

Spectral Design for the Healthcare Environment



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Learning Objectives

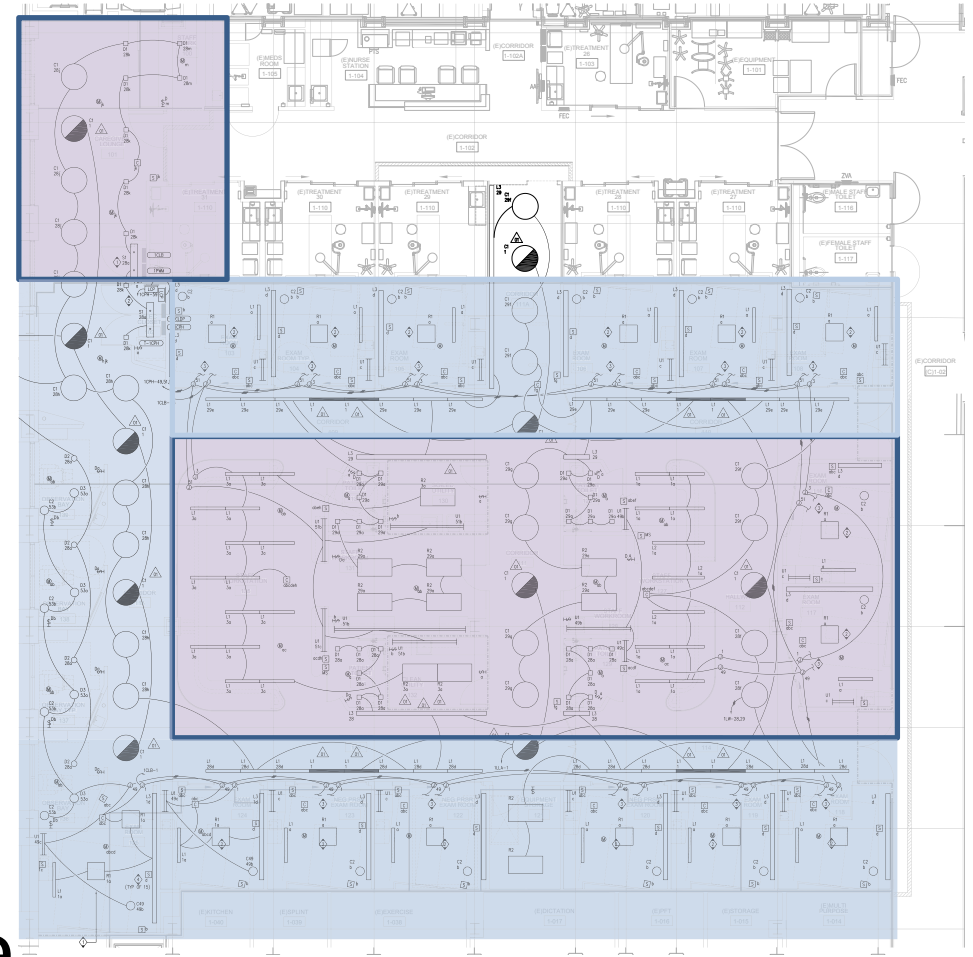
At the end of the this course, participants will be able to:

1. Understand the requirements for proper medical evaluation lighting
2. Understanding the potential for skin-based responses to light
3. Understand the considerations for elevating patient mood.
4. Understand circadian rhythm's role in the healthcare environment.

Who are we lighting for?

- Staff
 - Shift workers
 - Non-shift workers
- Patients
 - Long Stay Patients
 - Short Stay Patients

There is no single solution for everyone



Shift work

- We'll discuss towards the end
- Yes, there is a proposed solution

Patient Room



Good medical evaluation light should have:

- The ability to detect illness quickly
 - Cyanosis Observation
- The ability to clearly define veins
- Proper pupil constriction for optimal visual acuity of the doctor

Cyanosis

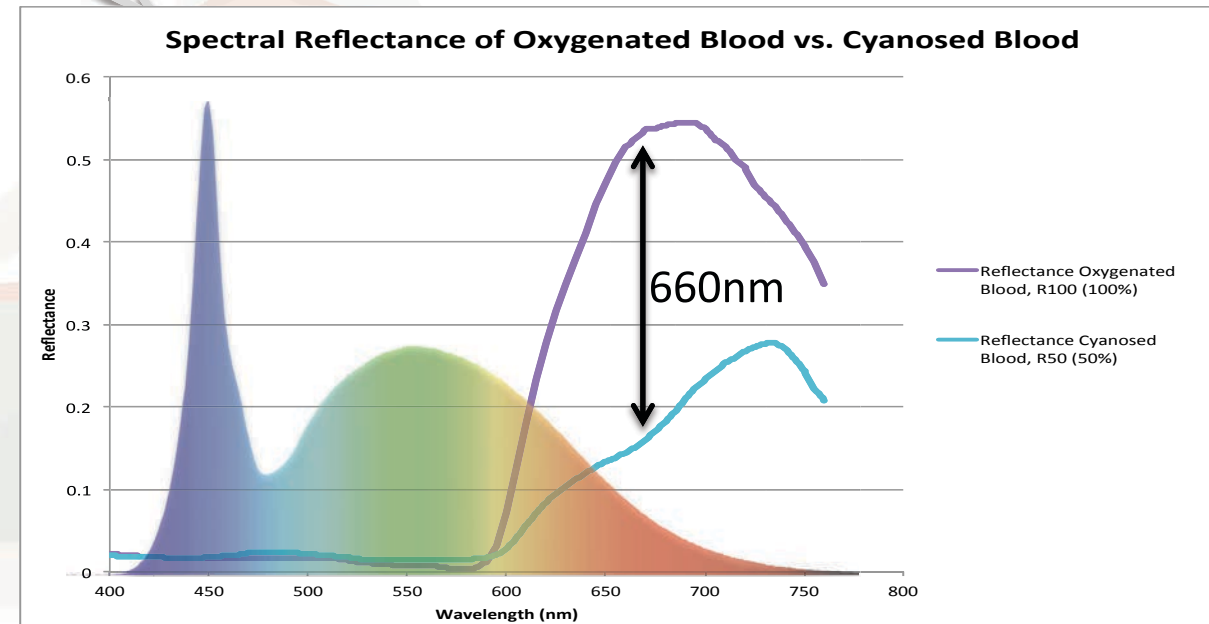
- Bluish coloration of the skin
- Signs of the following:
 - Sepsis
 - Pneumonia
 - Bronchiolitis
 - Pulmonary hypertension
 - Hypoventilation
 - COPD
 - Heart disease
 - Hypothermia
 - Arterial obstruction
 - Etc.





Good medical evaluation light should have:

- Good Cyanosis Observation Index (Midolo and Sergeyeva, 2007. Australian Hospital Engineer)
 - COI Less than 3.3
 - 660nm is key to discerning differences
- Good definition of veins
 - Similar to Cyanosis
 - Various levels of deoxygenation
- High CRI/TM-30



Reflectance of cyanosed blood compared to oxygenated blood

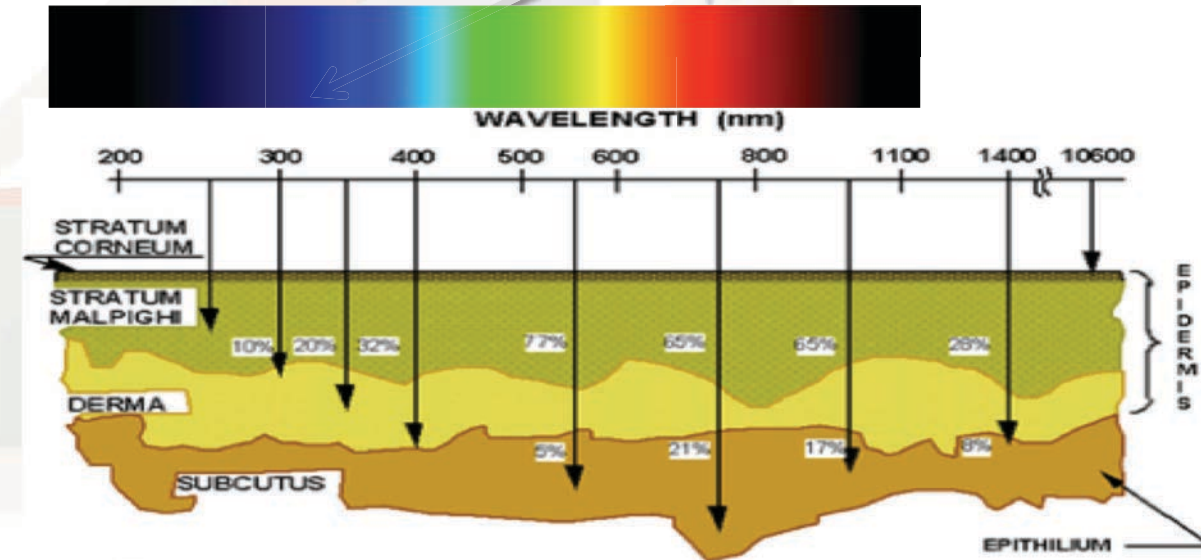
Cool “Daytime” White LED Light wont detect Cyanosis or Veins



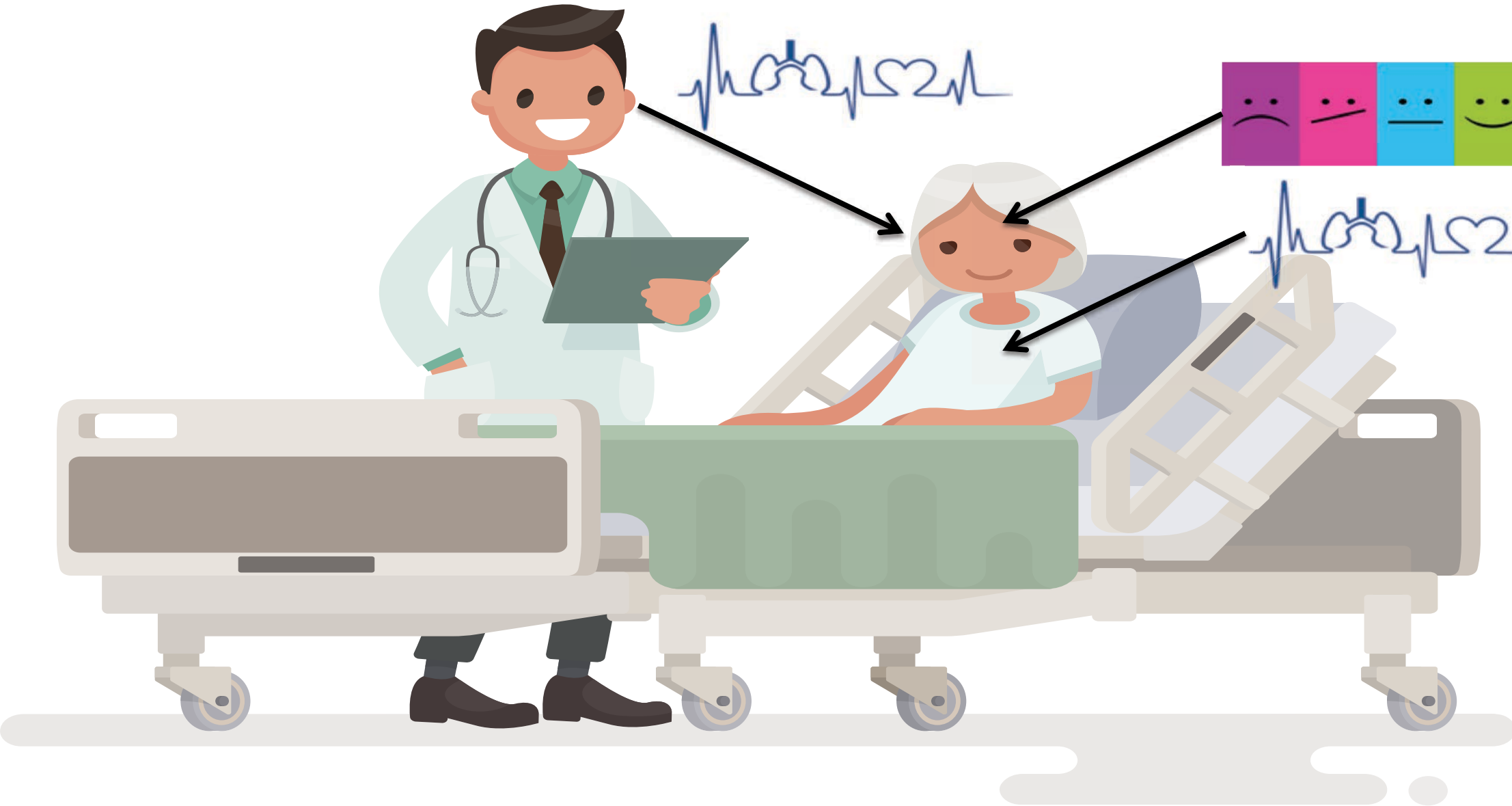


Far Red Health Benefits

- Far red penetrates the skin’s “optic window”, stimulating mitochondria (Sommer et al. 2001)
 - Increased energy levels (Karu et al. 1995)
 - Reduced oxidative stress (Darvey, 1998)
 - i.e. antioxidant properties
 - Reduced eye damage (Sivapathasuntharam et al. 2017)
 - Faster healing (Summer et al. 2001)
 - Collagen enhancement (Barolet et al. 2009)
 - Intercellular signaling throughout the body (Karu 2010)

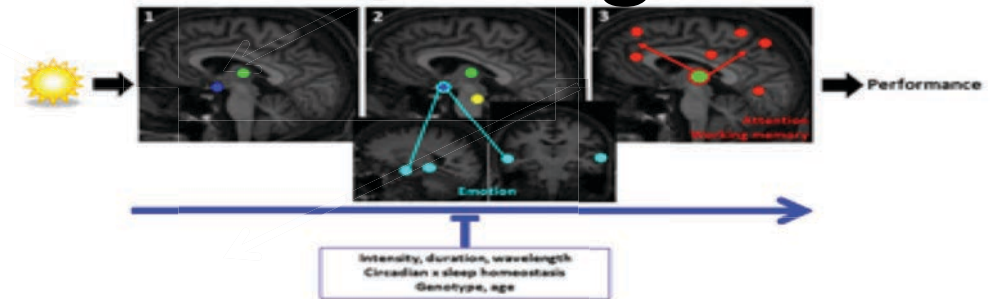


More research needs to be done on lower intensity red light





Measured Acute Brain Effects of Light



[Gaggioni et al. 2014, Frontiers in Systems Neuroscience]

fMRI neural correlates reveal light response in the brain (Gaggioni et al. 2014, FISN)

Increased Alertness

Increased working memory

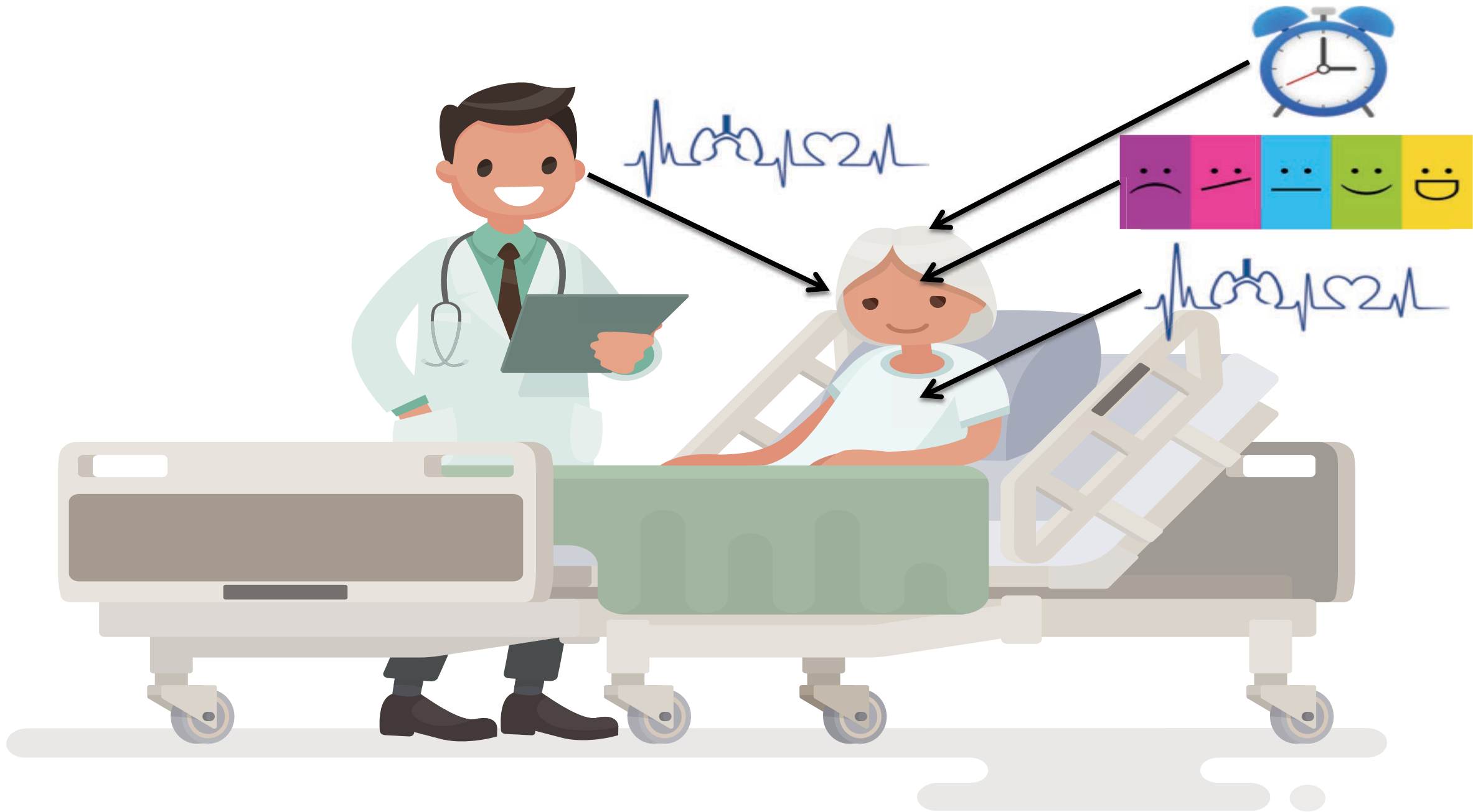
(i.e. figuring stuff out in your head)

Increase emotional response

(i.e. better mood)

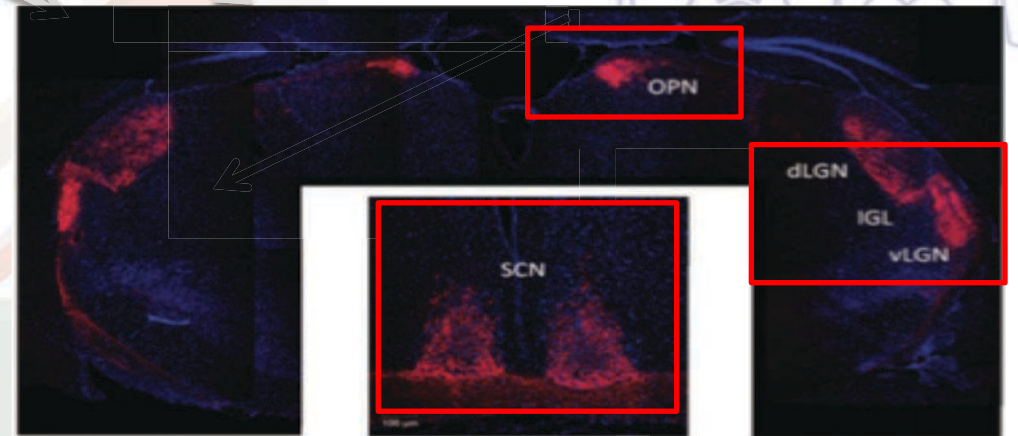
These processes are driven by newly found non image forming photoreceptors (ipRGC)

Increased light levels correlate to improved sleep, fatigue, mood, and pain (Bernhofer et al. 2014, Journal of Advanced Nursing)





Additional functions of the newly found photoreceptor



[Hughes et al. 2016, nature publishing group]

OPN: Drives Pupillary Light Reflex
Important for visual acuity

LGN: Brightness Perception

SCN: Location of Master Clock
Encodes brightness information
Entrains the circadian clock



What is the Circadian Clock?



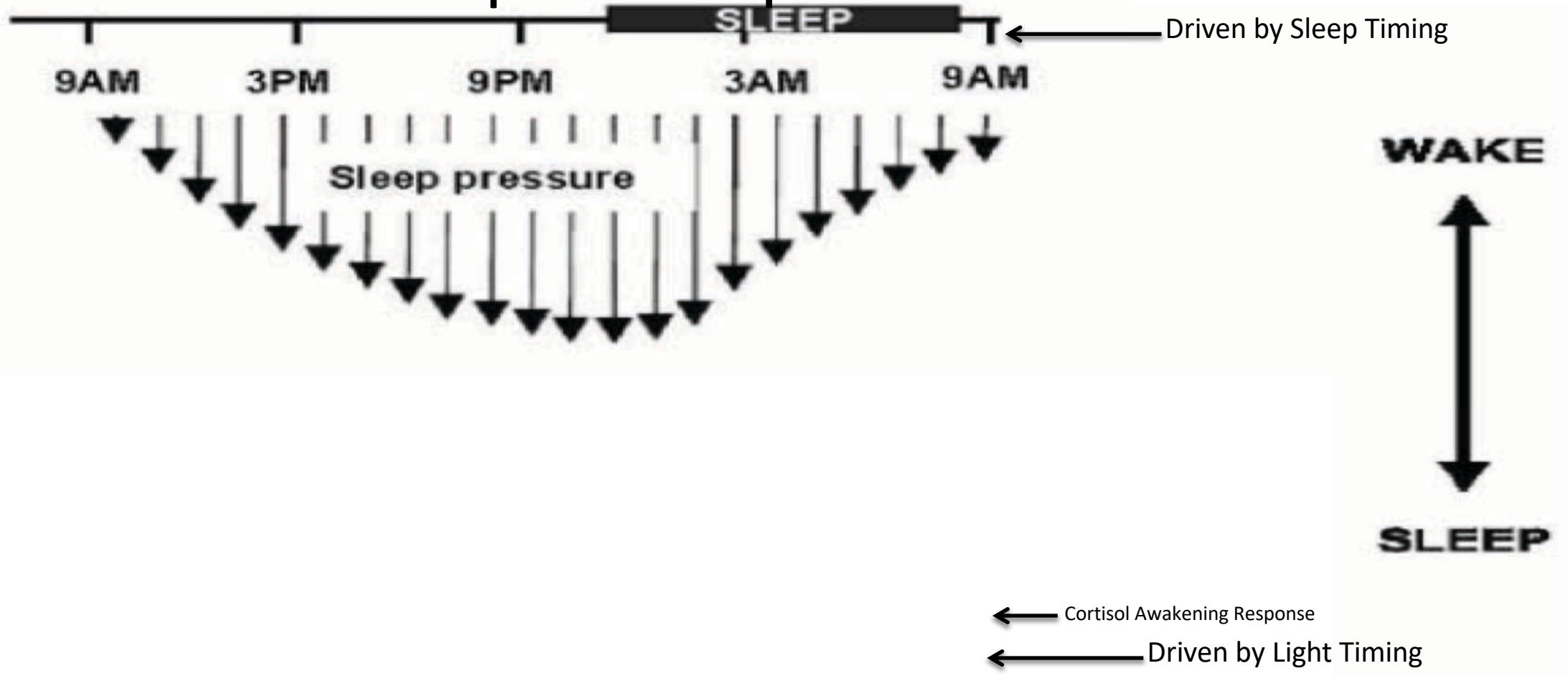
Strategically times the occurrence of biological processes to conserve resources

- Hormone Secretion
- Metabolism
- Alertness
- Sleep
- Many Others (enzyme activity, cell proliferation, bodily function, etc.)
- Large percent of genetic expression is circadian (Zhang et al, 2014.)
- Chronotherapy is an emerging field

Important to create a robust circadian signal: Better sleep, better healing, better chronotherapy



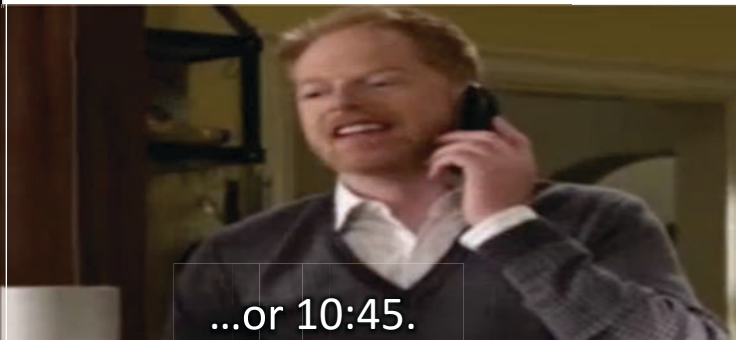
Sleep: a two-process model



[Schmidt et al. 2007, Cognitive Neuropsychology]

Chronotype Differences

Cam and Mitch making dinner reservations – Modern Family



Our self selected preference for bed time and wake time

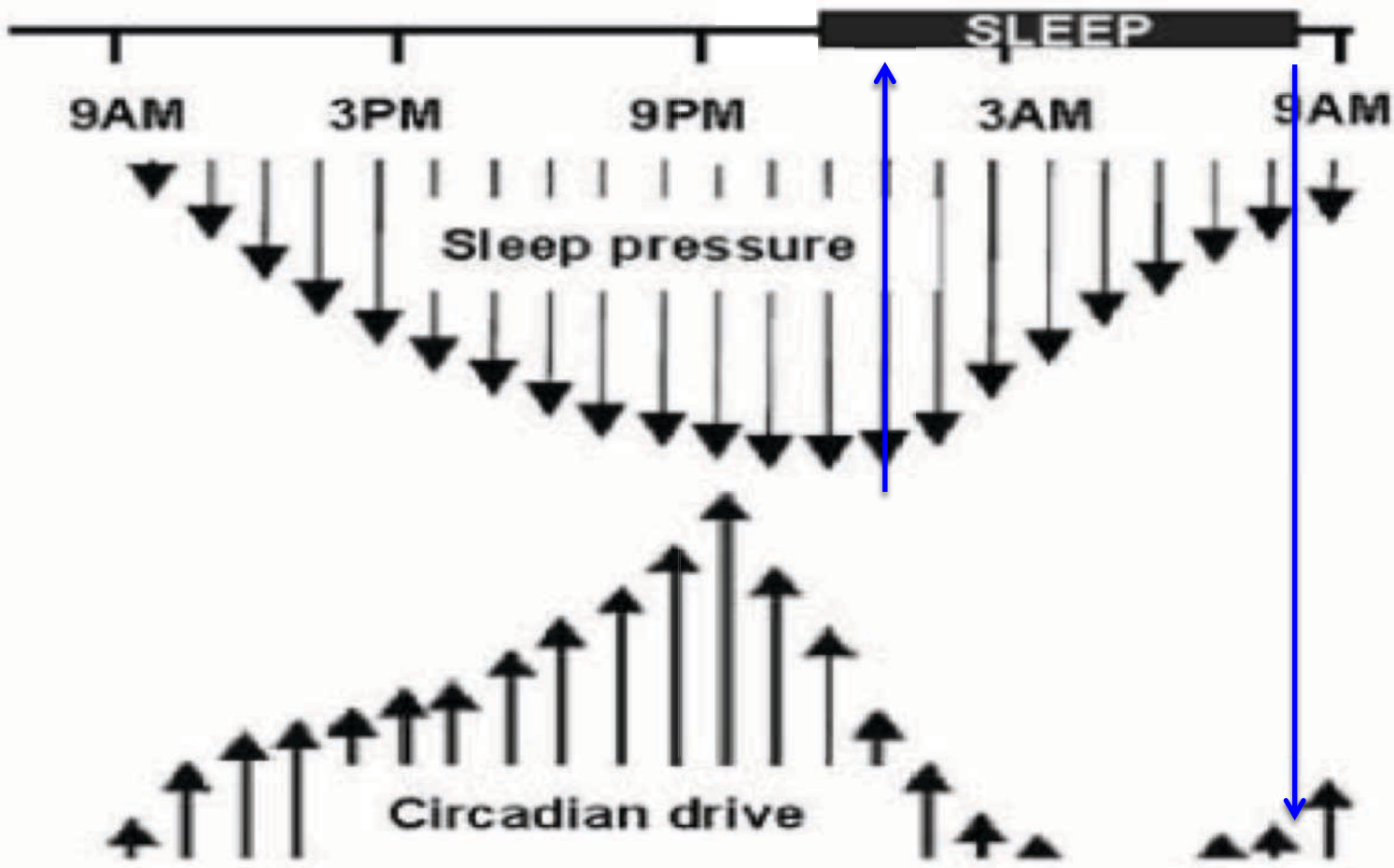
Age and Sex can help predict our preferences

Most of the time our social requirements and these preferences don't agree

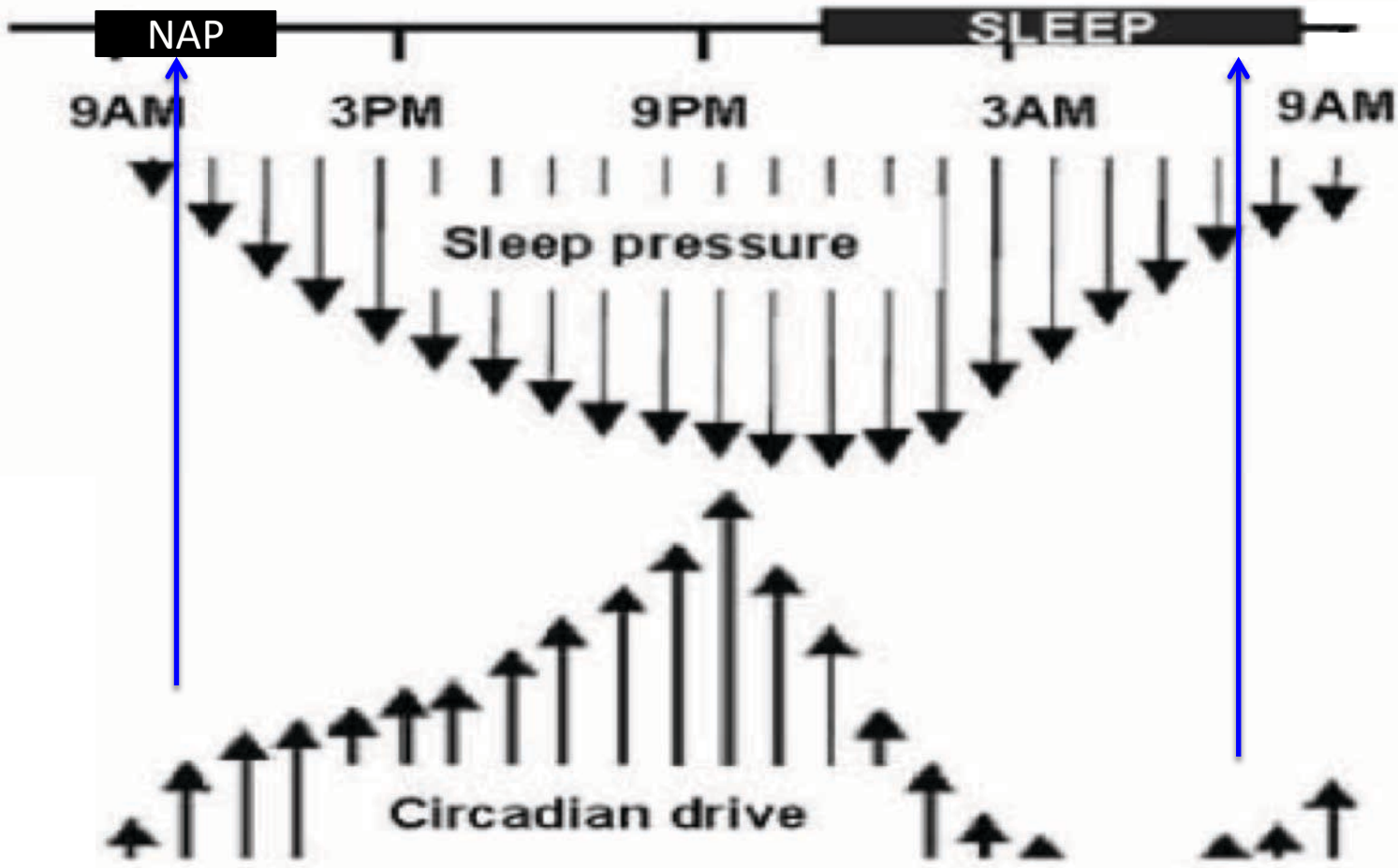
This misalignment leads to social jet lag

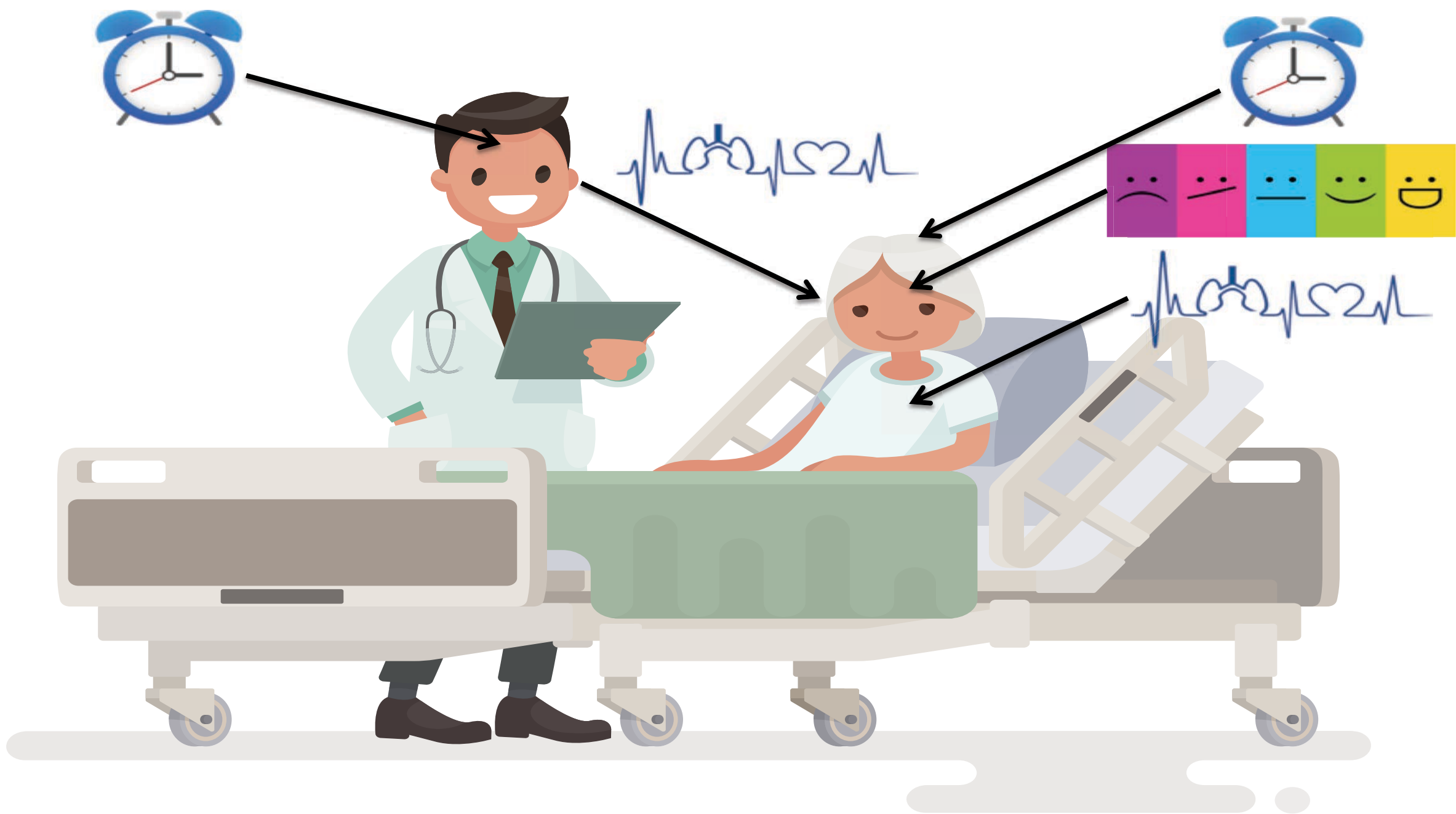
Social Jet lag is difference in sleep timing on work days versus free days.

LEDucation Night Owls



LEDucation
Early Birds





Shift Work

Aligning Work and Circadian Time in Shift Workers Improves Sleep and Reduces Circadian Disruption

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<http://dx.doi.org/10.1016/j.cub.2015.01.064>

Results:

- Night owls performed better on the night shift compared to early birds (sleep and circadian disruption)
- Early birds performed better on early morning shifts compared to night owls (sleep and circadian disruption)

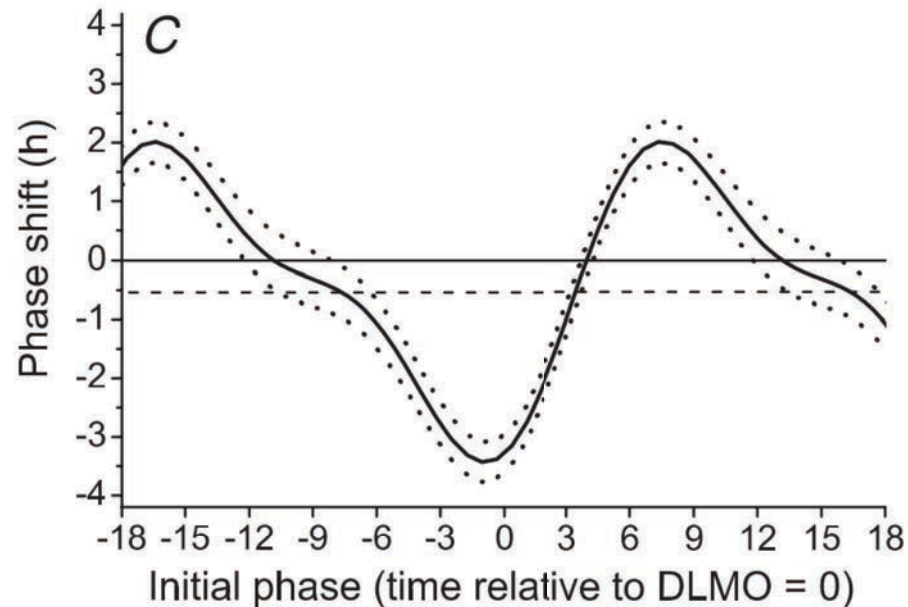
Shift work recommendations (operational)

- No rotating shift work
 - If that's not operationally feasible, the compromise is shift back and forth between two shifts (i.e. "day" and "swing" or "day" and "night" rather than "day", "swing", "night")
- Schedule based on chronotype
 - Night Owls will do better on the night shift (Vetter et al. 2015)
 - Early birds will do better on the graveyard shift (Vetter et al. 2015)
- You CAN shift these workers circadian rhythms to support their work schedule, but DON'T DO IT.
 - Compliance from shifting workers is tremendously low
 - Why? It requires them to stay on shifted rhythm during their off days too.

Shift work recommendations (lighting)

- So here's what you can do:
- We can shift rhythms to be early or late chronotypes
 - Light at night delays the circadian clock
 - Light early morning advances the circadian clock
- Create a large day/night differentiation
- Create a long day (4am to 10pm)
- Ideally paired with blue-blocking sunglasses if driving home while the sun is up

How to shift the clock?



Our daytime receptors look for daytime signals and sync our body to it.

When they receive daytime signals BEFORE they expect it. Our Clock SPEED UP (advance) to catch up.

When they receive daytime signals AFTER they expect it. Our clock SLOWS DOWN (delay) to not move ahead.

Shift work: Important Questions

- 12 hour shifts or 8 hours shifts?
- Dedicated shifts or rotating shifts?
- What hours are the shifts?
 - Example: day: 7a-3pm, swing: 3-11p, night: 11p-7a

Lighting Paradigm for (3) 8-hour shifts

	Nighttime			Daytime Lighting Scheme															Nighttime Lighting Scheme					
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Monday	Evening Shift			Day Shift												Swing Shift								
Tuesday	Evening Shift			Day Shift												Swing Shift								
Wednesday	Evening Shift			Day Shift												Swing Shift								
Thursday	Evening Shift			Day Shift												Swing Shift								
Friday	Evening Shift			Day Shift												Swing Shift								
Saturday	Evening Shift			Day Shift												Swing Shift								
Sunday	Evening Shift			Day Shift												Swing Shift								

- Evening shift will need to be advanced to become more morning type
- Swing Shift will need to be delayed to be more evening type
- Day shift, just provide a high daytime signal

Lighting Paradigm for (2) 12-hour shifts

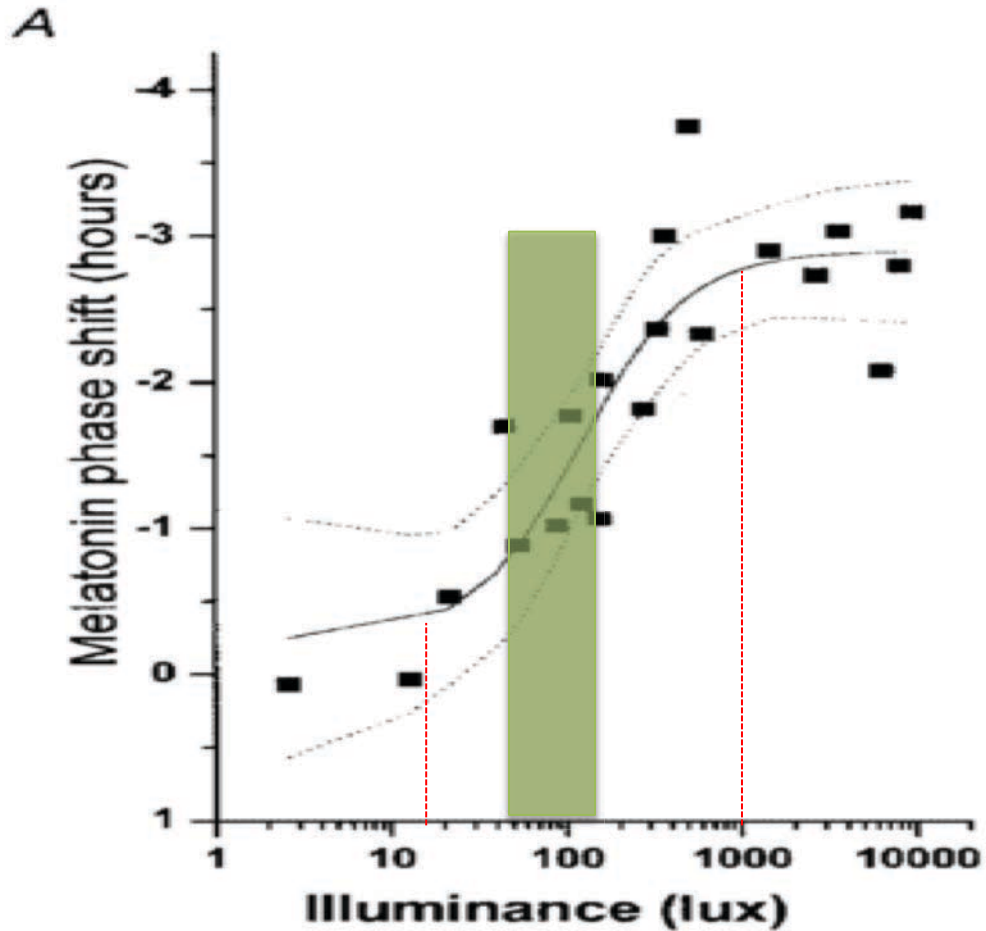
	Nighttime Lighting Scheme					Daytime Lighting Scheme																		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Monday	Night Shift					Day Shift												Night Shift						
Tuesday	Night Shift					Day Shift												Night Shift						
Wednesday	Night Shift					Day Shift												Night Shift						
Thursday	Night Shift					Day Shift												Night Shift						
Friday	Night Shift					Day Shift												Night Shift						
Saturday	Night Shift					Day Shift												Night Shift						
Sunday	Night Shift					Day Shift												Night Shift						

- Night Shift will need to be delayed to be more evening type
- Avoid any potential morning stimulation to the night shift
- Provide access to blue-blocking for night shift workers

How do we create daytime and nighttime lighting schemes?

- Intensity
- Spectrum
- Spatial Distribution (directionality)

Intensity



Sigmoidal Response Curve:

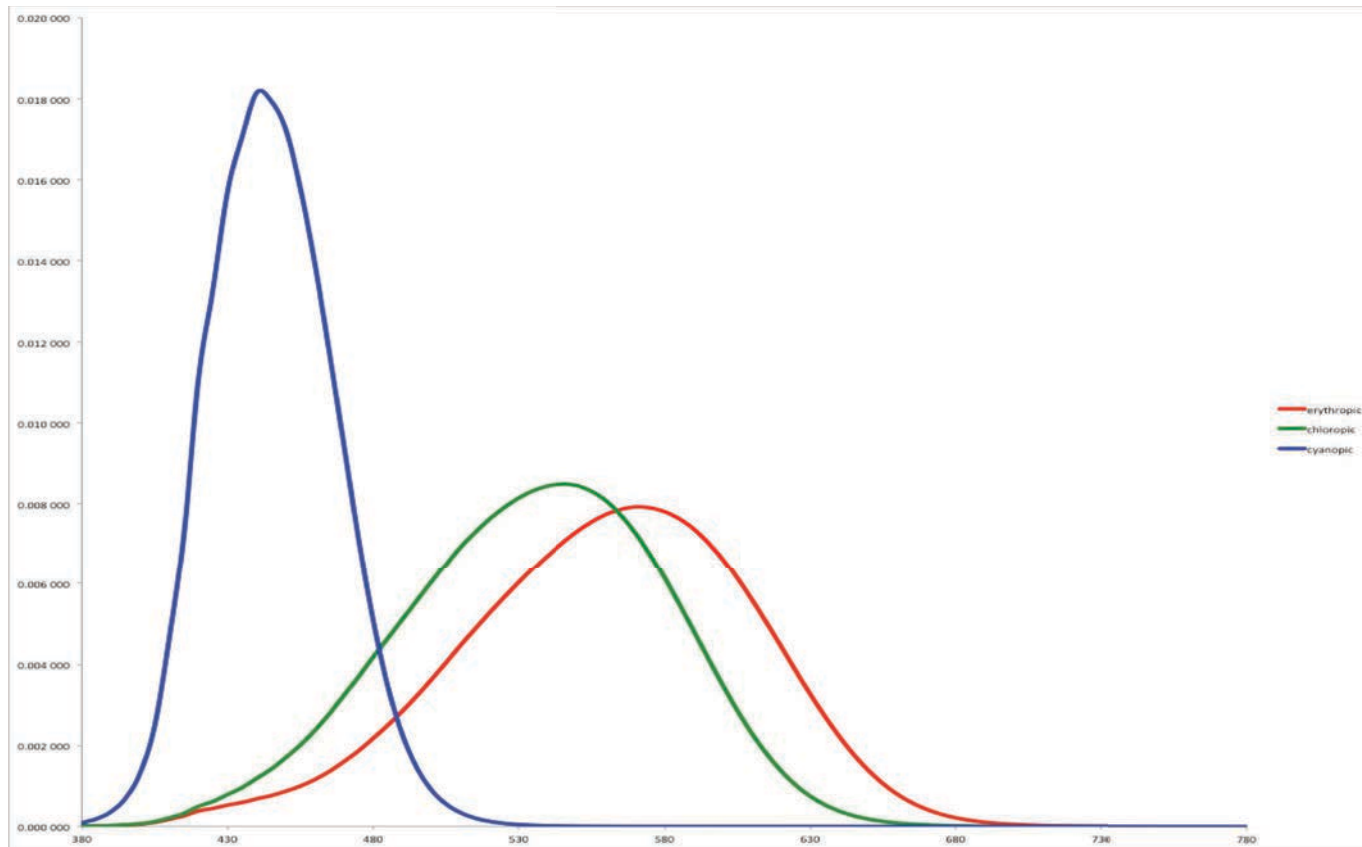
- Floor at < 15 vertical lux
- Ceiling at > 1,000 vertical lux
- Linear transition from 50 to 500 vertical lux

Try to create a clear delineation of day versus night

(Zeitzer et al. 2000)

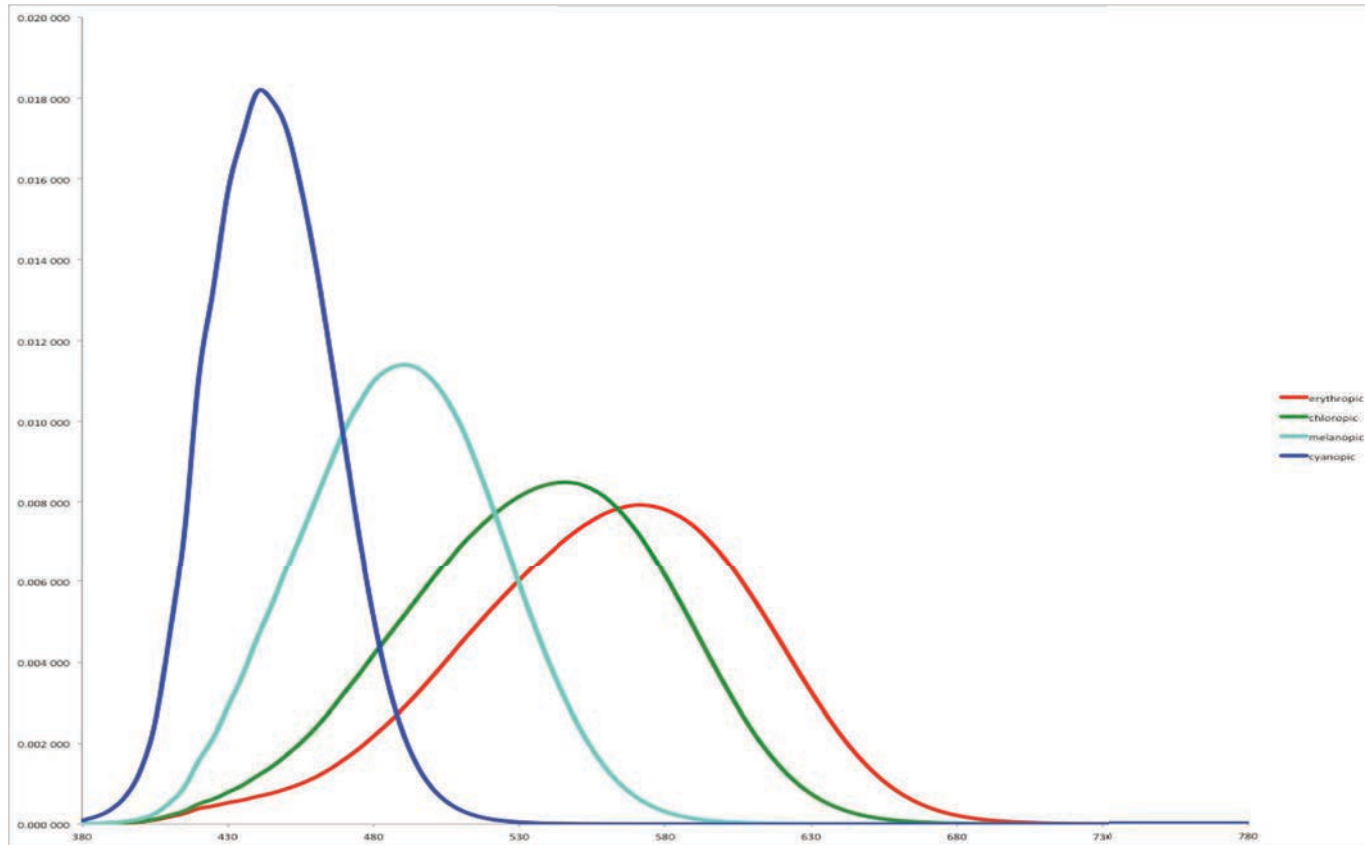
Spectrum

Cones for color vision



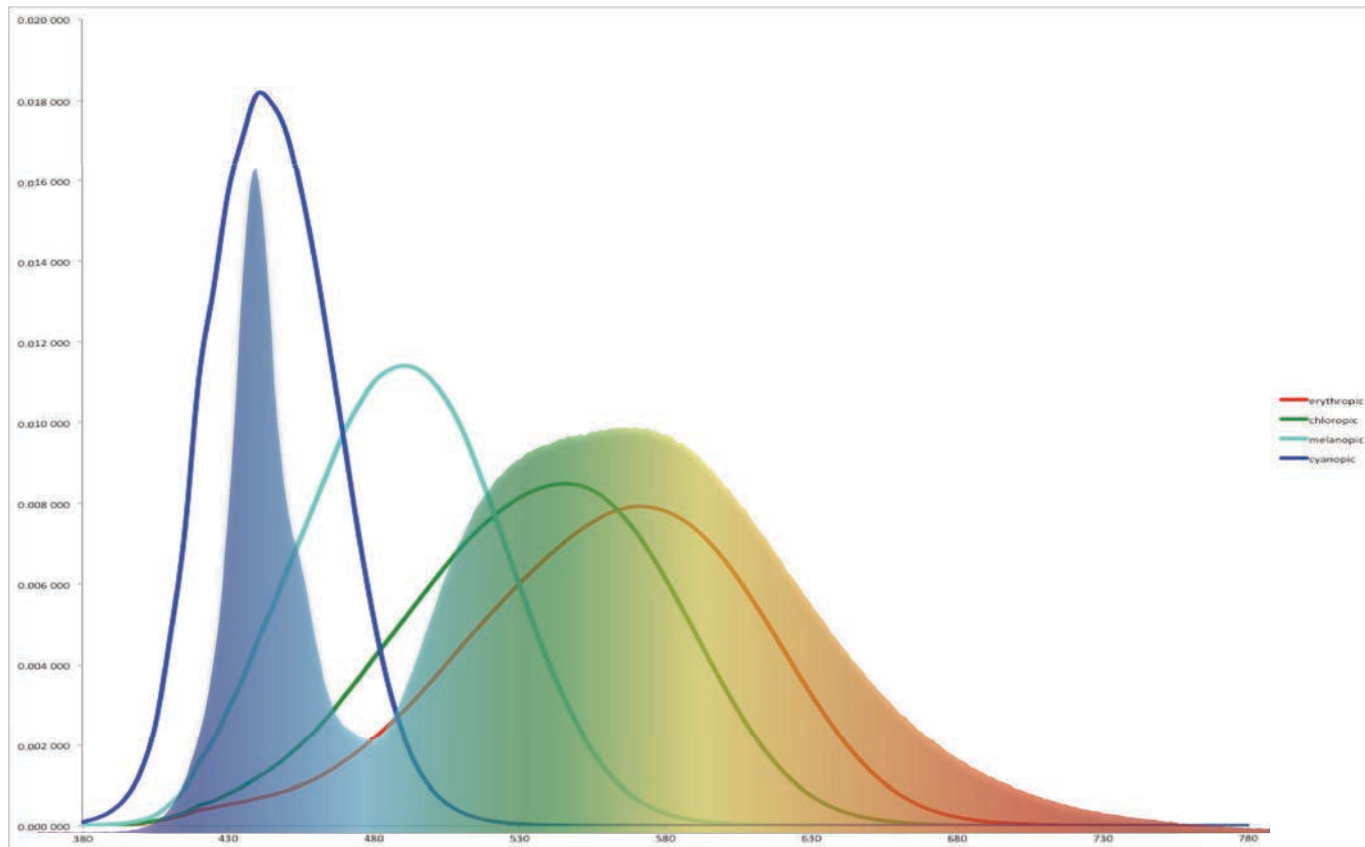
[Lucas et al. 2014, Trends in Neuroscience]

Addition of Melanopsin



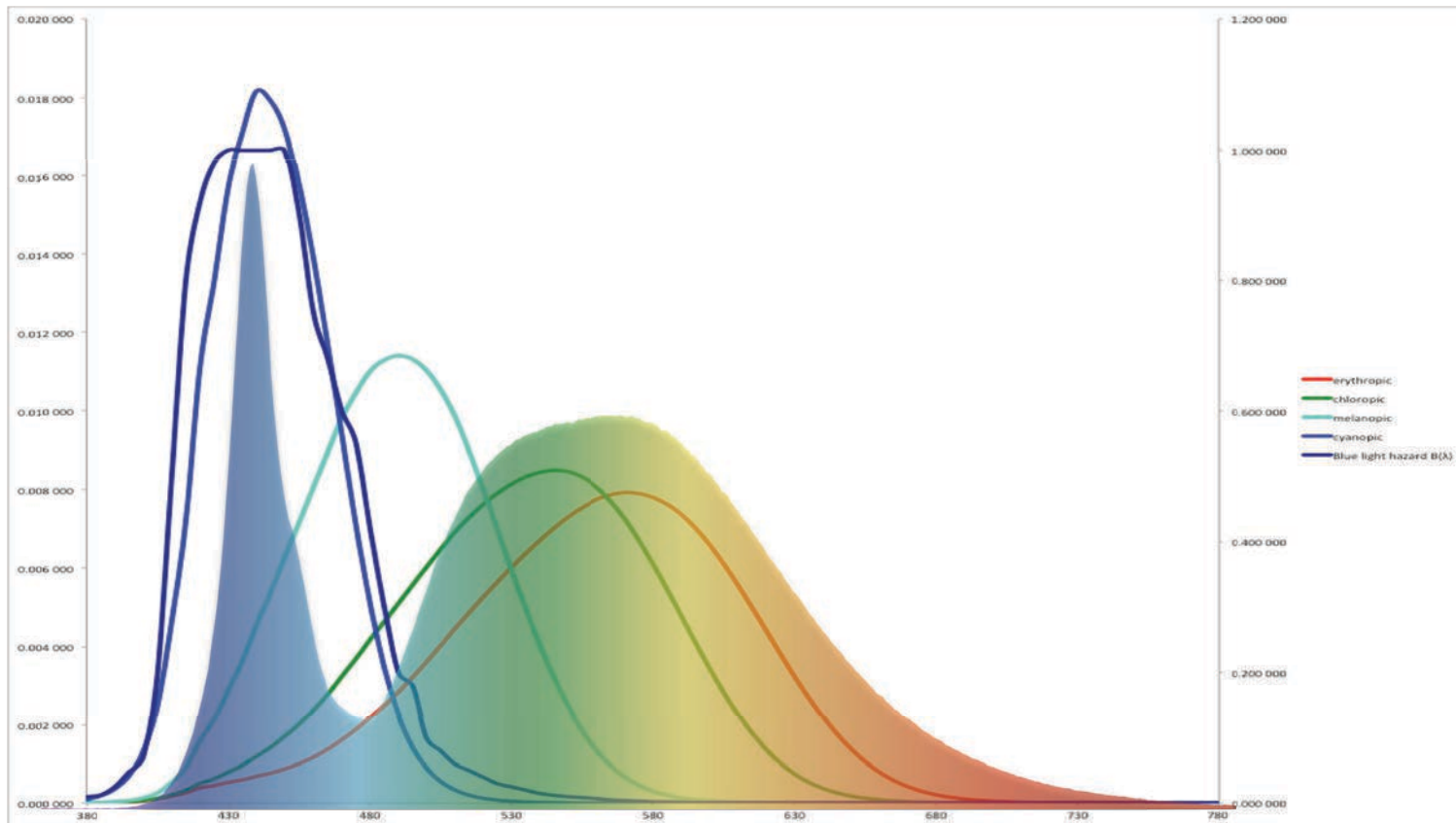
[Lucas et al. 2014, Trends in Neuroscience]

5000K “Daylight” LED



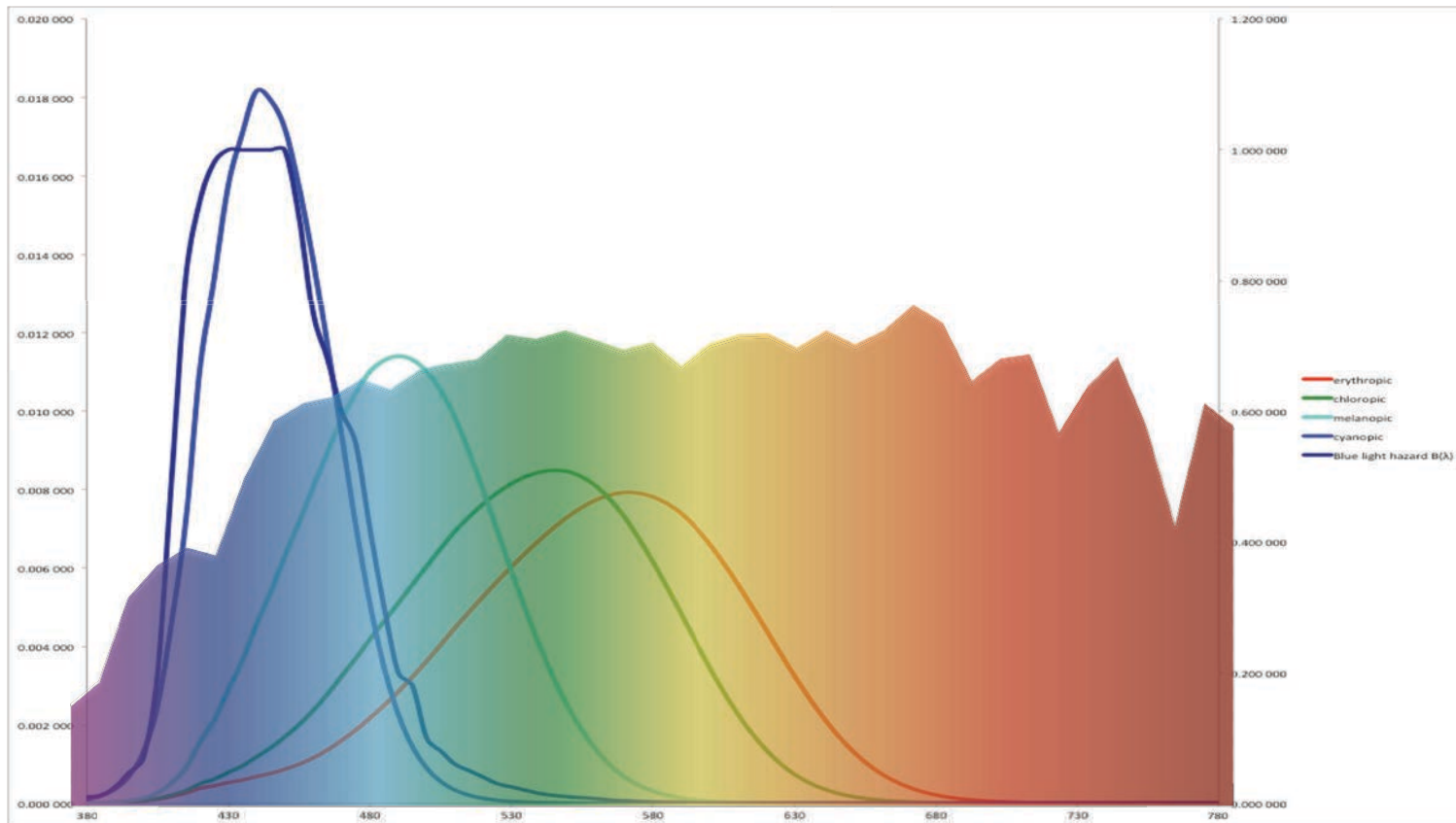
[Lucas et al. 2014, Trends in Neuroscience]

Bad Blue for reference



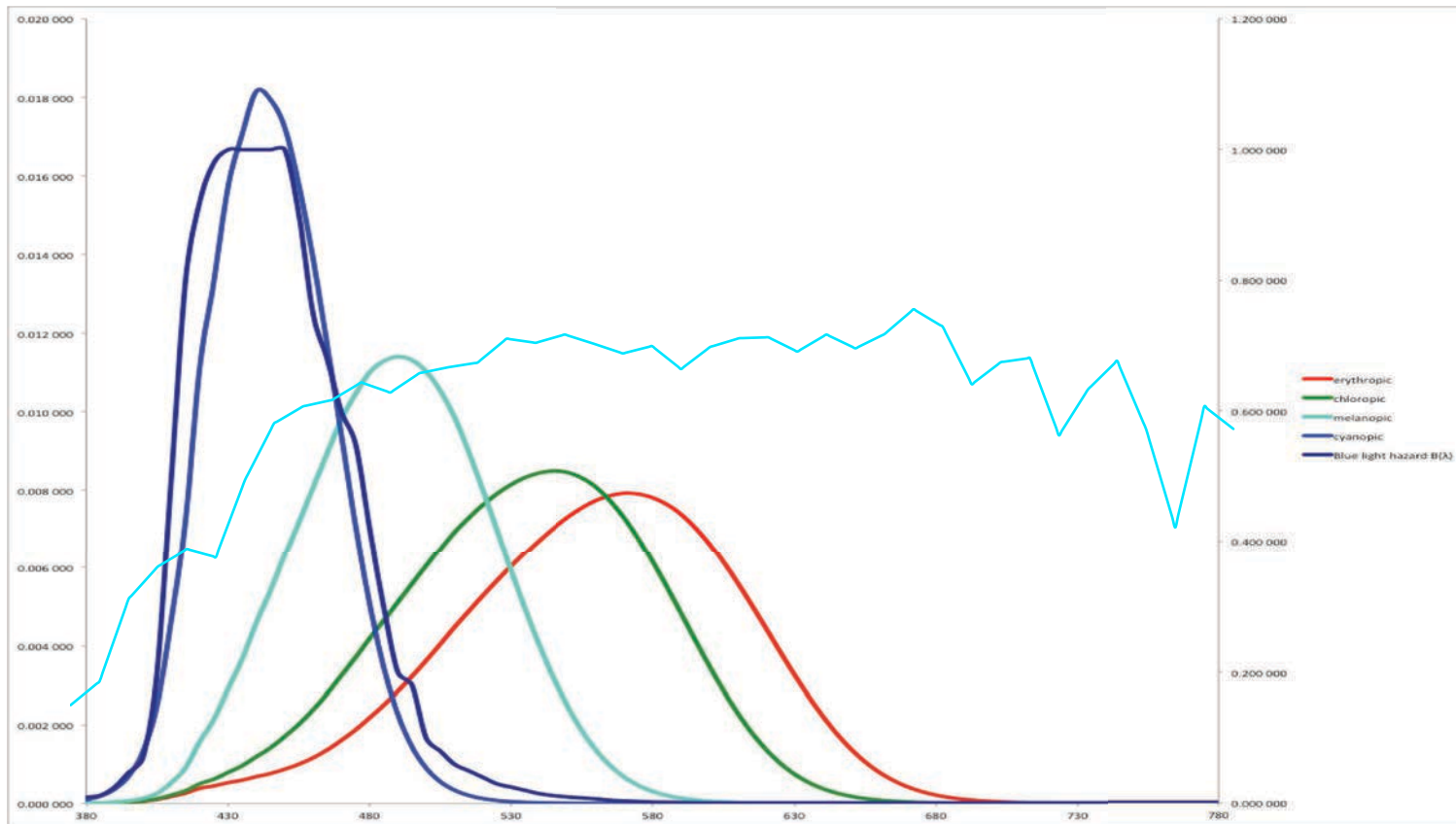
[Lucas et al. 2014, Trends in Neuroscience]

5000K Daylight



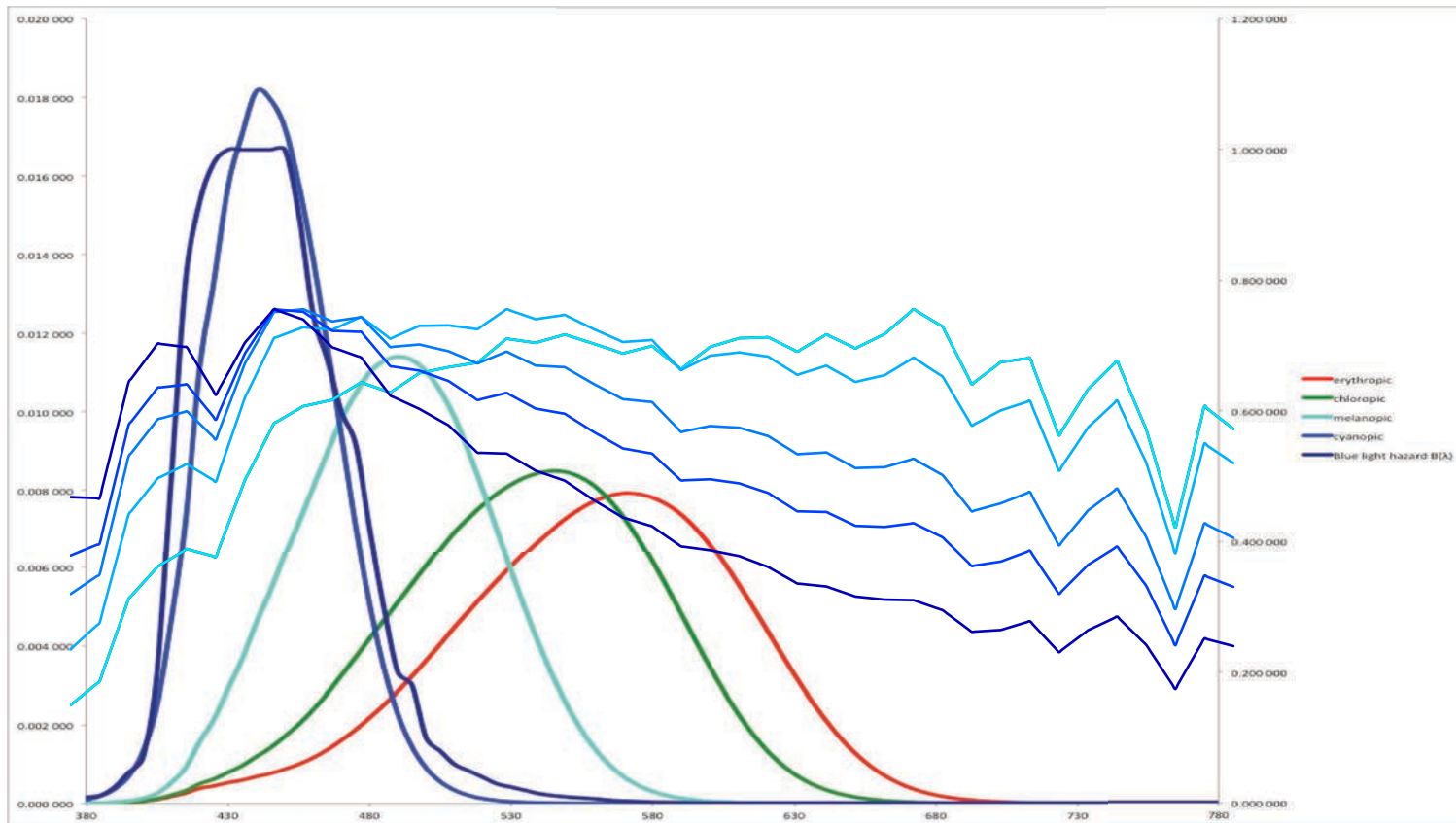
[Lucas et al. 2014, Trends in Neuroscience]

5000K Daylight



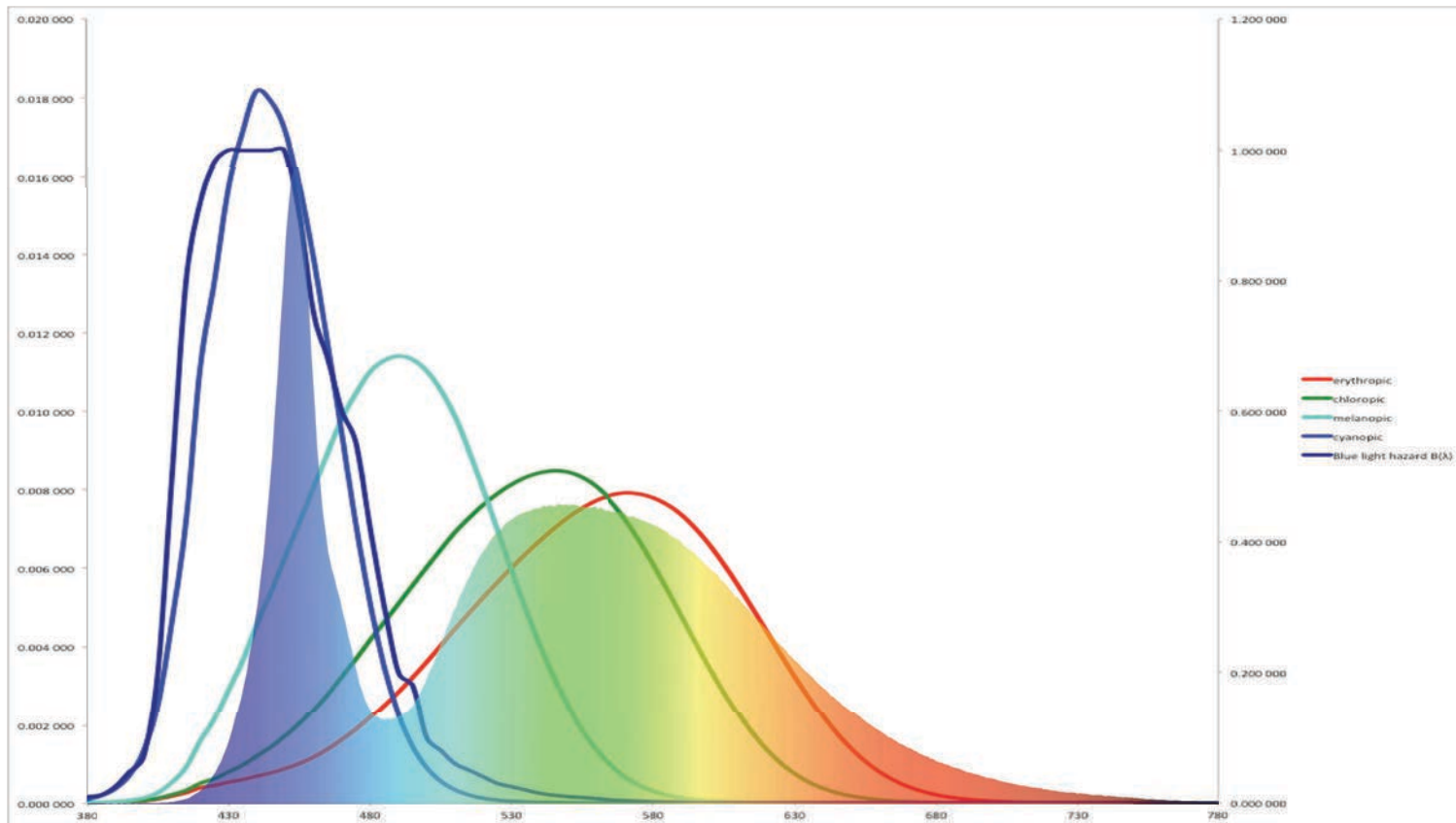
[Lucas et al. 2014, Trends in Neuroscience]

5000K thru 10,000K Daylight



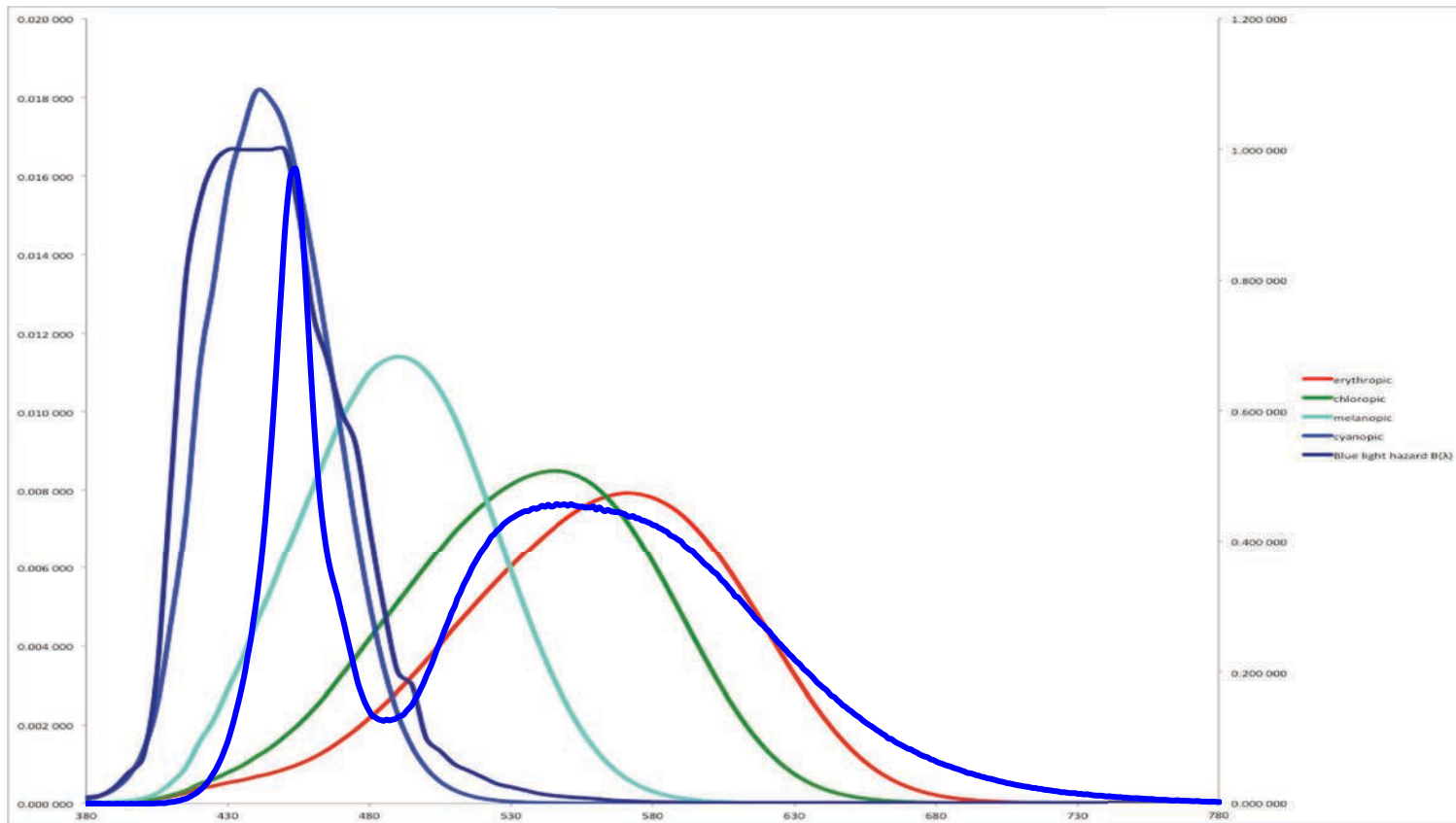
[Lucas et al. 2014, Trends in Neuroscience]

LED Color Changing



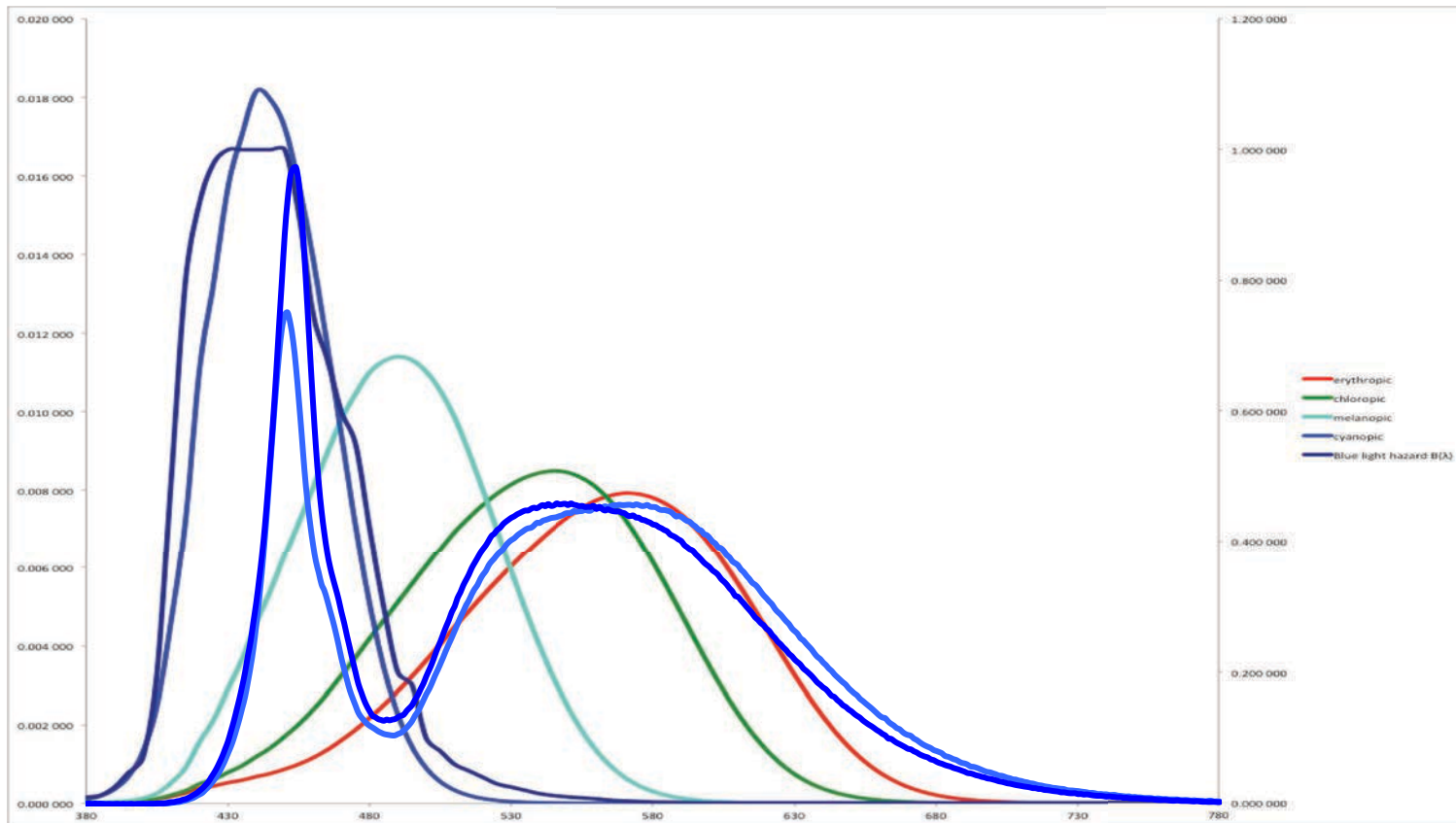
[Lucas et al. 2014, Trends in Neuroscience]

6500K LED



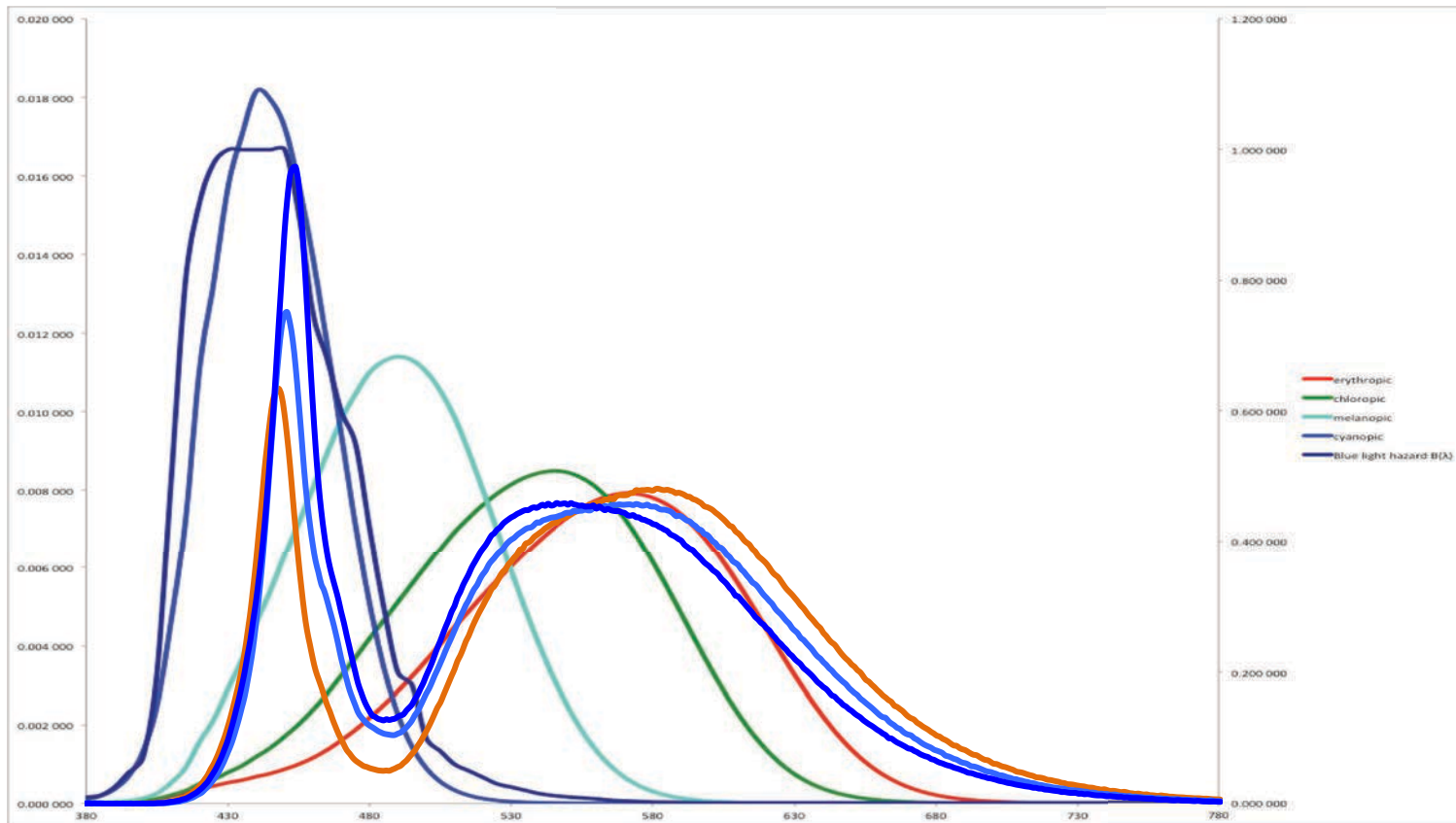
[Lucas et al. 2014, Trends in Neuroscience]

5000K LED



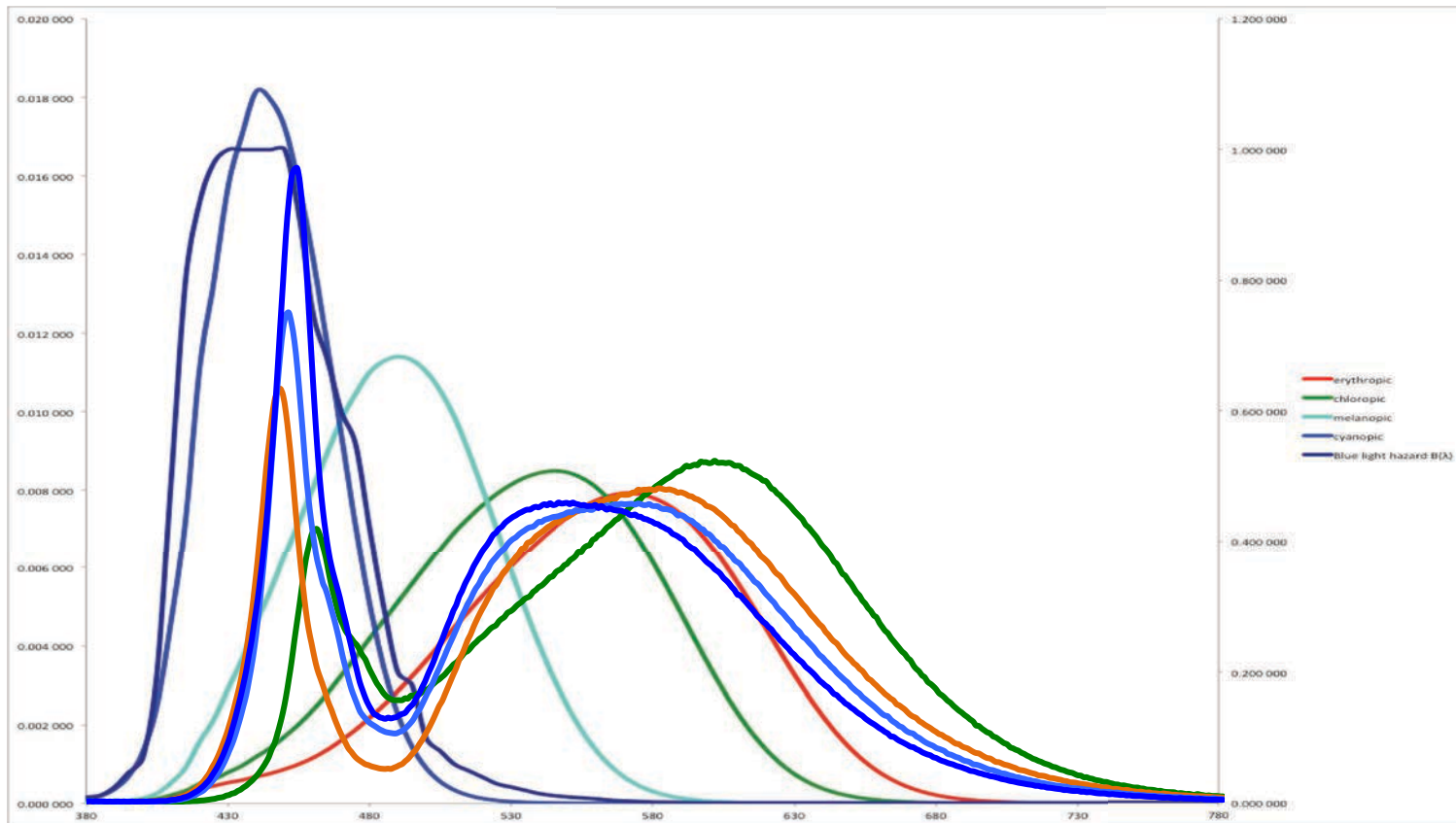
[Lucas et al. 2014, Trends in Neuroscience]

4000K LED



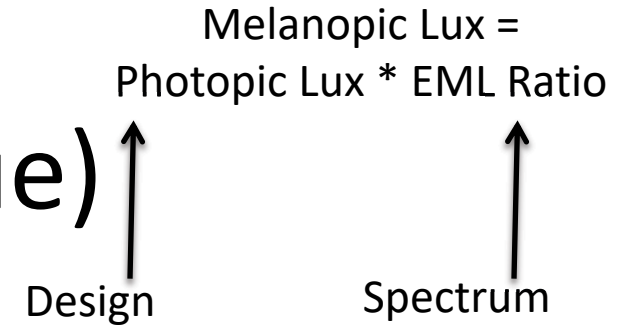
[Lucas et al. 2014, Trends in Neuroscience]

3500K LED

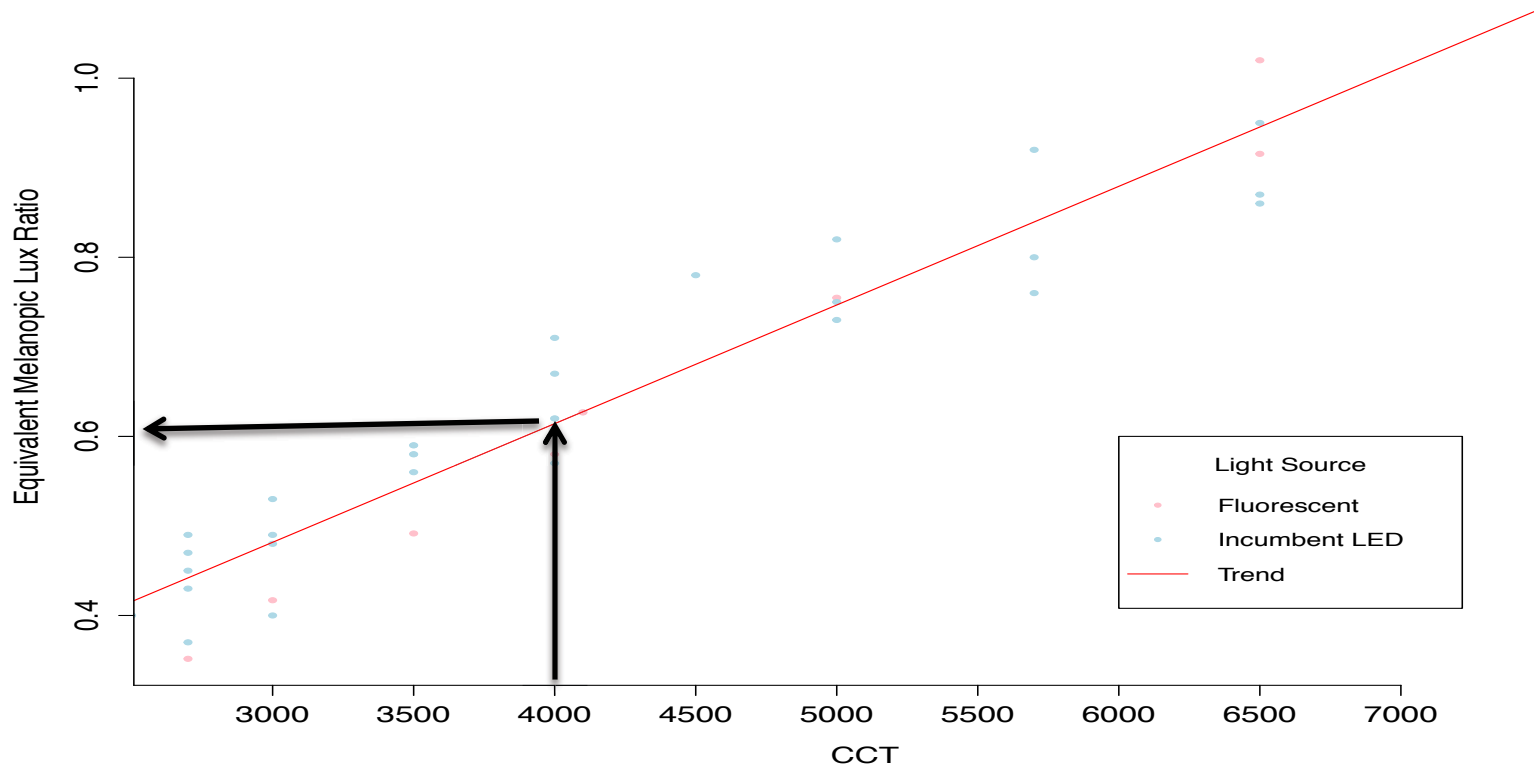


[Lucas et al. 2014, Trends in Neuroscience]

Melanopic Lux (Good Blue)



Equivalent Melanopic Lux (EML) Ratio versus CCT



Example:

200 vertical melanopic lux target
Customer wants 4000K

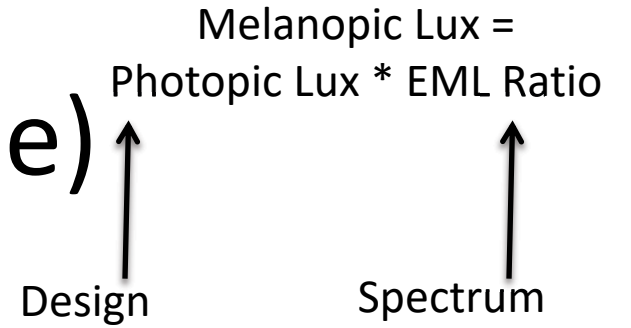
EML ~ 0.61

$$\frac{200}{0.61} = \text{Photopic Lux} \times \frac{0.61}{0.61}$$

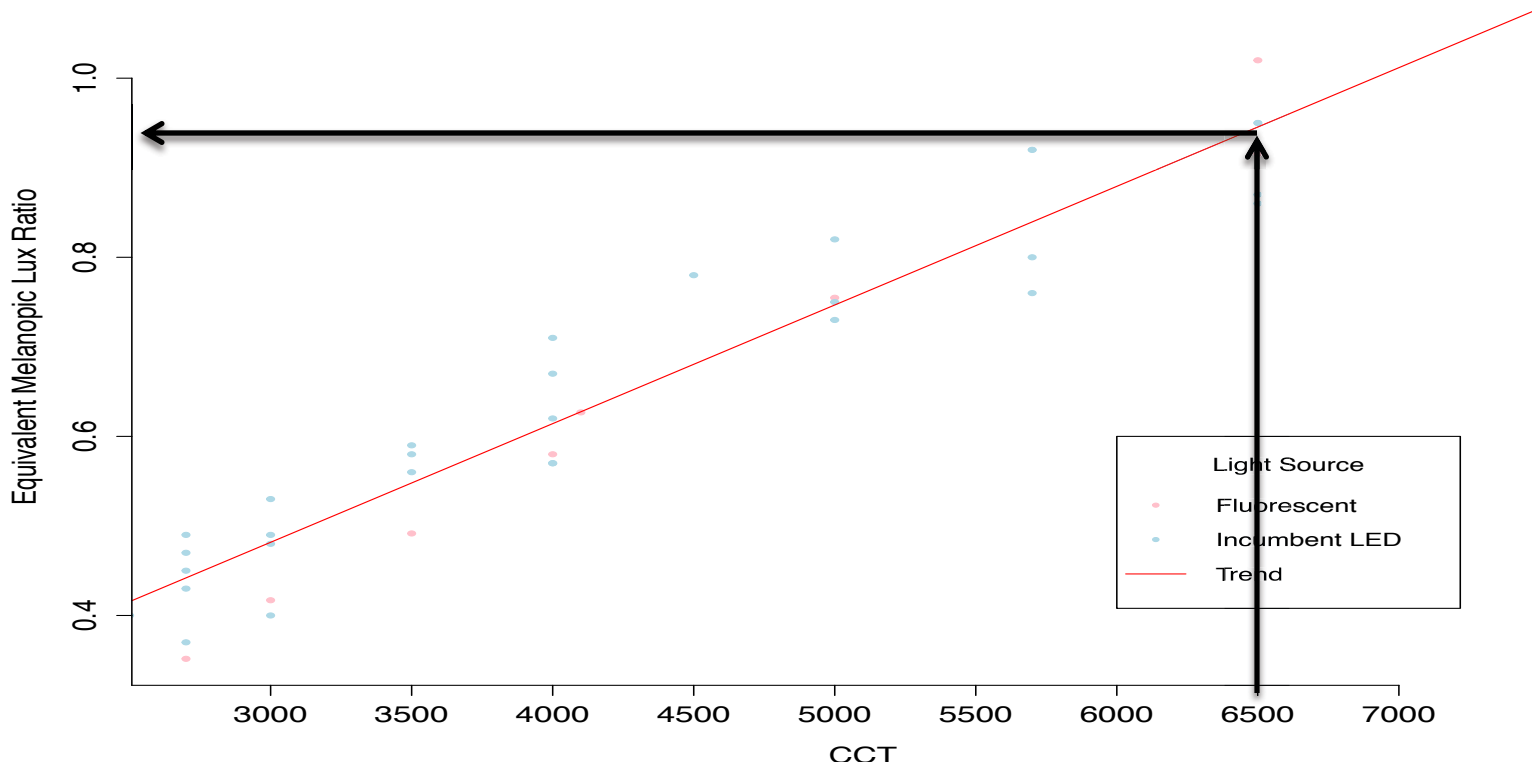
328 = Photopic Lux

30 = Foot Candles (vertical)

Melanopic Lux (Good Blue)



Equivalent Melanopic Lux (EML) Ratio versus CCT



This is a little better, but cringe-worthy 6500K

Another Example:

200 vertical melanopic lux target

Customer will live with 6500K

EML ~ 0.93

$$\frac{200}{0.93} = \text{Photopic Lux} \times \frac{0.93}{0.93}$$

215 = Photopic Lux

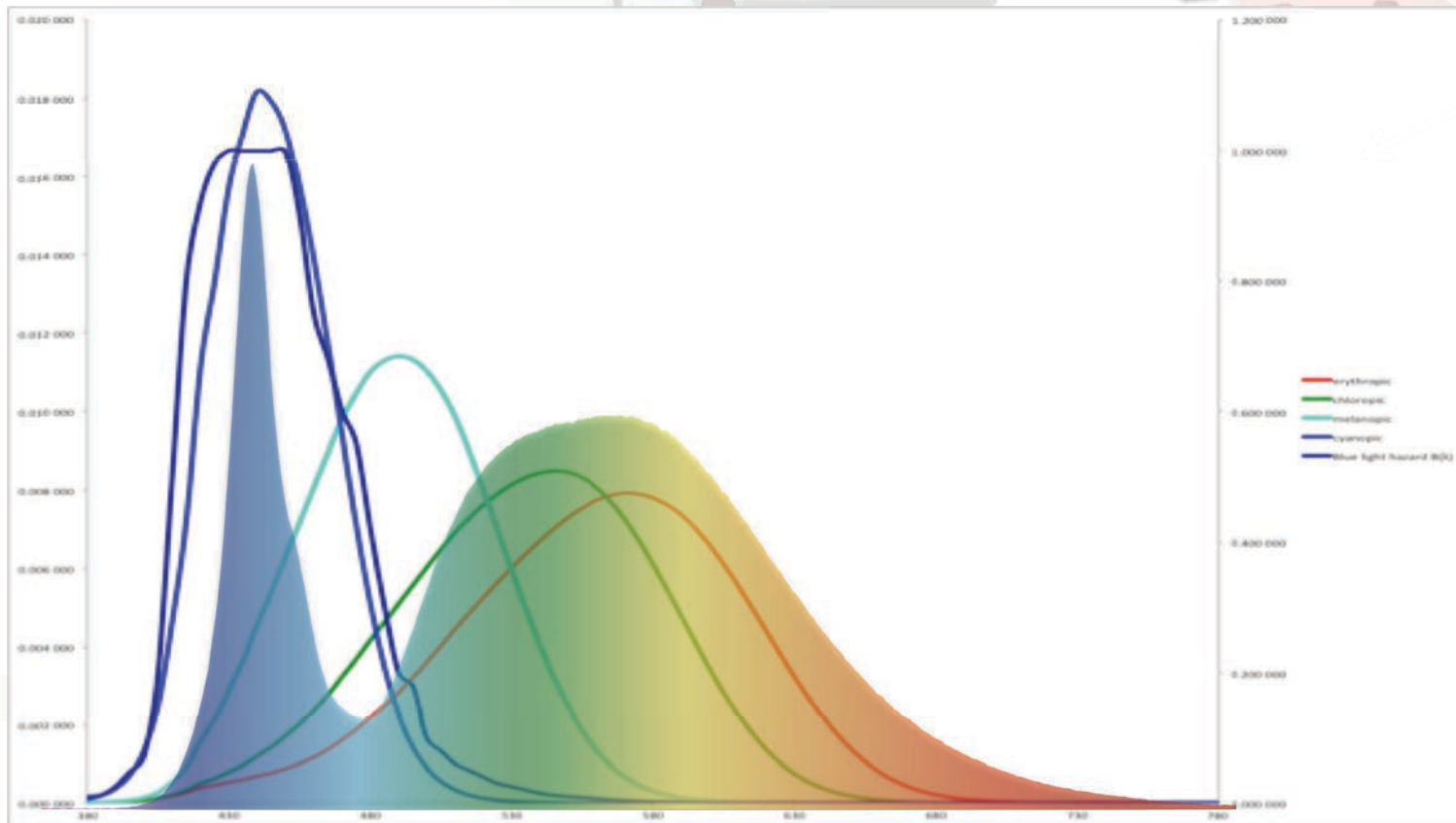
19.5 = Foot Candles (vertical)



Blue Light Hazard: ANSES Research

- France's equivalent of FDA and OSHA combined
- Research was motivated by the unnatural and unbalanced spectrum of LED lighting, hypothesizing they are at higher risk than previous light sources.

Why would LED have a higher risk?



[Lucas et al. 2014, Trends in Neuroscience]

- Remember: melanopsin drives our pupillary light reflex
- LED spectrum pinpoints blue light hazard
- Under-stimulates melanopsin
- LED spectrum undermines our natural protection mechanism



ANSES: Identified High Risk Groups

- Children
- Bright light environments
- Eye diseases that make them susceptible to hazards

“ANSES recommends: To avoid the use of light sources emitting cold-white light (light with a strong blue component) in places frequented by children (maternity wards, nurseries, schools, leisure centers, etc.) or in the objects they use (toys, electronic display panels, game consoles)” – Behar-Cohen et al. 2011, Progress in Retinal and Eye Research

Cool White LED Light should NOT be in hospitals

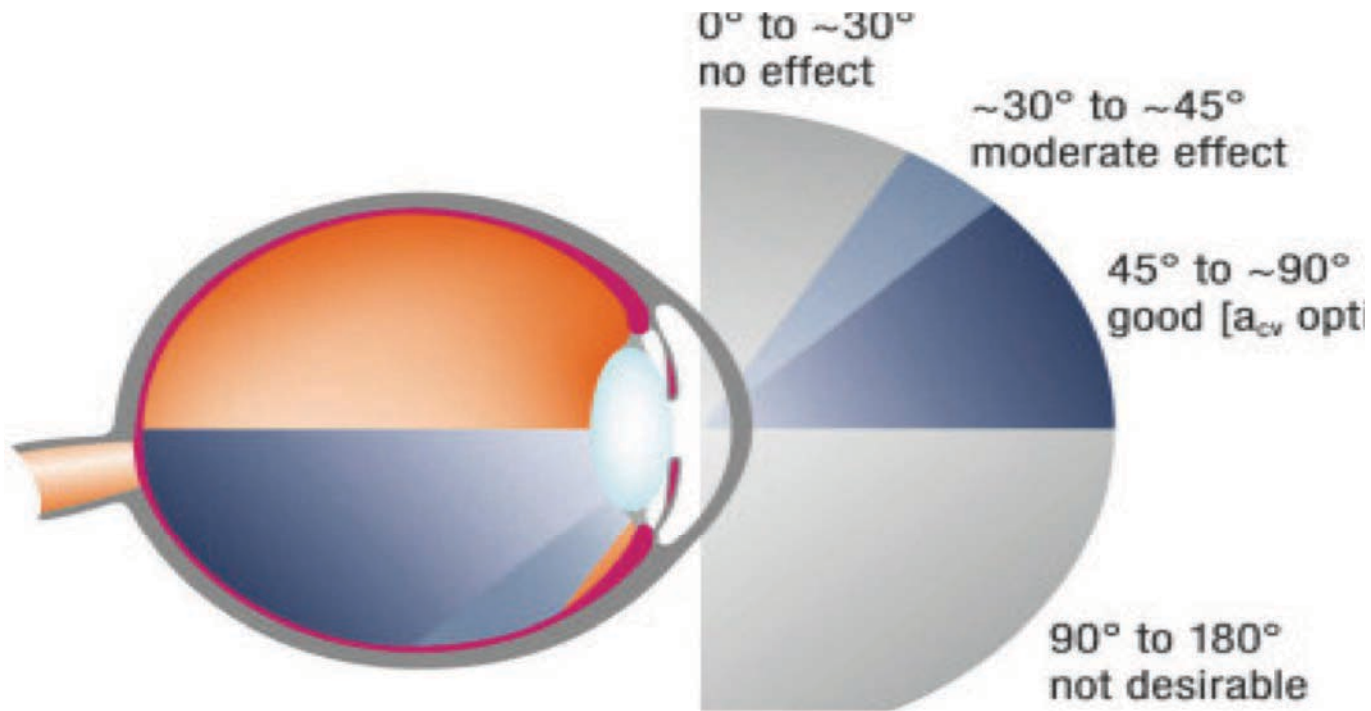
SCHEER report

- Says LED lights are safe for most healthy individuals, except two groups
 - Children under 3 years old
 - Elderly

Cool White LED Light should NOT be in hospitals

Spatial Distribution (Directionality)

Spatial Distribution



Light coming from above the horizon is best

Light coming from below has negligible effect (Glickman et. al 2003, Lasko et al. 1995)

Side periphery is okay as well. (Adler et al. 1992)

Designing for horizontal illuminances may have little effect

Spatial Distribution



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Spatial Distribution



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Nighttime

SKY

Horizon

FIRE

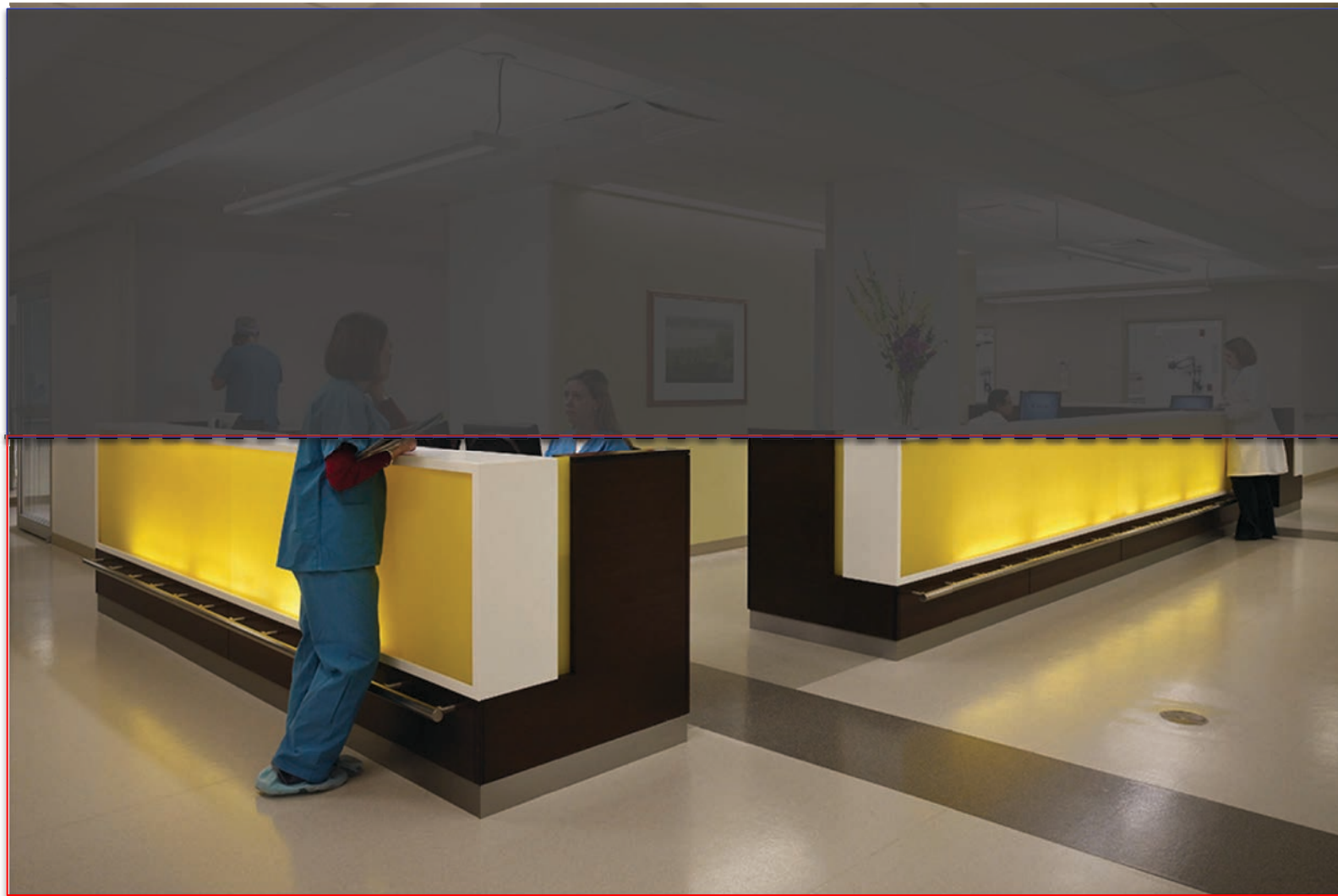


Nighttime

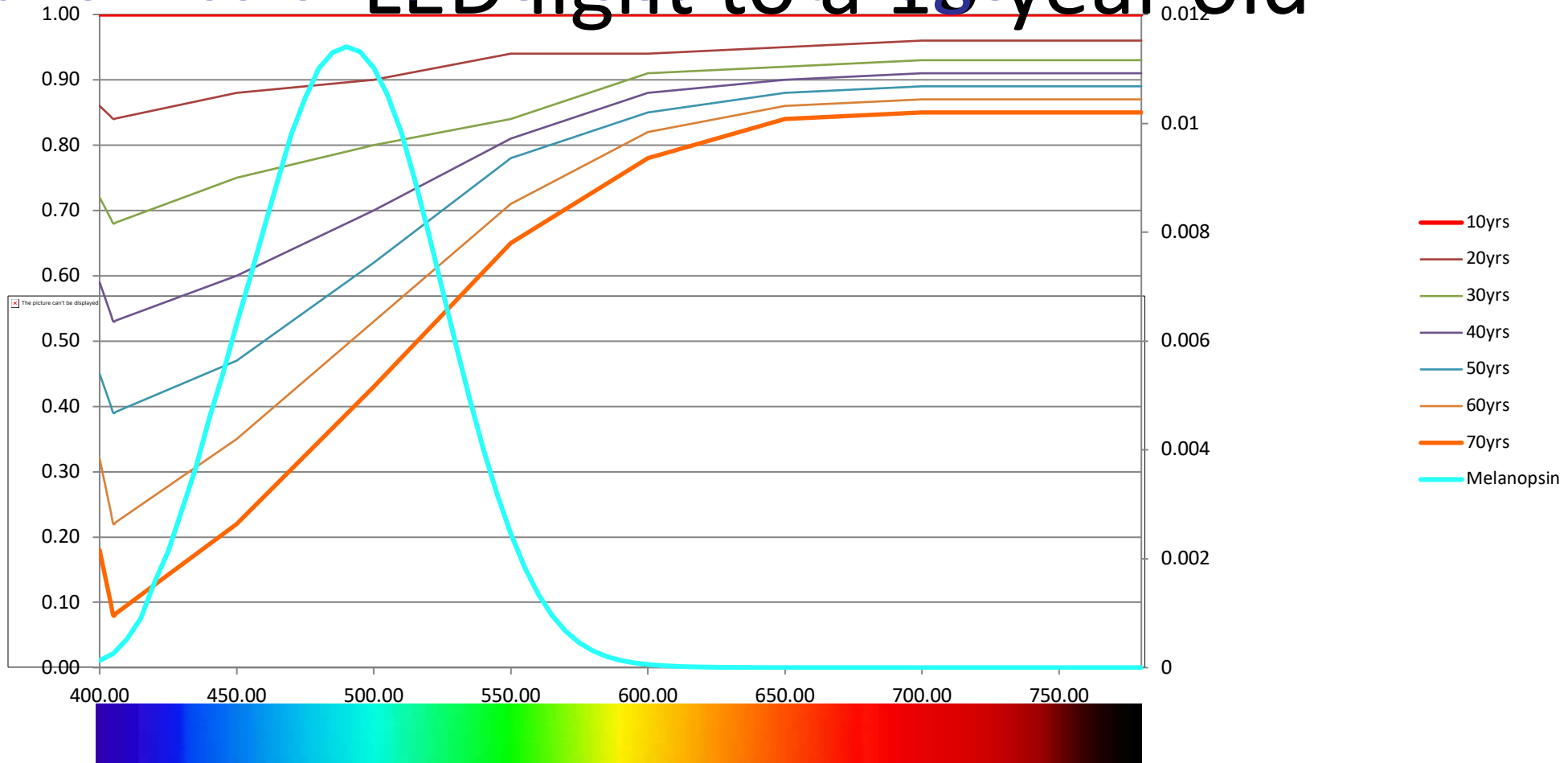
SKY

Horizon

FIRE

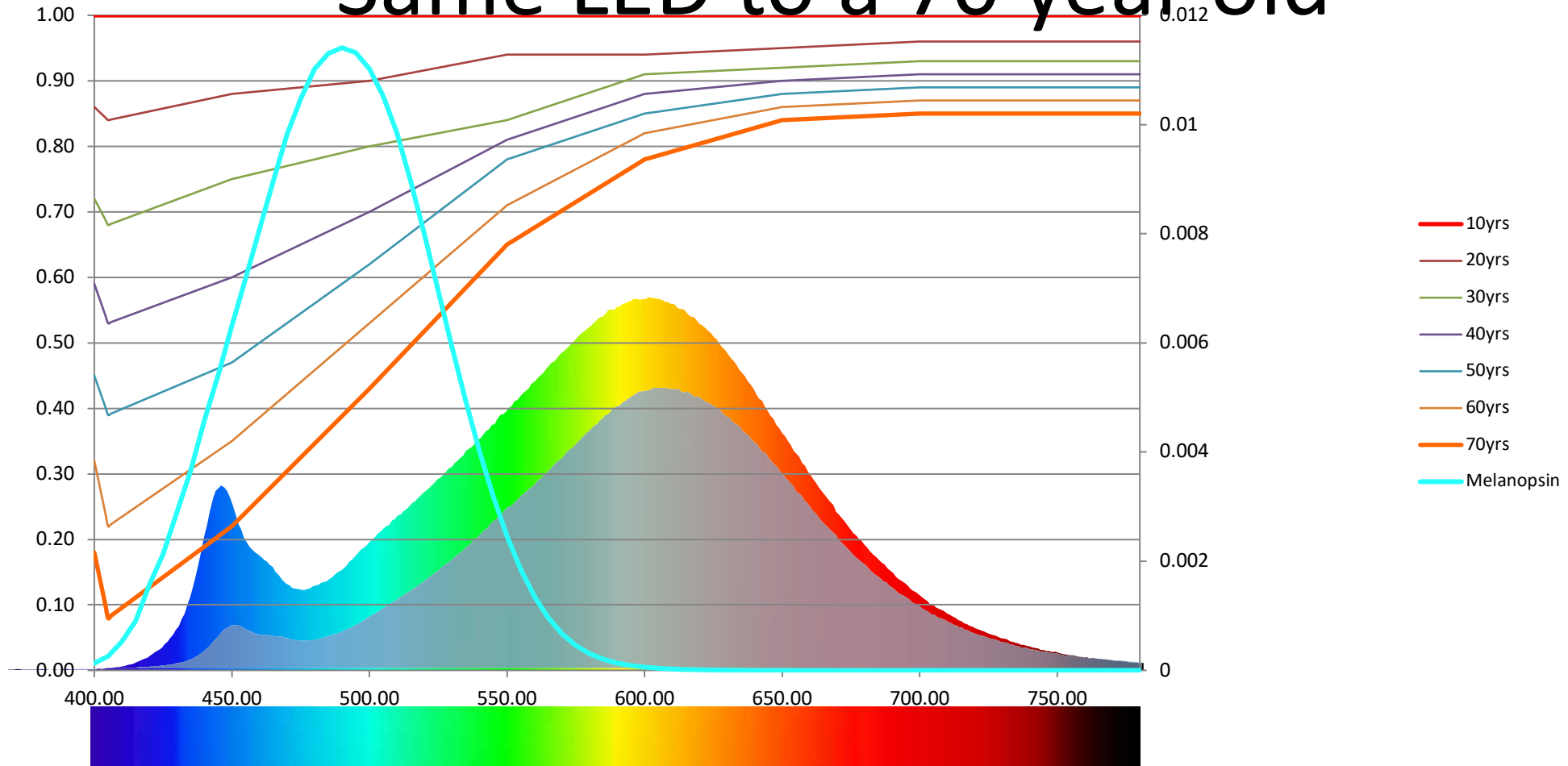


Transmission of lenses with age



[Adapted from Kessel et al. 2010, Journal of Cataract and Refractive Surgery]

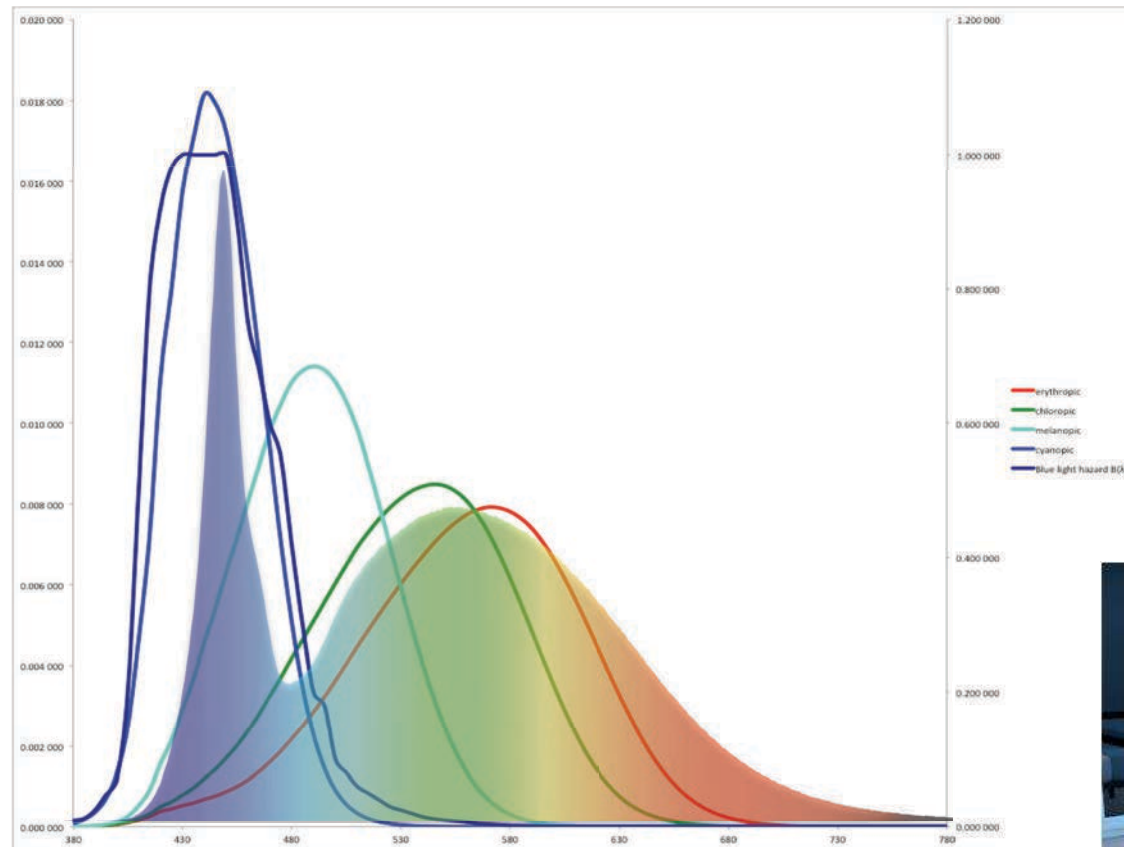
Same LED to a 70 year old



[Adapted from Kessel et al. 2010, Journal of Cataract and Refractive Surgery]

Traditional LED Light is not appropriate for the elderly leducation.org

Traditional “Circadian” Daytime Spectrum LED Product



EML ratio = 0.87
BLH ratio = .0933
CCT = 6000K
R9 < 0
COI = 24 (recommendation less than 3.3)

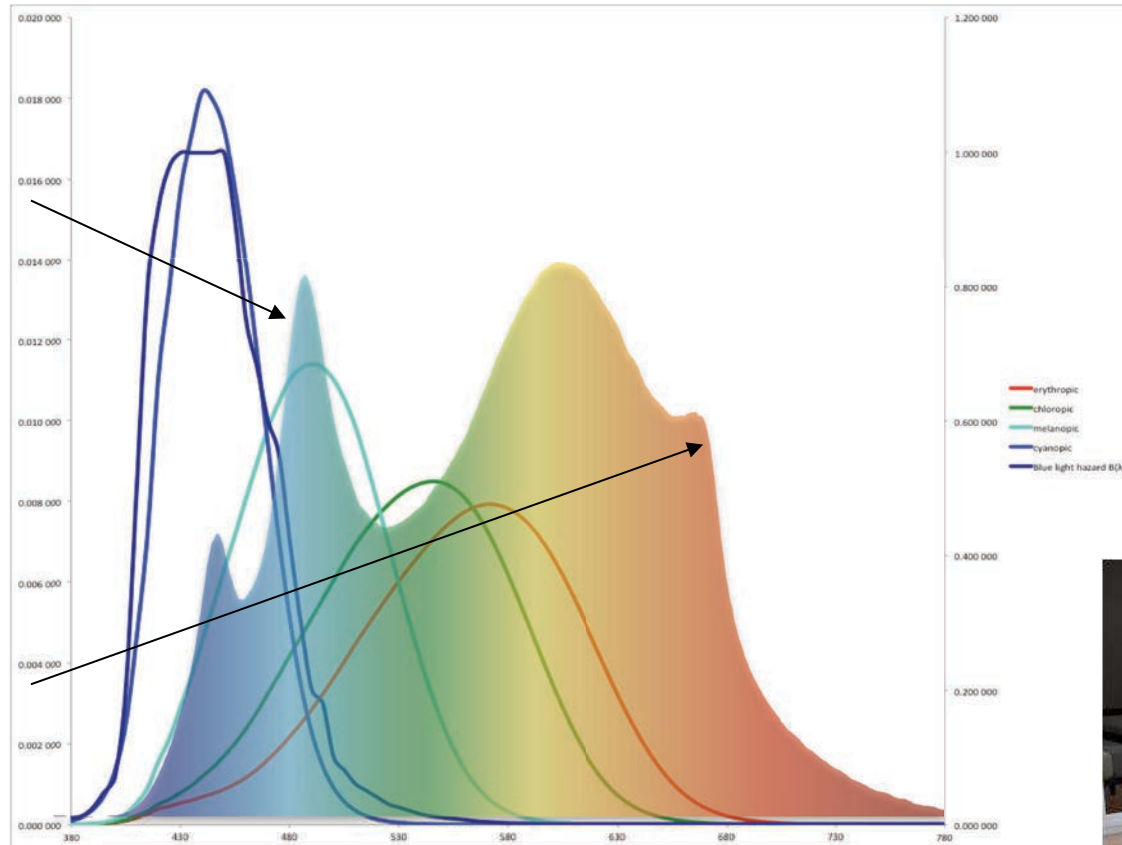
[Lucas et al. 2014, Trends in Neuroscience]



Reimagined Circadian LED

SkyBlue component for enhanced daytime circadian stimulation and mood

Far-red component for better medical evaluation and healing potential

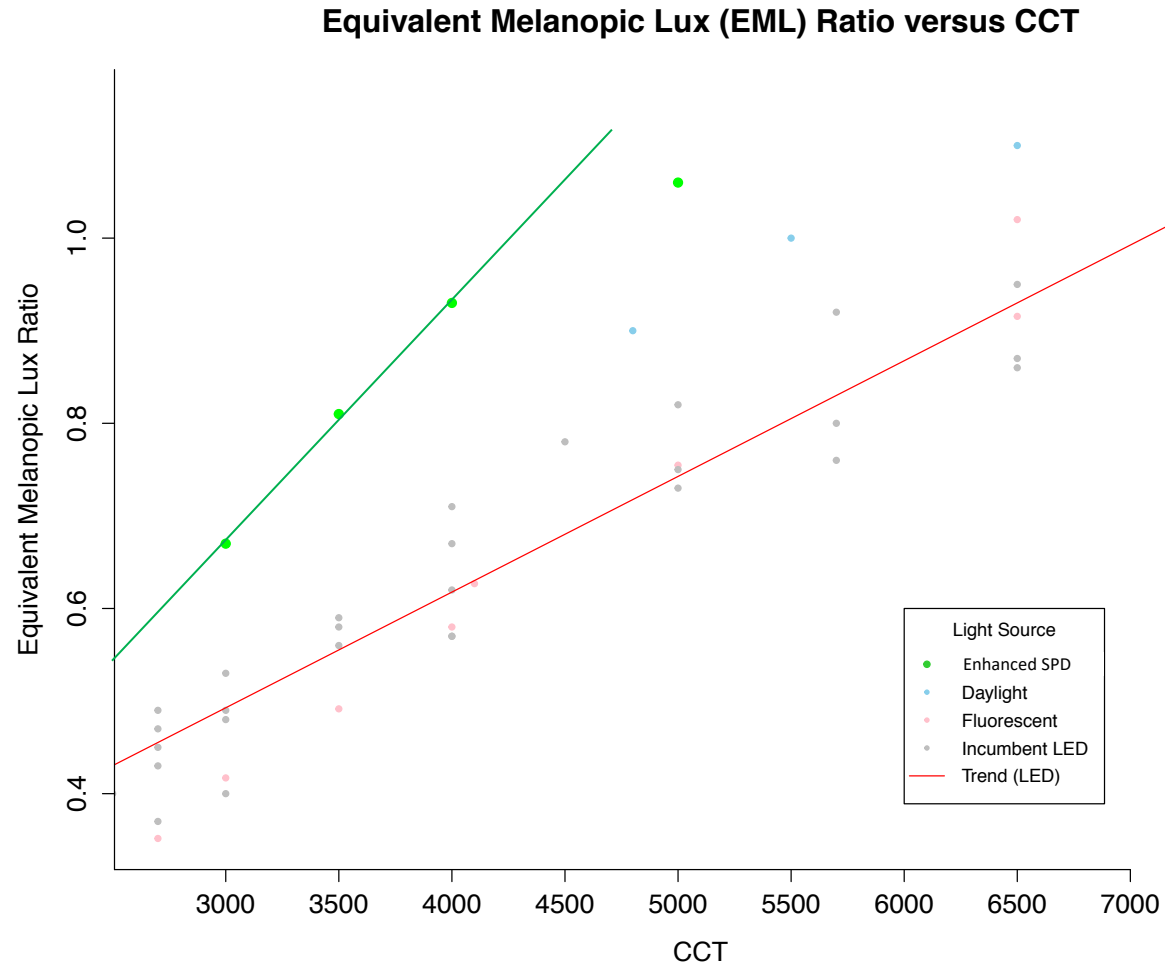


EML ratio = 0.9
BLH ratio = .0401
CCT = 4000K
R9 > 50
COI = 2.1 (recommendation less than 3.3)

[Lucas et al. 2014, Trends in Neuroscience]



Melanopic Lux Trend



Putting it all together

- Daytime Hours:
 - High Melanopic Lux (or CS) Spectrum
 - High vertical lux
 - Emphasis on Vertical Lux
- Nighttime Hours:
 - Low Melanopic Lux (or CS) Spectrum
 - Low vertical lux
 - Emphasis on Horizontal Lux

	Staff	Long Stay Patients (greater than 1 week)	Short Stay Patients
Daytime	Elongated Daytime about shift times (i.e. 4am to 10pm)	Astronomical Clock or 6am to 6pm schedule	Astronomical Clock or 6am to 6pm schedule

Thanks for you Attention



SCIENTIFICALLY
ENGINEERED

Robert Soler

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www.bioslighting.com

<https://fluxometer.com/rainbow/#!id=BIOS%20Lighting/BIOS%20Puck%204000K>

This concludes The American Institute of Architects Continuing
Education Systems Course

