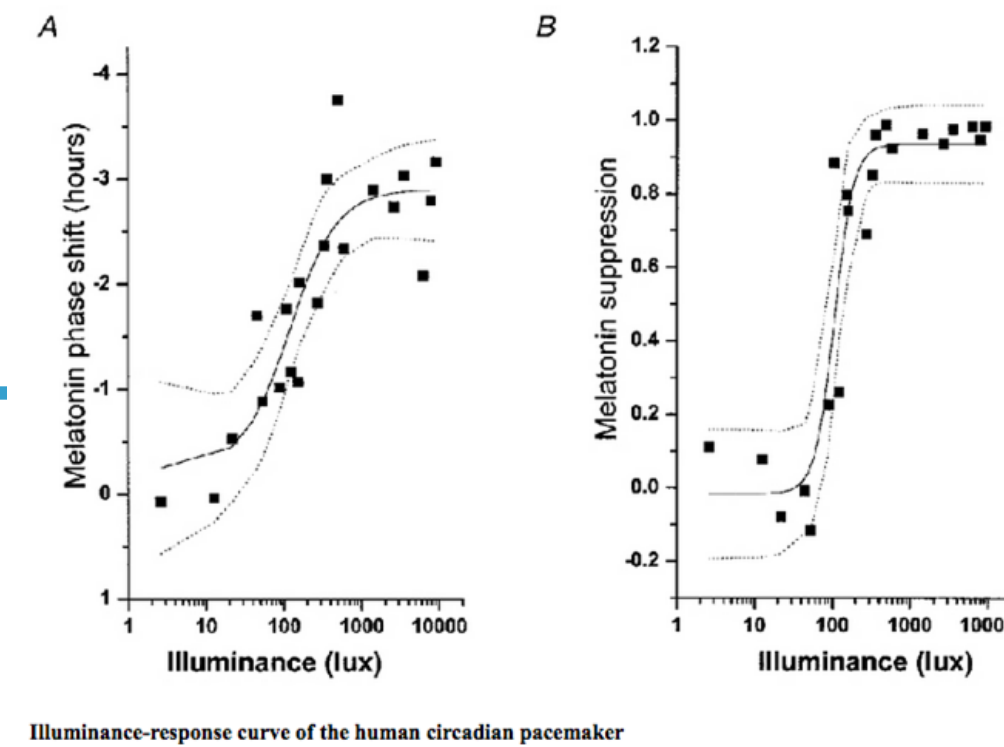
- Retinohypothalamic tract (RHT)
- Photic information transmitted to the suprachiasmatic nucleus (SCN)



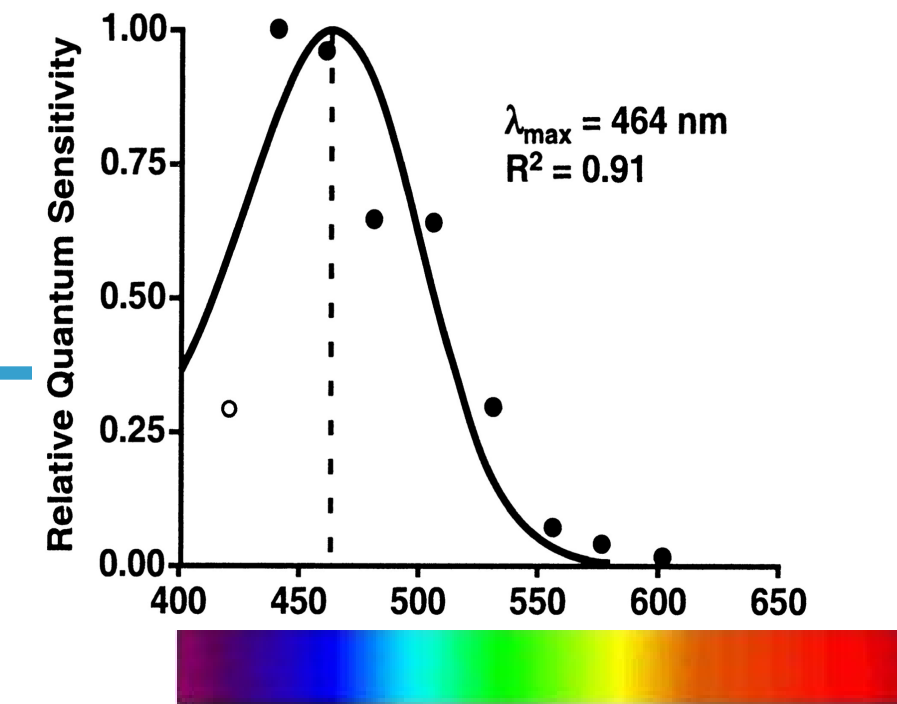
# Circadian-Targeted Light: Three Critical Factors



Timing

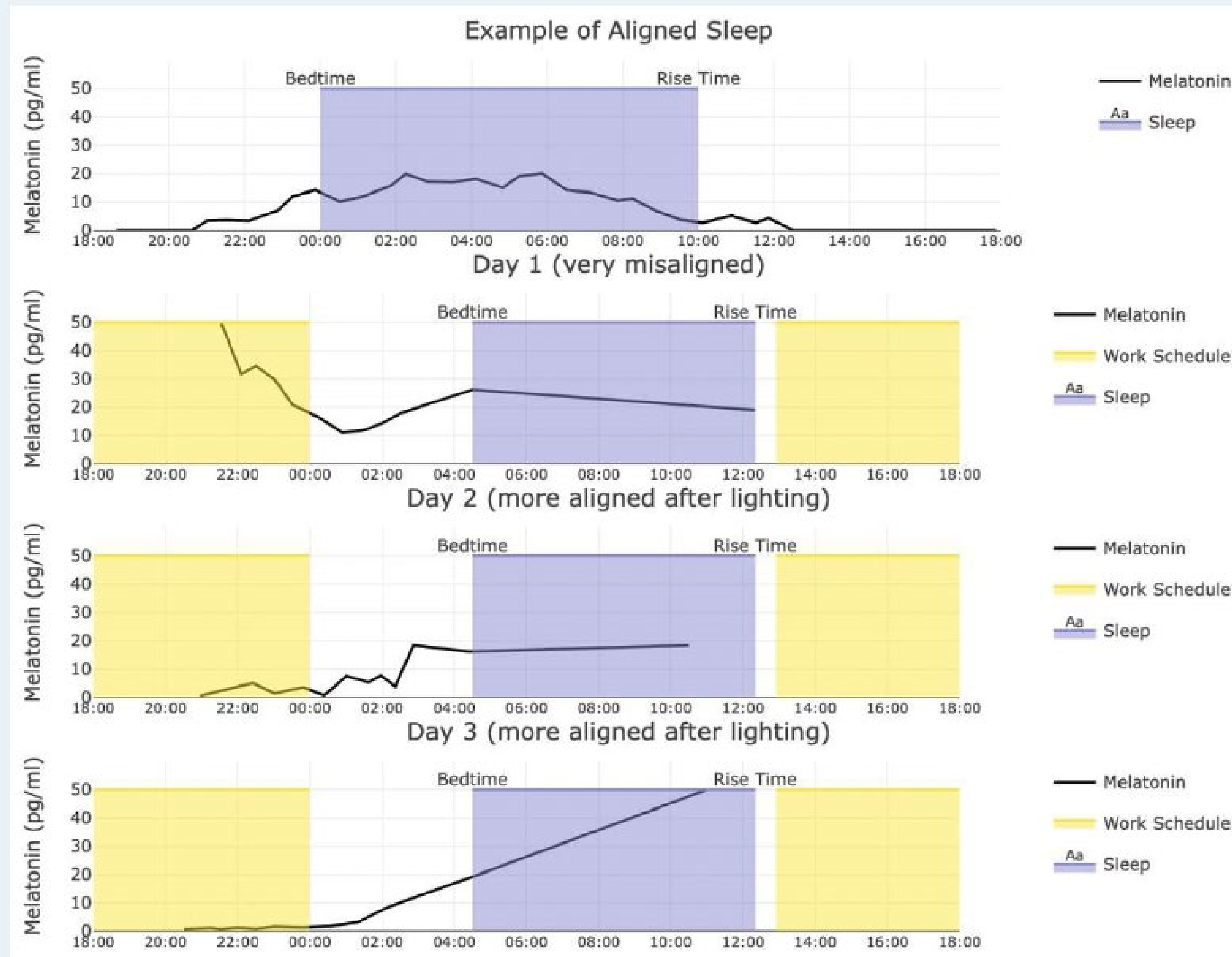


Intensity



Spectral Characteristics

# Maritime Vessel Example of Circadian-Alignment to External Schedule



# Light Considerations Related to Circadian Rhythms

- Properties to consider
  - Intensity
  - Spectrum
  - Duration
  - Timing (clock time and circadian)
  - Light history
  - Sleep history
  - Light controller/controllability of light
- Best measured at a horizontal plane (eye-level)
- Best presented as melanopic equivalent daylight (D65) illuminance (melanopic-EDI)



## Melanopic-EDI

- High melanopic-EDI delivered at the appropriate circadian phase supportive for alertness and circadian rhythm alignment
- Low melanopic EDI delivered at the appropriate circadian phase facilitates sleep initiation, consolidation, and circadian rhythm alignment

# Long Term Benefits of Application of Proper Lighting as it Relates to the Circadian System

- Long term benefits
  - Mitigate fatigue
  - Mitigate costly mistakes
  - Enhance performance
  - Improved decision-making
  - Improved mental and physical health
- Circadian-targeted lighting can help mitigate adverse consequences of circadian misalignment