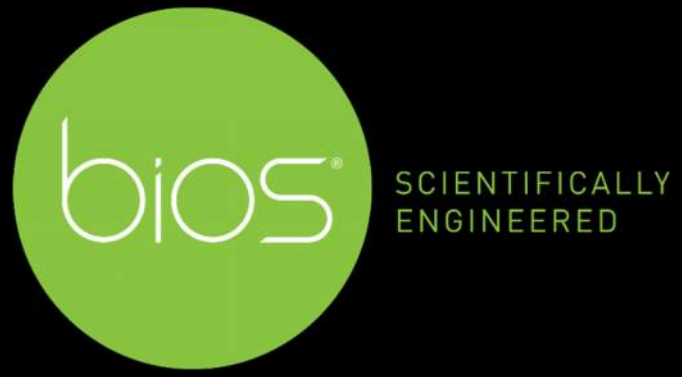
Biologically Focused Lighting –
The Truth about Circadian Lighting



Ken Esterly – VP of Sales

About BIOS

- We are a NASA Spin-Off
  - Robert Soler (VP of Technology) developed the first LED light on Space Station
  - Circadian Lighting for Space Station
- Jet Lag Mitigation Expert for Professional Athletes
  - Olympic Ski and Snowboard team
  - Los Angeles Dodgers
  - Pittsburgh Pirates
- Named Inventor on over 75 issued patents
- PhD student at UCSD and Salk Institute
  - Behavioral Neuroscience
- National Science Foundation (NSF) Fellow
- WELL Faculty Member

First LED light aboard NASA's ISS (Credit: nasa.gov)

NASA's Flexible lighting system (credit: wired.com)

Company's Lighting System Can Pinch Hit for the Sun

The development of lighting countermeasures for sleep disruption and circadian misalignment during spaceflight

George C. Brainard[a], Laura K. Barger[b], Robert R. Soler[c], and John P. Hanlin[a]

Purpose of review

The review addresses the development of a new solid-state lighting system for the International Space Station (ISS) that is intended to enhance the illumination of the working and living environment of astronauts and to improve sleep, circadian entrainment, and daytime alertness.

Recent findings

Spaceflight missions often expose astronauts and mission support ground crews to atypical sleep–wake cycles and work schedules. A recent, extensive study describes the sleep characteristics and use of sleep-promoting pharmaceuticals in astronauts before, during, and after spaceflight. The acceptability, feasibility, and efficacy of the new ISS solid-state lighting systems are currently being tested in ground-based, analog studies. Installation of this lighting system on the ISS is scheduled to begin later this year. In-flight testing of this lighting system is planned to take place during ISS spaceflight expeditions.

Summary

If the new ISS lighting system is capable of improving circadian entrainment and sleep during spaceflight, it should enhance astronaut health, performance, well-being, and safety. Such an advance would open the door to future lighting applications for humans living on Earth.

BIOS Overview – Healthcare to Schools

Winner of Commercial Real Estate Awards for 2019 “Best Medical Project”

UC San Diego Health's uniquely designed geriatric emergency department is installing specialized LED lighting in its pioneering new ED, a move it says will be helpful for clinicians working lengthy overnight shifts – and also help with the detection and diagnosis of dangerous conditions such as sepsis.

Course Description

With growing emphasis on healthy built environments, circadian lighting is a popular topic that many designers and end-users are being asked to explore. This lecture will outline the science behind circadian lighting, telling an easy-to-understand story that helps explain what we should expect from circadian lighting, as well as address important design considerations, who should expect to benefit from circadian lighting and what those benefits are.

This session will also give some insight into blue light hazard and what you need to know about it.

Learning Objectives

At the end of the this 4 hour course, participants will be able to:

1. Understand the basic science of circadian rhythms and its interaction with light.
2. Describe the design considerations needed for implementing circadian lighting.
3. Understand how color tuning addresses circadian lighting needs.
4. Understand how light spectrum addresses circadian lighting needs.

Interior Design Continuing Education Council (IDCEC)

- Your attendance will be reported to IDCEC by your instructor after this CEU. Please do not share the class-code with anyone who has not attended this CEU.
- Certificates of completion will be issued electronically through your IDCEC account once attendance has been reported for you. Please allow 5 business days for attendance reporting.
- Attendees who do not have a unique IDCEC number will be provided with a paper Certificate of Completion after this CEU.
- WELL certified

About THIS presentation

- MOST presentations give statistics or anecdotal evidence about gains seen from circadian lighting
  - People you don't know
  - A study you don't know the details of
  - Correlations between CCT and performance
- THIS presentation will guide you through the fundamental science of ***why*** circadian lighting makes sense, from the vantage point of the person you know best – ***YOU!***

International Space Station

First LED light aboard NASA's ISS (Credit: nasa.gov)

NASA's Flexible lighting system (credit: wired.com)

Part 1: Scientific Background

- Non-visual photoreceptors
- Circadian rhythms and sleep
- Chronotypes
- Social Jet Lag

Hawthorne Effect

- 1920's – Western Electric (Telephone part company) commissioned study to evaluate the effect of lighting on productivity.

- First they raised the light levels
  - Increased productivity
- Next they lowered the light levels
  - Productivity increased more
- Raised again
  - Productivity increased more

Conclusion: People's behavior changes when you know you're being observed

Evidence Based Design Requirements

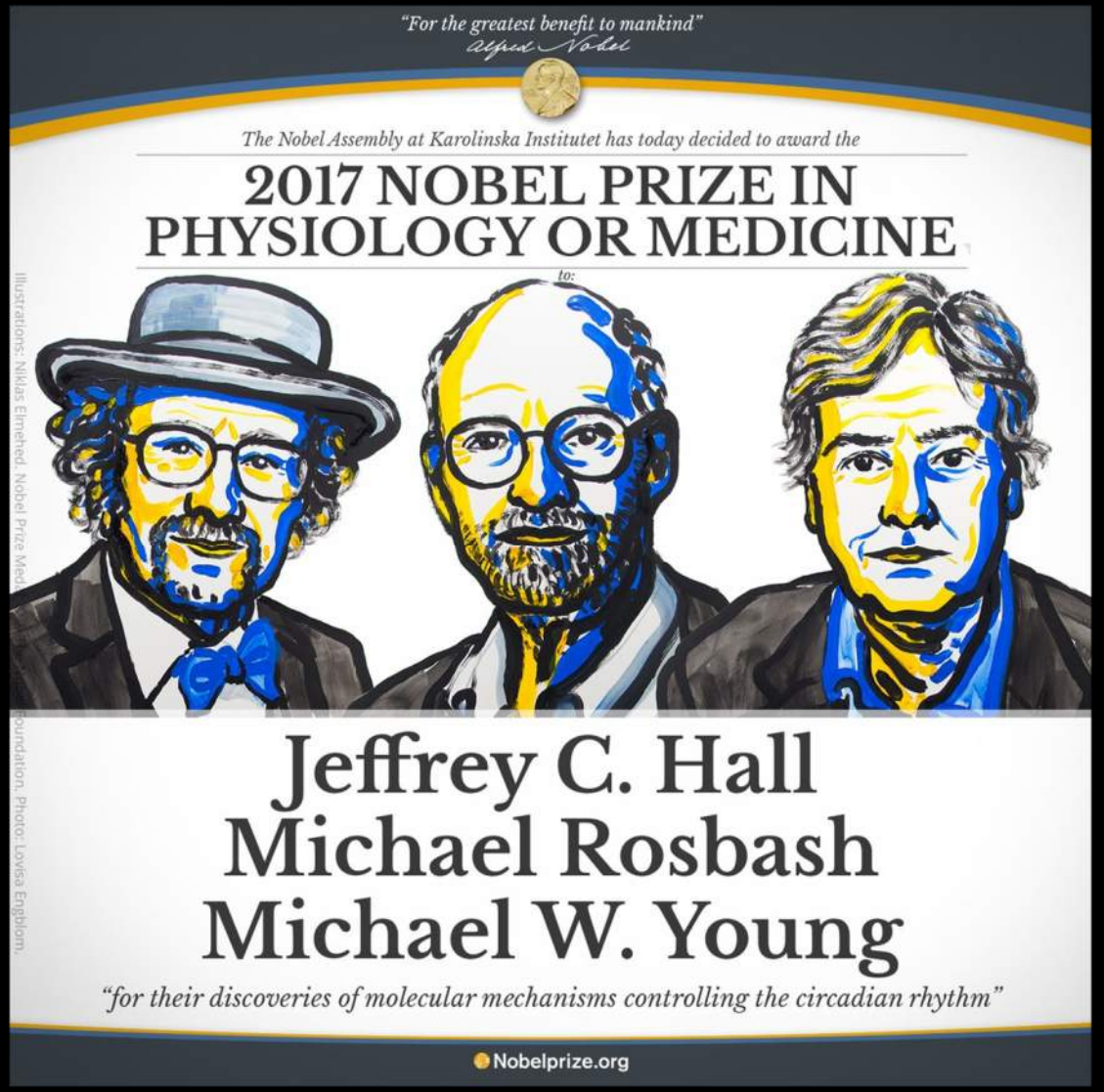
- Needs to avoid false positives and bias
- Needs to apply the fundamental science behind what we should expect….i.e. what is the point?
- Psycholgical vs Biological?

What’s the point of Circadian Lighting?

- Restore a 24-hour cycle
- Humans have evolved around a robust time cue – The Sun
- Modern society has broken this relationship
- How can we replicate this cue indoors?

Circadian Rhythms

- 2017 Nobel Prize was awarded to physiologists who discovered mechanisms of circadian rhythms
- Circadian rhythms is a pervasive part of all biology
- Each cell has its own clock (Panda – Circadian Code, 2018)
- 43% of mammalian genetic expression is circadian (Zhang et al. 2014)
- Strategic timing for resource efficiency (Brown 2016)



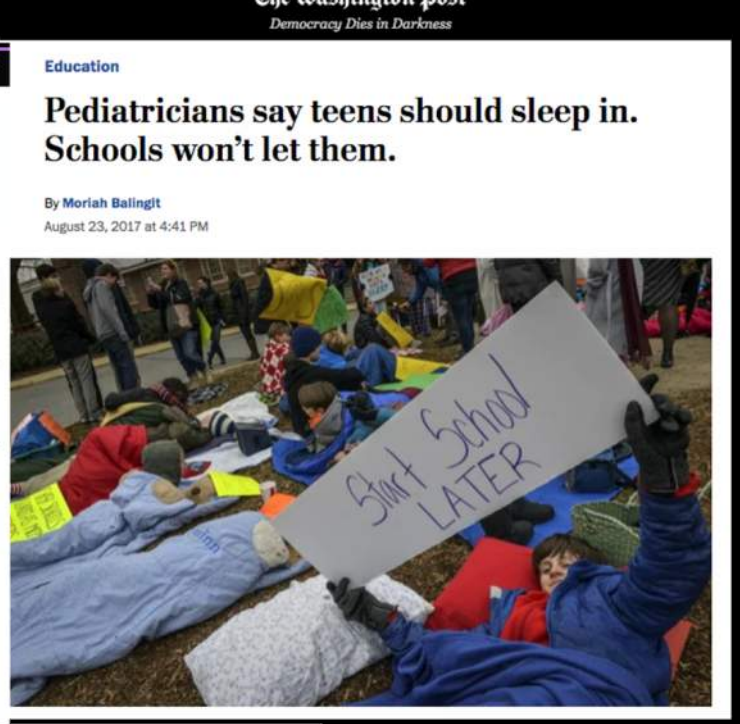
Social Acceptance

Popular periodicals are beginning to write on the importance of doing things according to your circadian rhythms

Social Acceptance

Popular periodicals are beginning to write on the importance of doing things according to your circadian rhythms

And the problems that arise when we don't



People have varying reactions on how screen time affects sleep. Now comes a study conducted by researchers from Salk Institute pinpointing how certain cells in the eye process ambient light, resetting internal body clocks.

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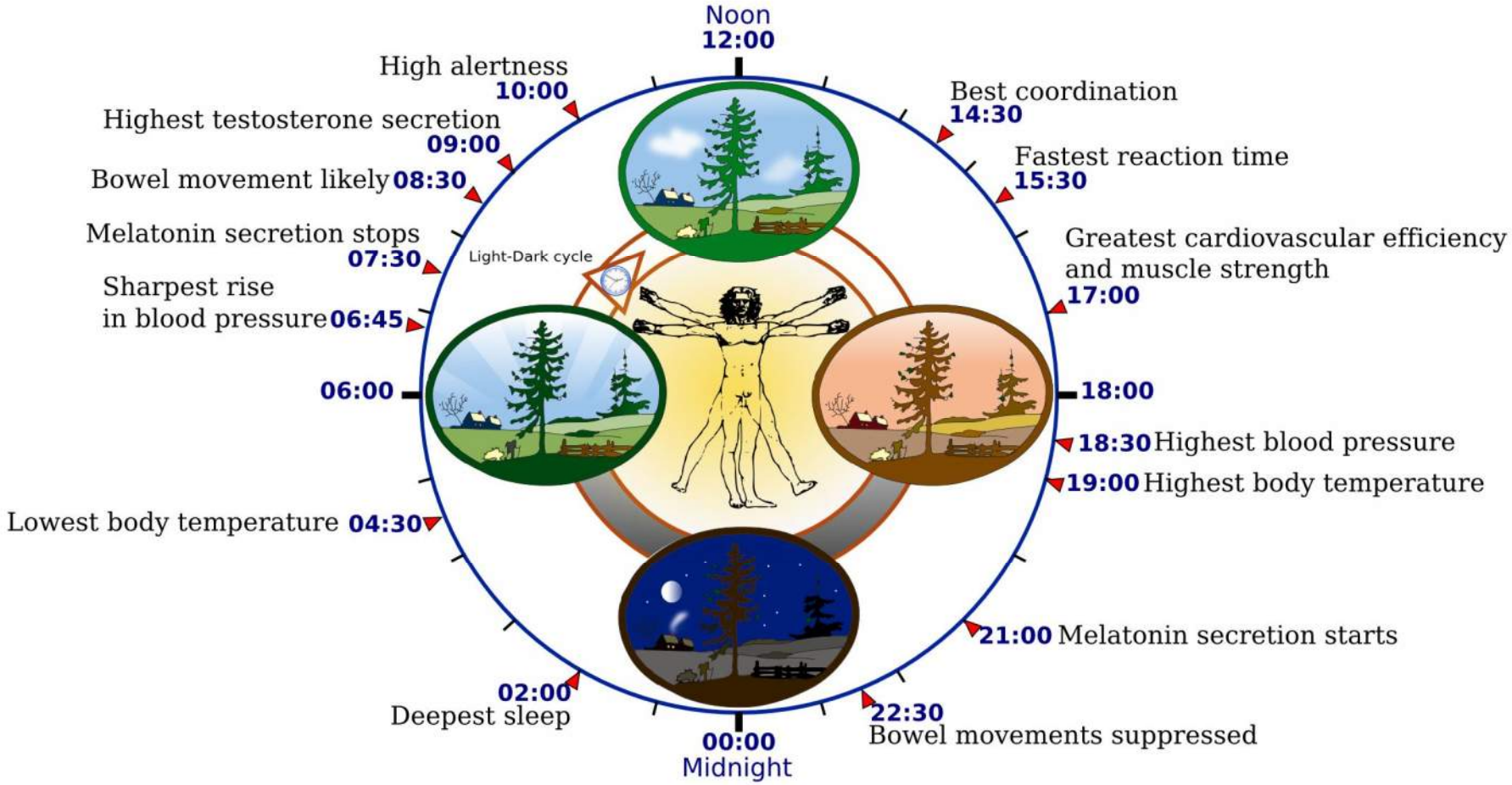
Sunlight Makes You Skinny & Blue Light Makes You Fat: 11 Ways To Biohack Light To Optimize Your Body & Brain.

Average Persons Rhythm



Source: https://commons.wikimedia.org/w/index.php?curid=3017148

Not all White Light is Created Equal

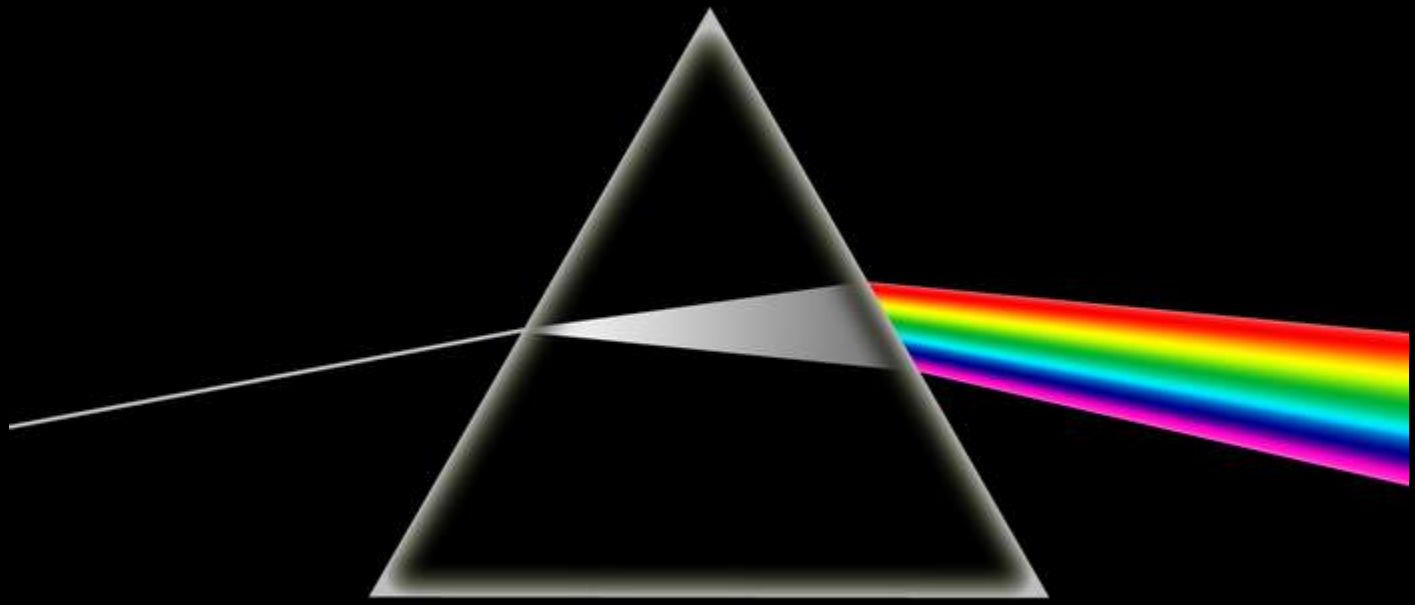


Photo Credit: www.designaddict.com

What's the difference?

6500K Daylight

Photo Credit: www.designaddict.com

5000K LED

Photo Credit: www.usa.philips.com

6500K Daylight

Breakdown of impact of different wavelengths of light in daylight

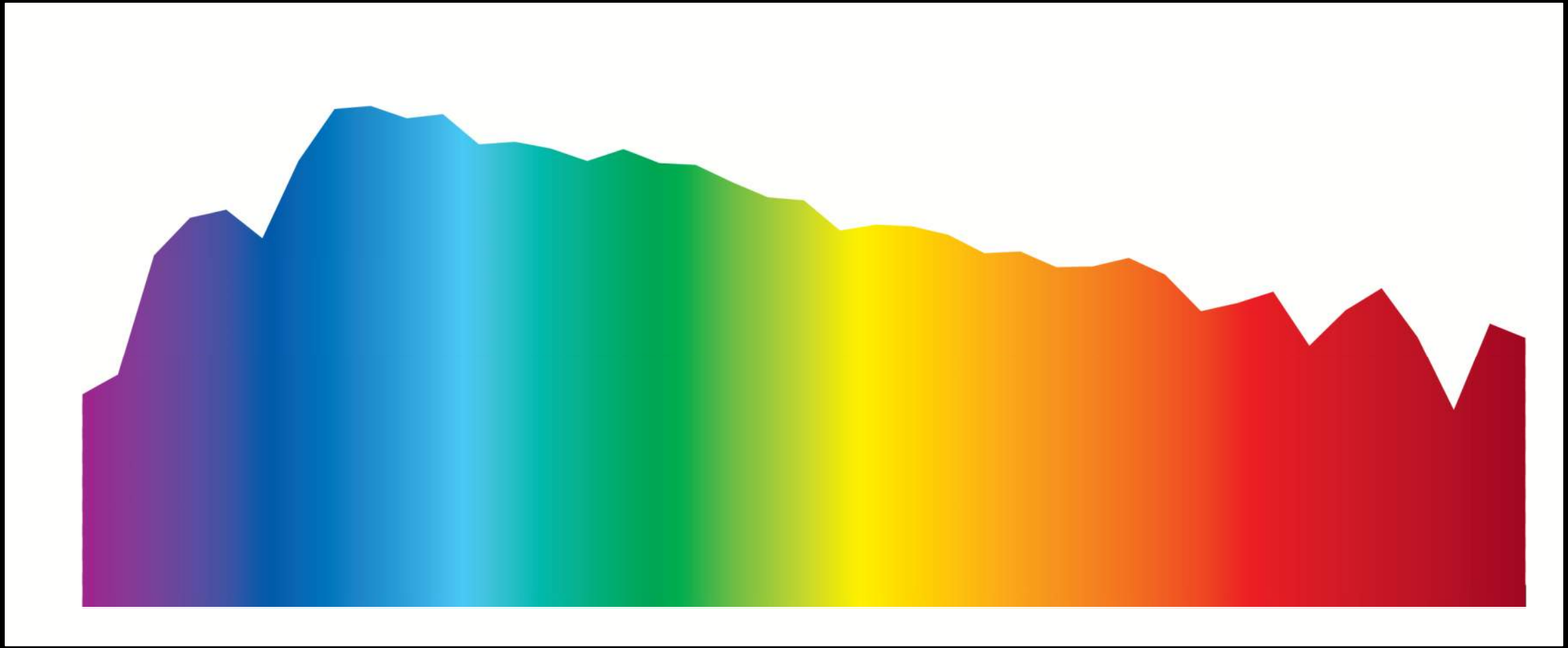
6500K Daylight

Now let’s compare to legacy LED / Tunable White

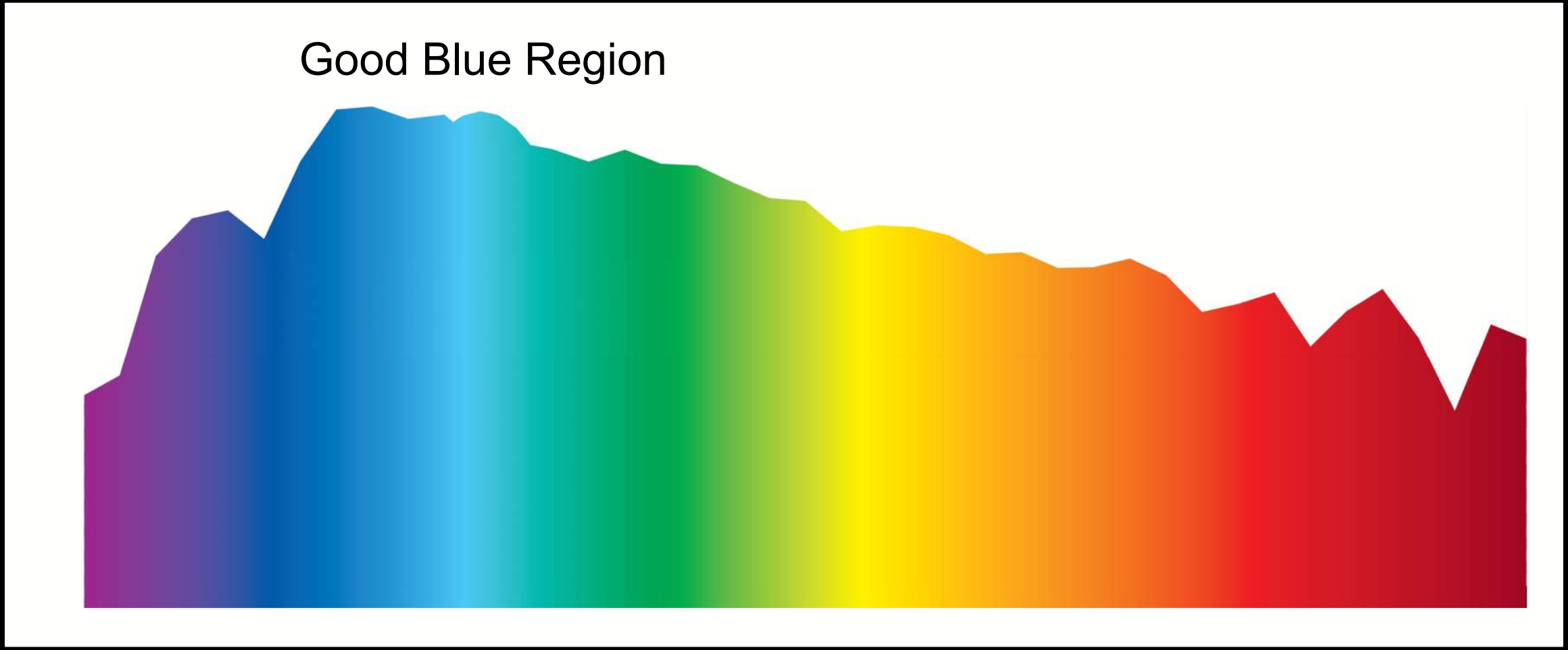
5000K LED


Breakdown of impact of different
wavelengths
of light in LED “daylight/Tunable white”
END OF DAY CUE
GLARE AND MACULAR DEGENERATION
NON-VISUAL RESPONSE
VISUAL EFFICIENCY
MEDICAL DIAGNOSIS, HEALING AND ENERGY

Blue Light Paradox (John Marshall, 2017)



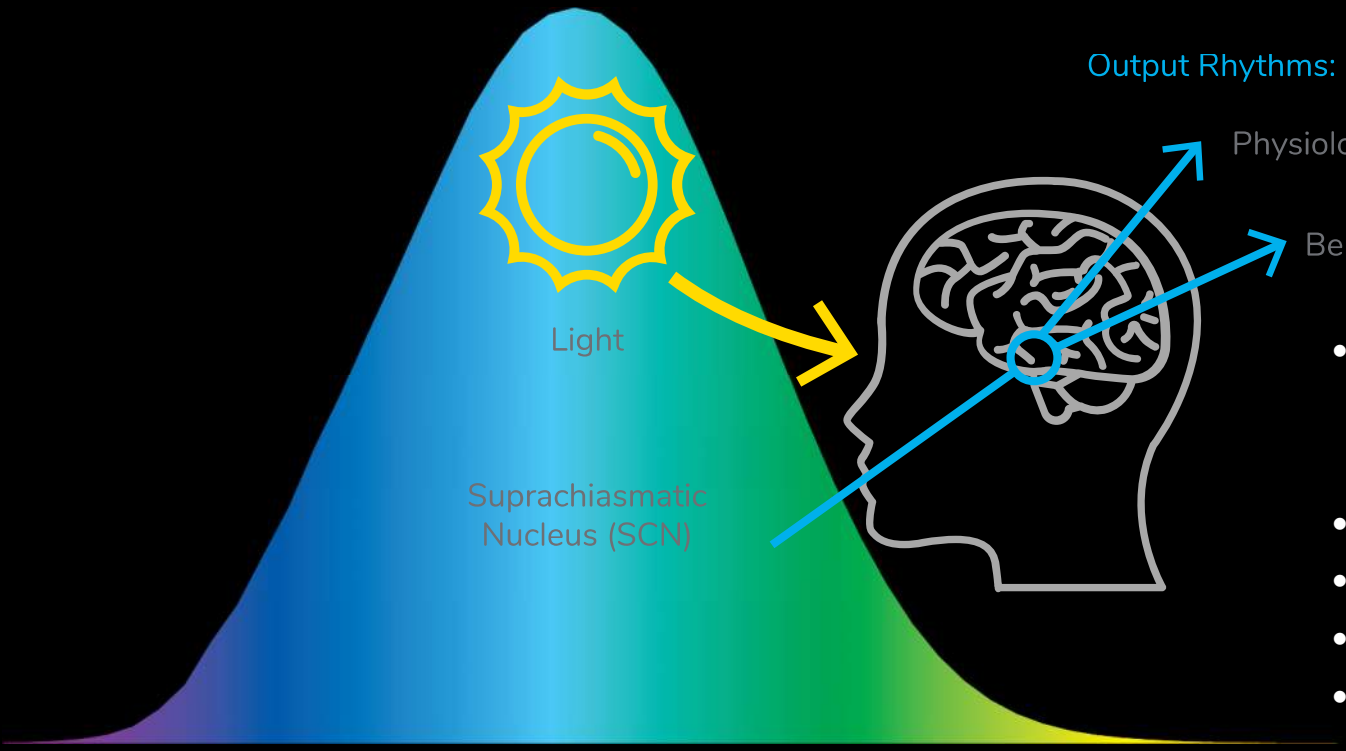
Blue Light Paradox (John Marshall, 2017)

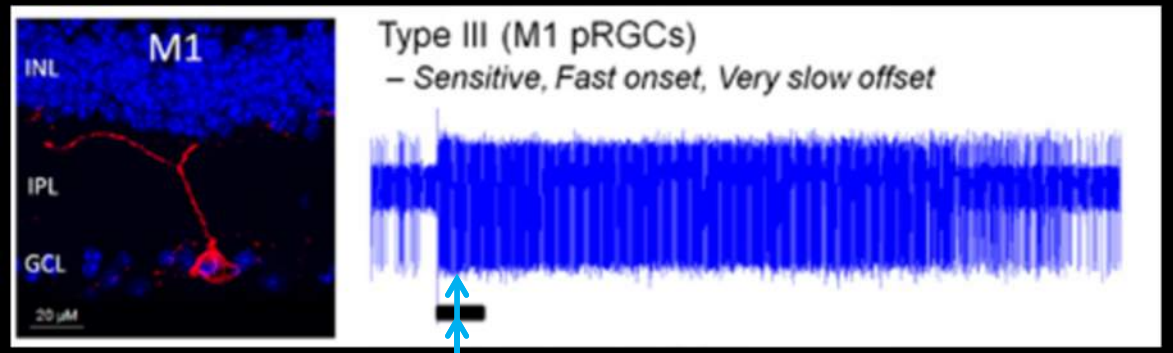


Bad Blue Region

The Overlap

Melanopsin

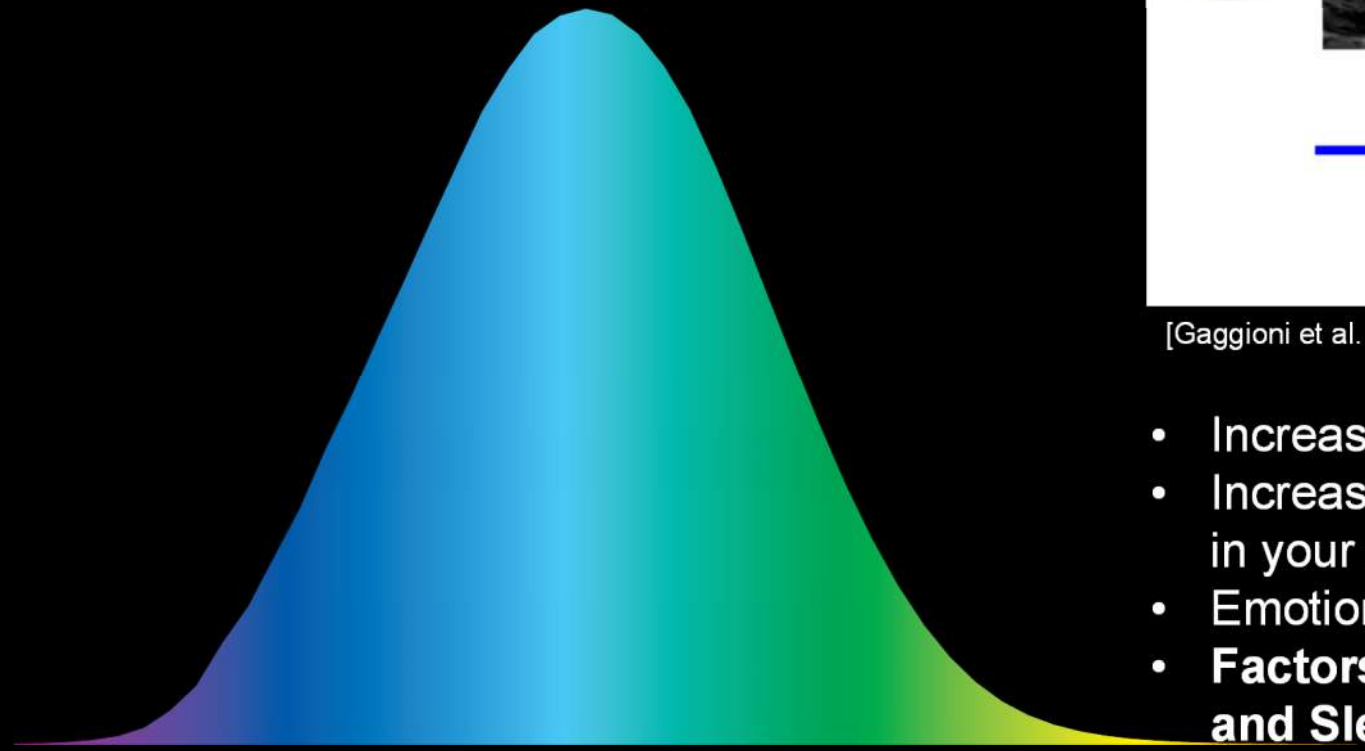


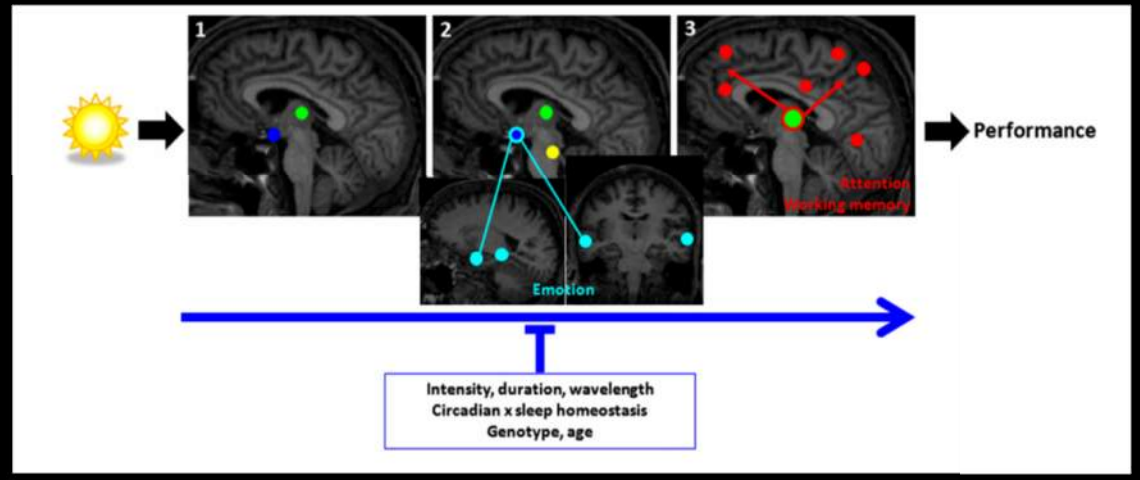


[Hughes et al. 2016, nature publishing group]

- Photopigment in newly found subset of cells in the retina (ipRGCs) Each ipRGC has some 10,000 melanopsin molecules that capture light
- ipRGCs respond quickly to light (black bar)
- Sustained response well after light is gone (blue spikes)
- Integrates light over time
- **Intensity, wavelength and duration are important**

Measured Acute Brain Effects

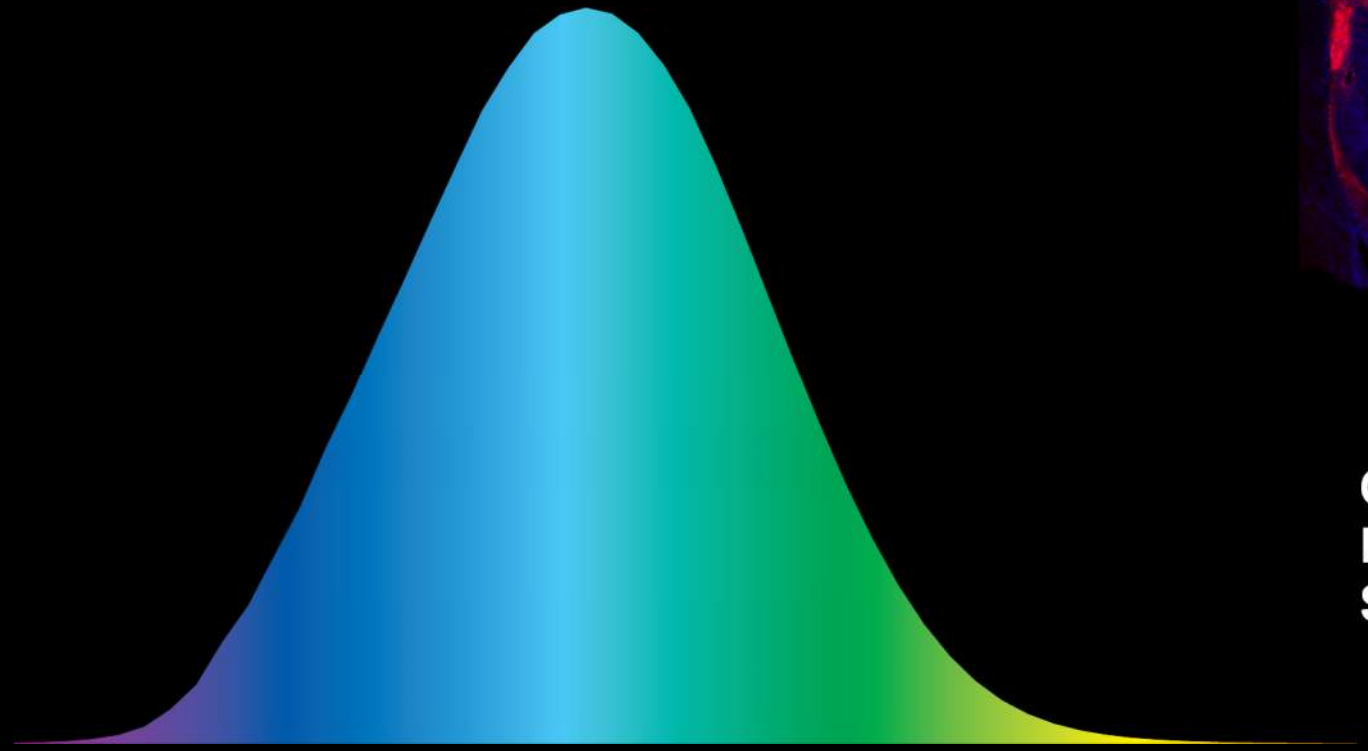


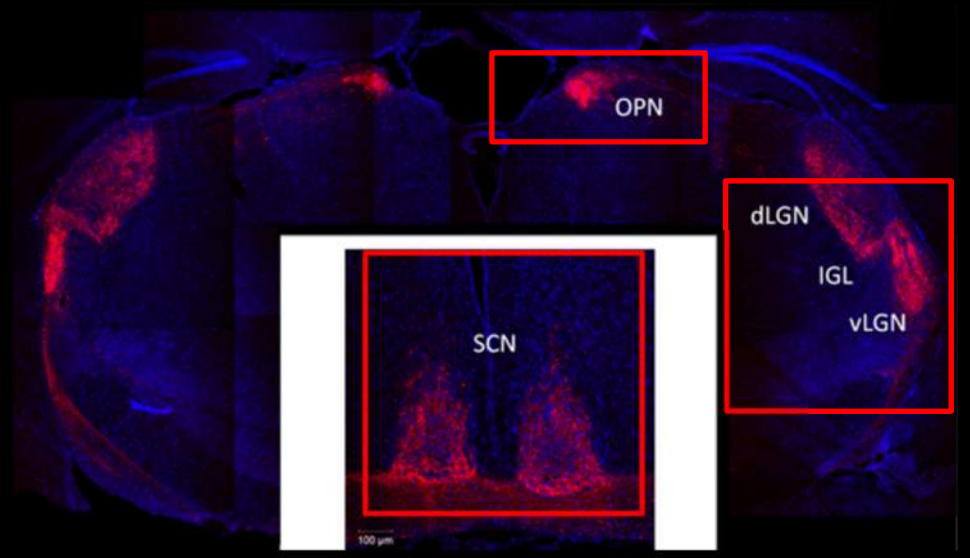


[Gaggioni et al. 2014, Frontiers in Systems Neuroscience]

- Increased Alertness (Gaggioni et al. 2014, FISN)
- Increased working memory (i.e. figuring stuff out in your head)
- Emotional response
- **Factors are Intensity, Duration, Wavelength and Sleepiness.**

Other Measured Effects

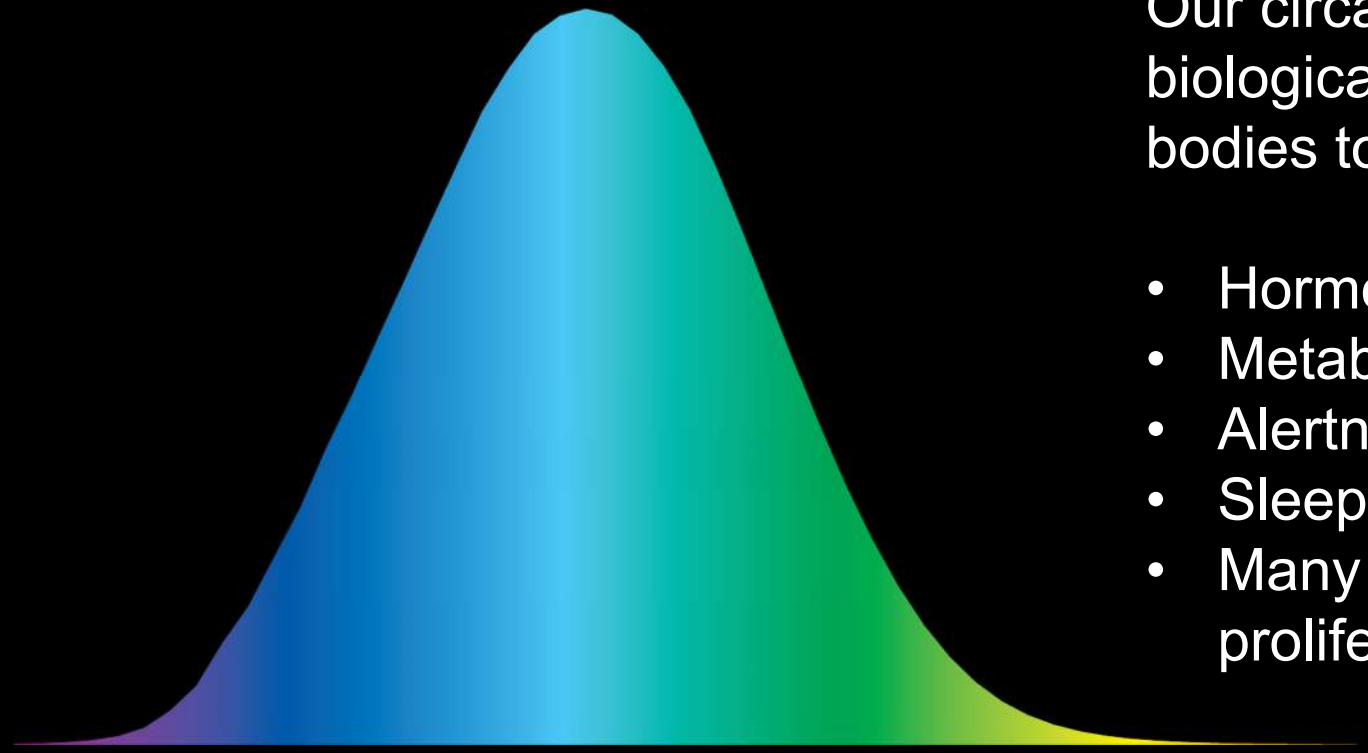




[Hughes et al. 2016, nature publishing group]

OPN: Drives Pupillary Light Reflex
LGN: Brightness perception
SCN: Location of Master Clock
Encodes brightness information
Entrains the circadian clock

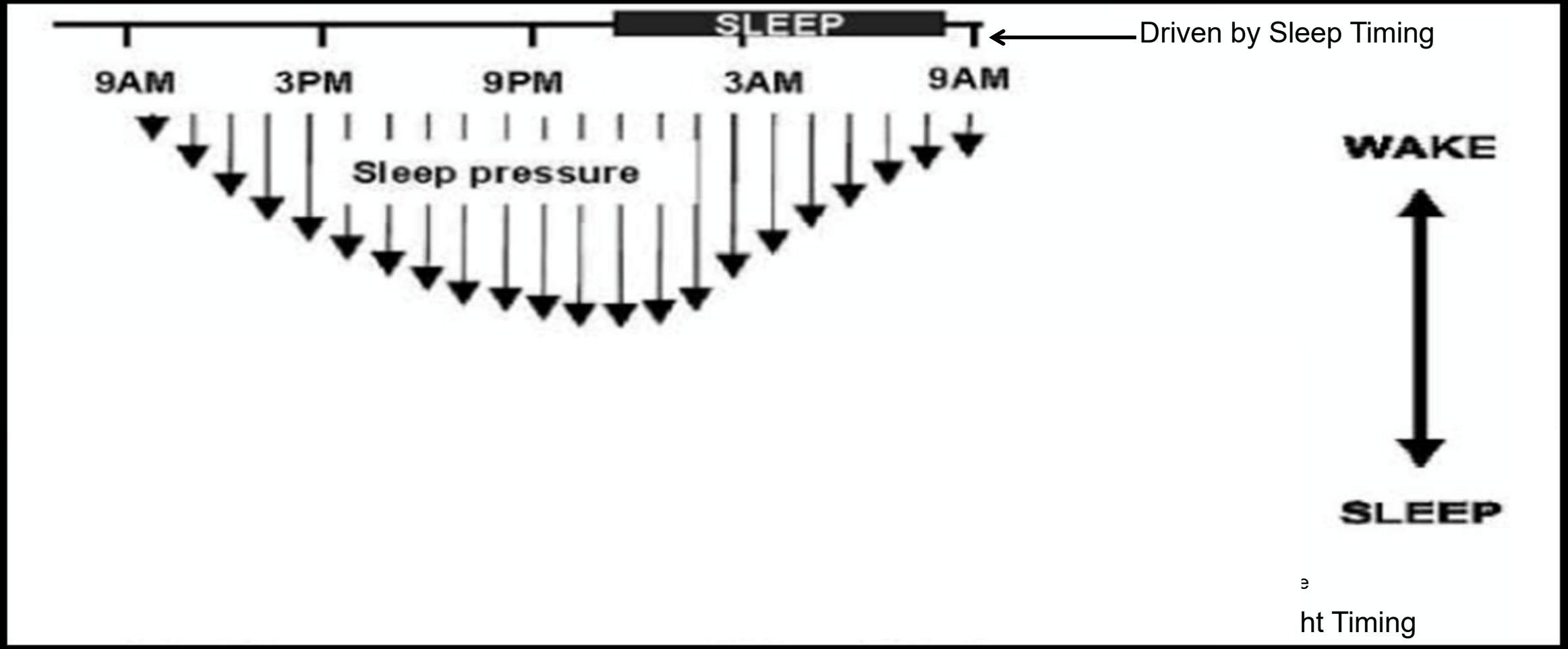
What is the Circadian Clock?



Our circadian clock regulates our biological processes to allow our bodies to conserve resources.

- Hormone Secretion
- Metabolism
- Alertness Profile
- Sleepiness Profile
- Many others (blood pressure, cell proliferation, enzyme activity, etc.)

Sleep – A Two Process Model



[Schmidt et al. 2007, Cognitive Neuropsychology]

Chronotype Differences

EXAMPLE: Modern Family – Mitch and Cam making dinner reservations

They can take us at 5:15...

What are we, 80?

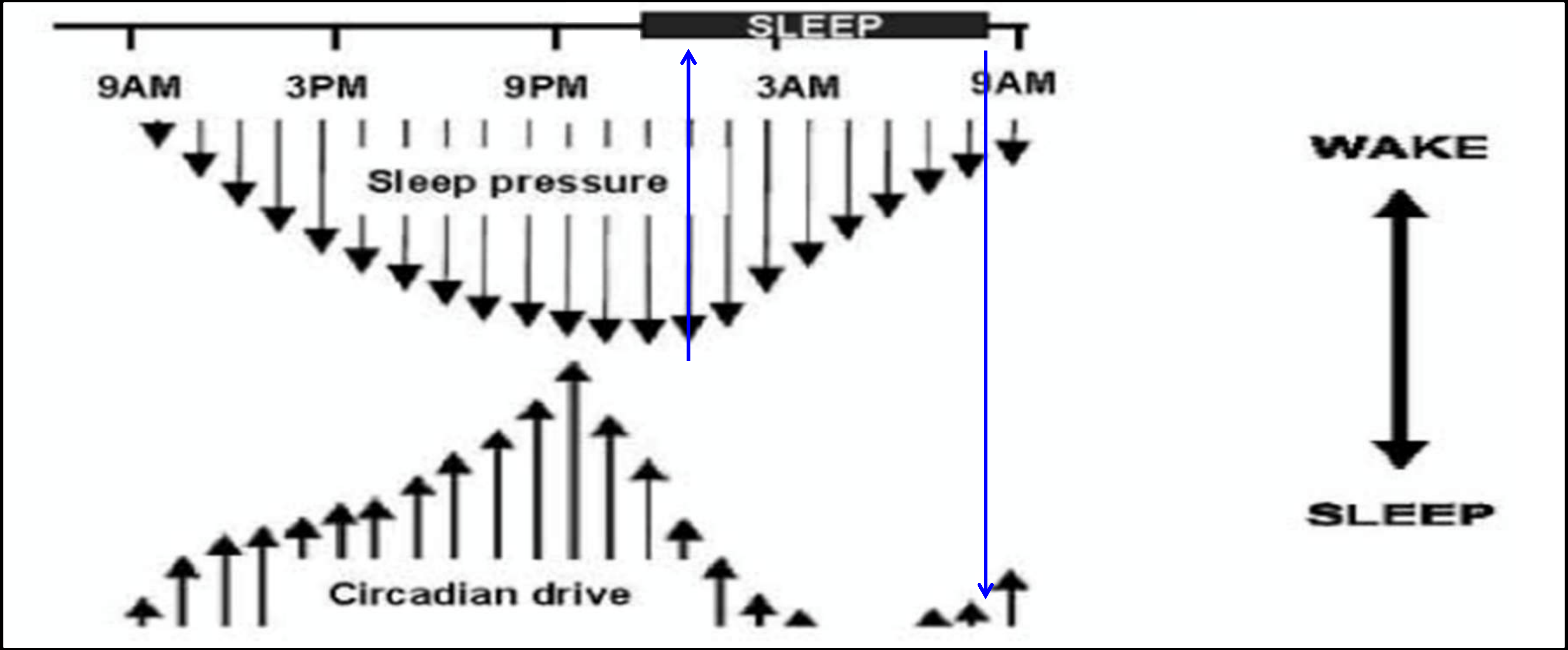
…or 10:45...

What are we, 20?

[Roenneberg 2012, Harvard University Press]

- Chronotype = Time-type
- 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 sleep 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.

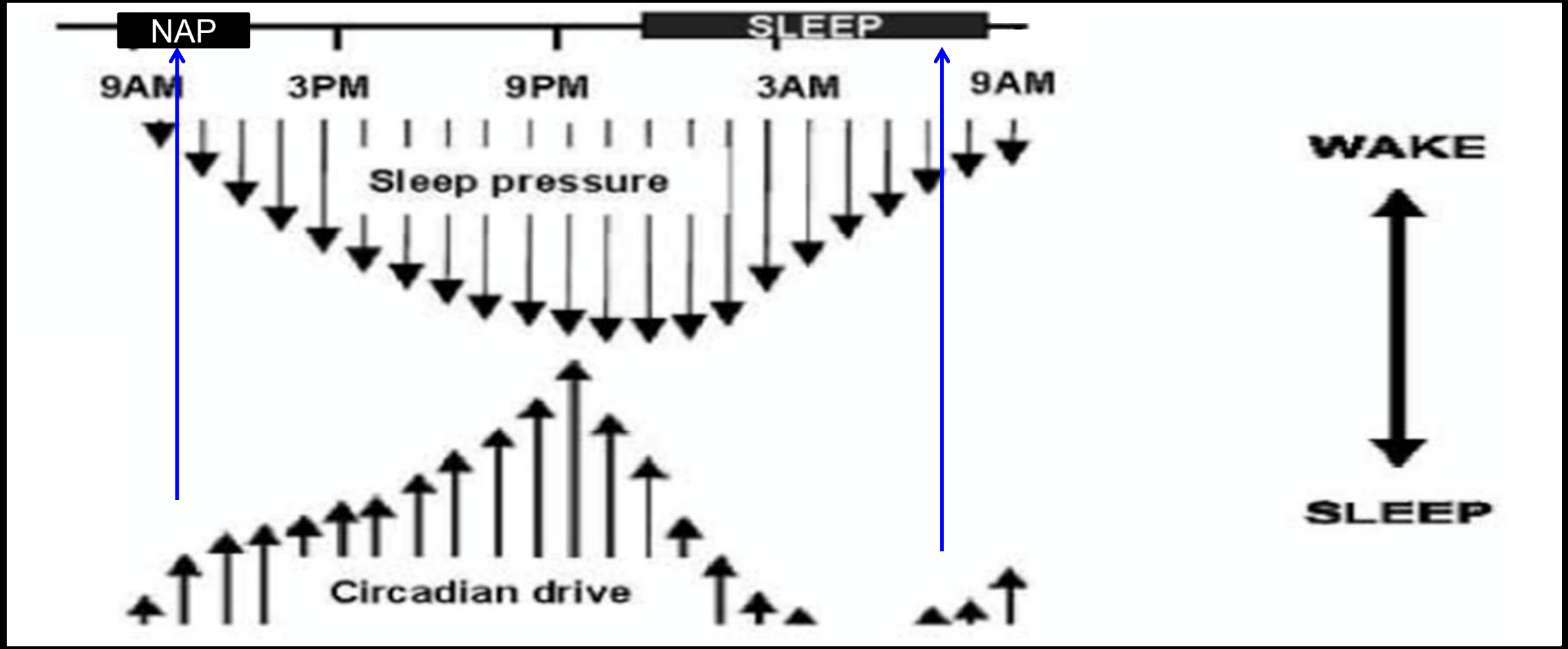
Night Owls



Morning light on night owls, reduces ADHD symptoms (Fargason et al 2017)

Higher variance in sleep timing is best predictor of poor school performance
(Smarr 2014)

Early Birds



Sleep fragmentation increases risk of Alzheimer's Disease and cognitive decline
(Lim et al. 2011)

Health Concerns of Social Jet Lag

- Greater chance of obesity (Roenneberg et al. 2012)
  - 33% greater chance with each hour of SJL
- Increased addiction to nicotine and alcohol consumption (Wittman et al. 2006)
- Increased risk of cardiovascular disease (Wong et al. 2015)
- Increased risk of metabolic disease (Scheer et al. 2009)
- Overall attenuation of circadian process (Jan-Dijk et al. 2012)

- **87**

et lag

(Ro

Chronotypes in Modern Society

- We spend more than 90% of our time indoors under electric light
- Light signals at the flip of a switch
- Indoor lighting signals are inappropriate
  - -Too dim to be day
  - -Too bright to be night
- In presence of a stronger, more appropriate light cue, Chronotypes become more consolidated

Camping study looked at this…

Current Biology 23, 1554–1558, August 19, 2013 ©2013 Elsevier Ltd All rights reserved http://dx.doi.org/10.1016/j.cub.2013.06.039

Report

Entrainment of the Human Circadian Clock to the Natural Light-Dark Cycle

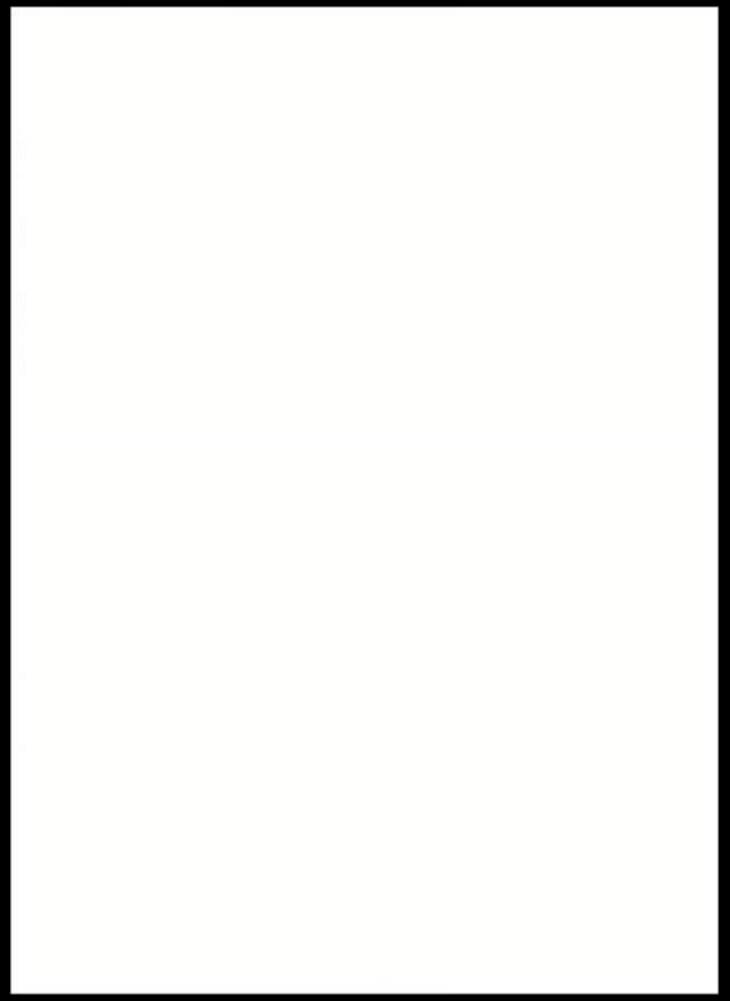
Kenneth P. Wright, Jr.,[1,*] Andrew W. McHill,[1] Brian R. Birks,[1]
Brandon R. Griffin,[1] Thomas Rusterholz,[2]
and Evan D. Chinoy[1]
[1]Sleep and Chronobiology Laboratory
[2]Sleep and Development Laboratory
Department of Integrative Physiology, University of Colorado
Boulder, Boulder, CO 80309-0354, USA

Objective: Take a group of college students out on a two week camping trip to see how chronotype changes

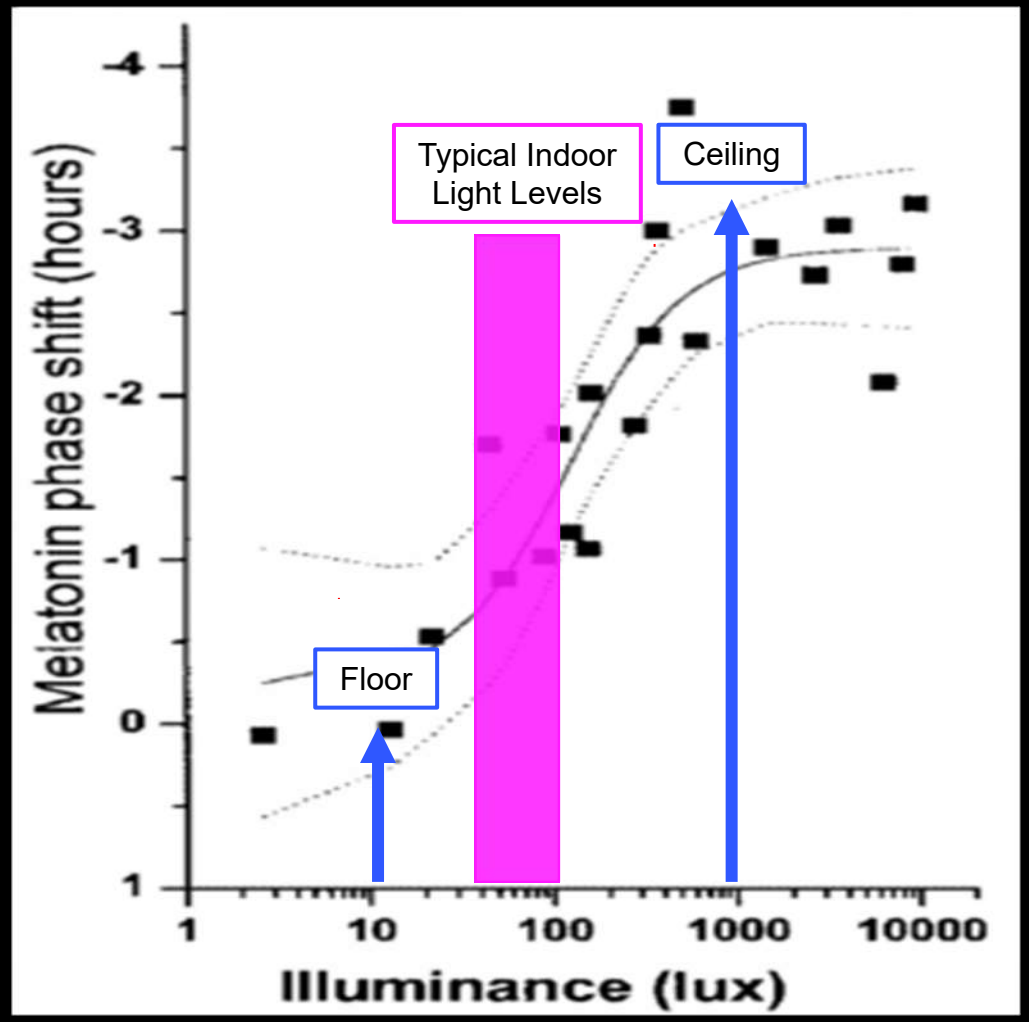
Camping Study Results…

- Measured the variance of chronotype before the camping trip

- Measured the variance of chronotype after the two week camping trip



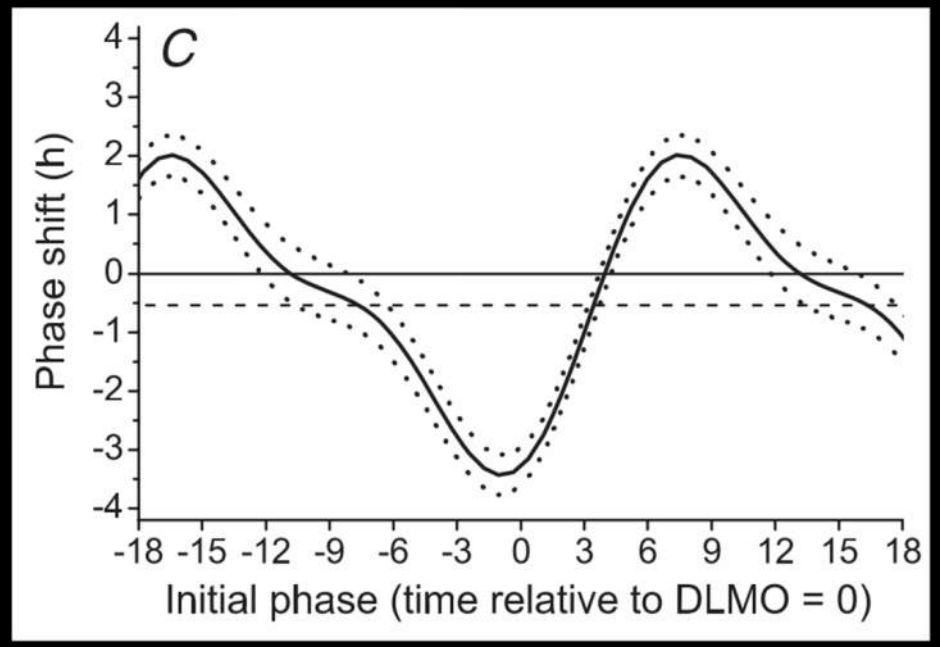
Light Levels + Melatonin Response



(Zeitzer et al. 2000)

- Sigmoidal Response Curve:
  - Floor at < 15 vertical lux
  - Ceiling at > 1,000 vertical lux
  - Linear transition from 50 to 500 vertical lux
- Typical Indoor light levels fall in-between these two areas.
- We are constantly in a state of biological twilight – where our bodies aren't receiving a strong signal one way or the other.
- **This means there is an great deal of opportunity for indoor lighting to help create that robust daytime signal.**

Timing Matters

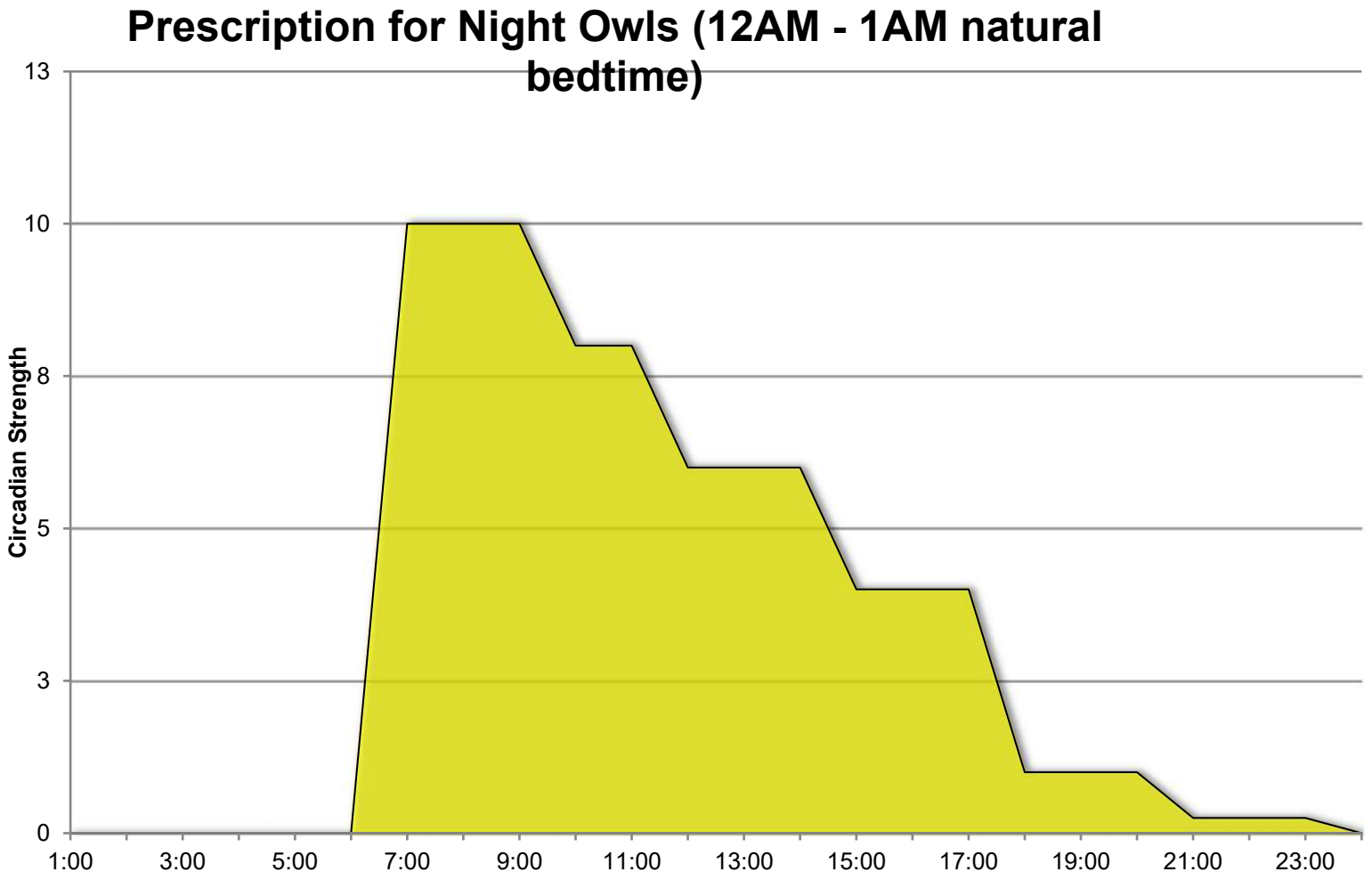


(St. Hilaire et al. 2011)

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.


Prescription for Night Owls (12AM - 1AM natural bedtime)
Circadian Strength
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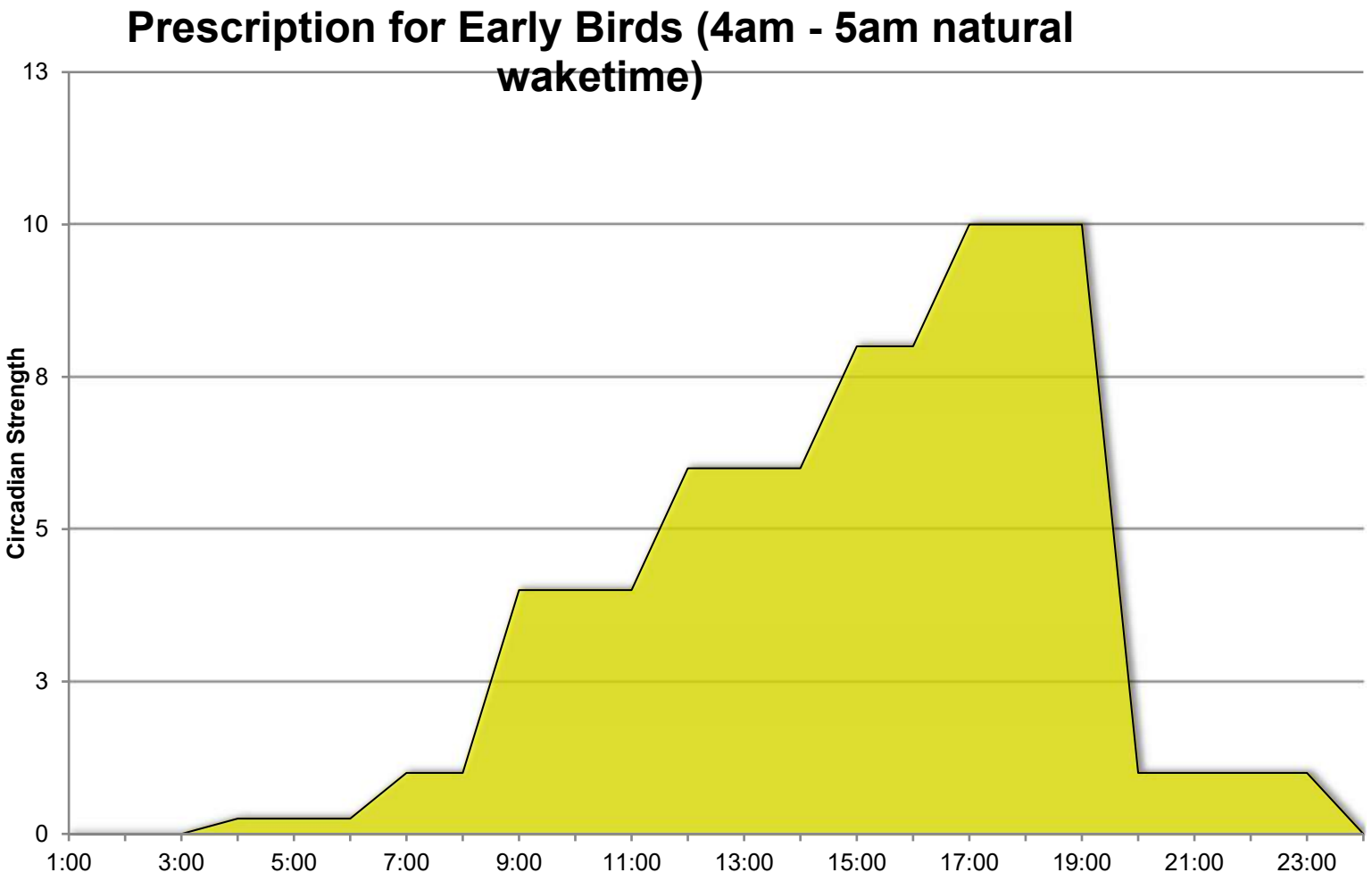
Prescription for Early Birds (4am - 5am natural waketime)
Circadian Strength
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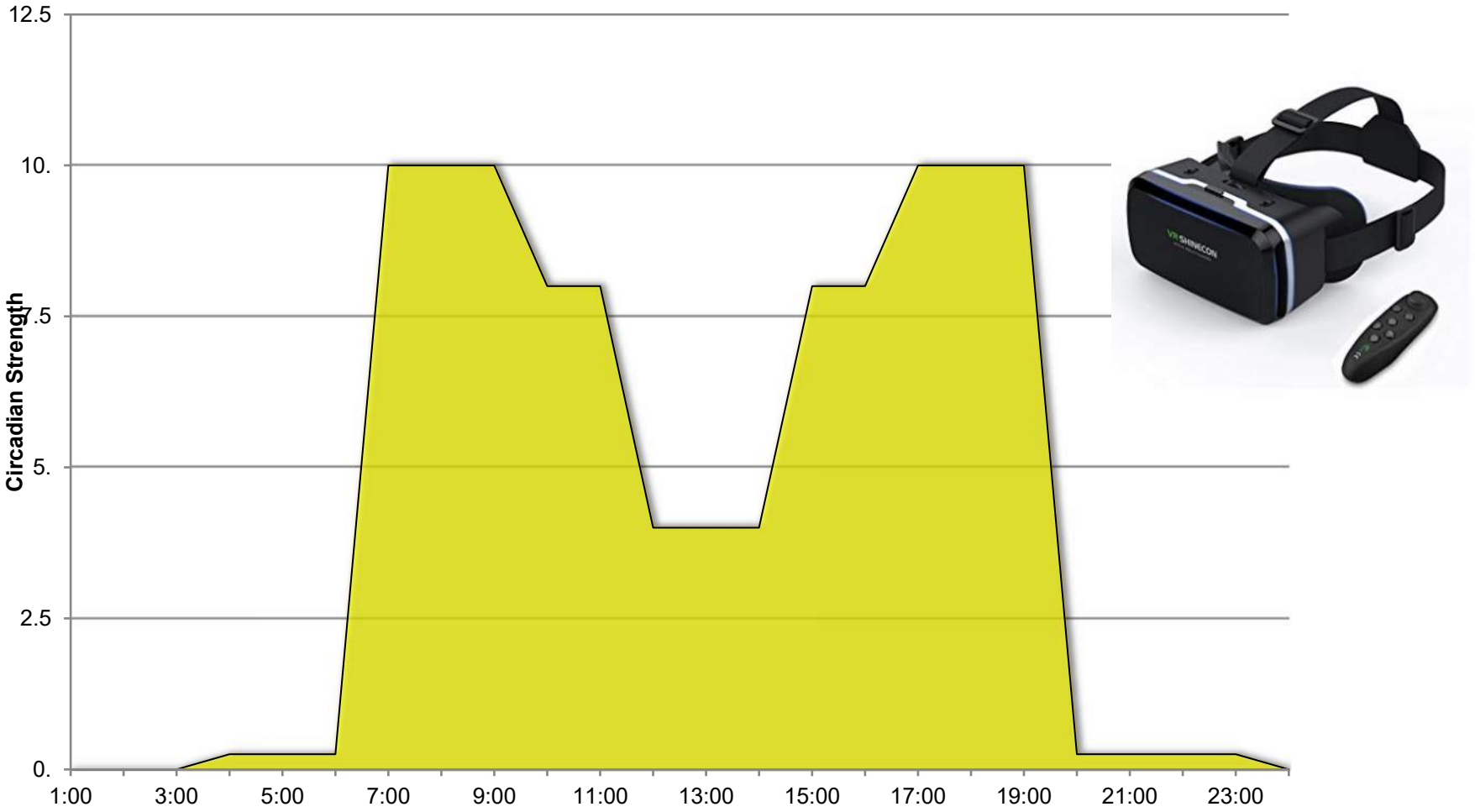
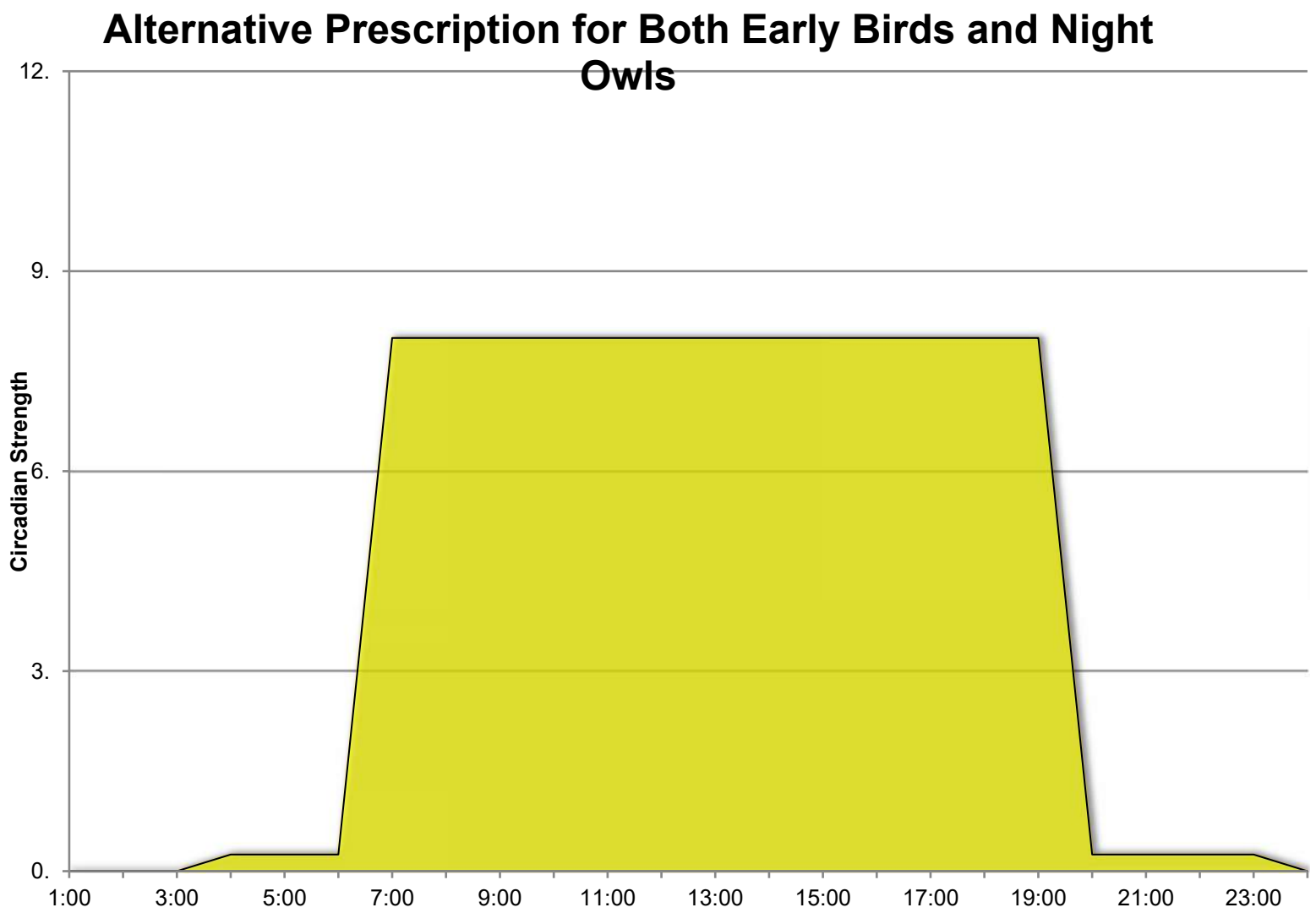
Prescription for Both Early Birds and Night Owls




Alternative Prescription for Both Early Birds and Night Owls
Circadian Strength
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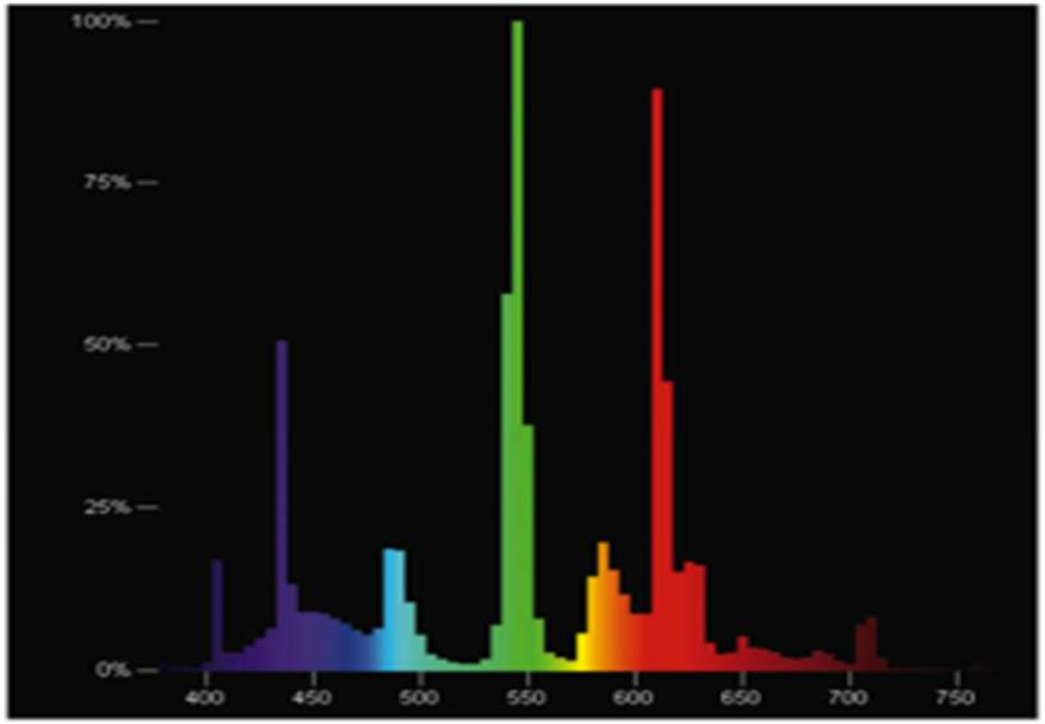
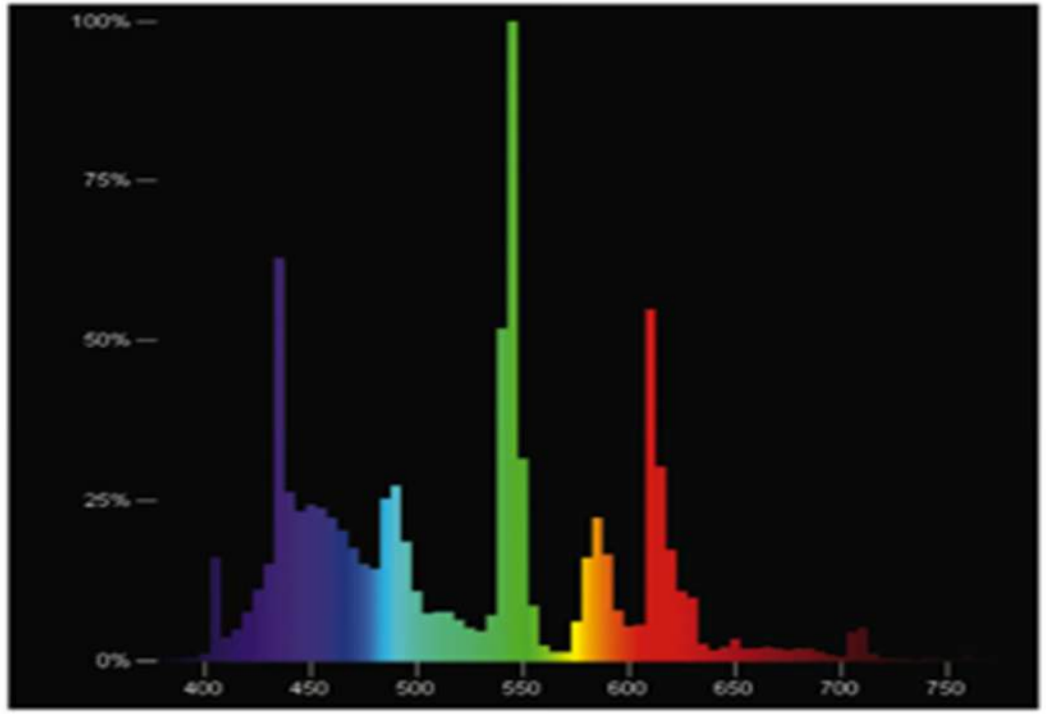
Can we do this indoors?

Original article

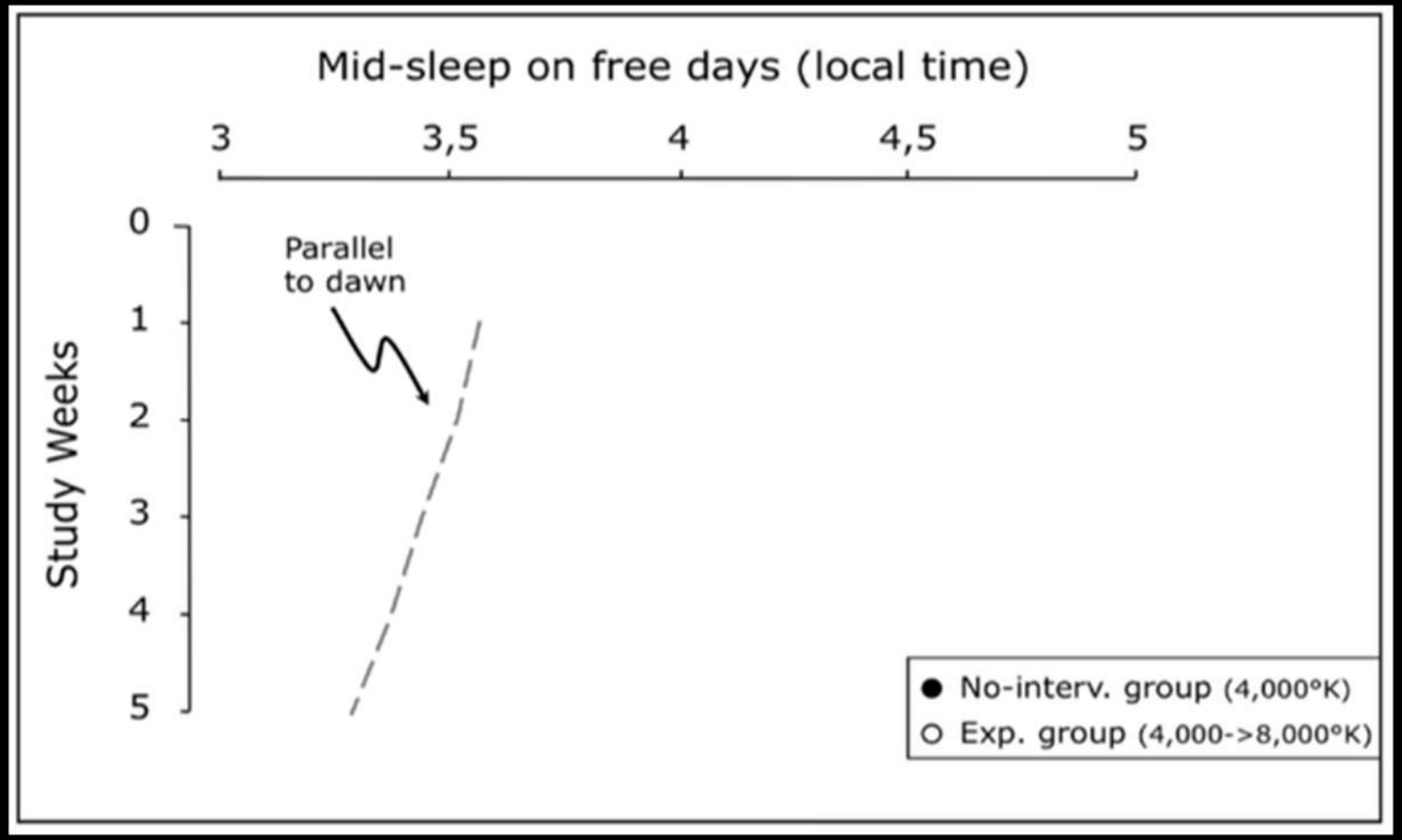
Scand J Work Environ Health 2011;37(5):437-445





Objective: Can we entrain to normal office lighting?

Results



- Experiment was done when day were getting longer and dawn came sooner each day
- Control group (4000K) mid-sleep was 30 minutes earlier
  - They shifted with the change of the season
- Experimental group (8000K) mid-sleep had negligible change
  - They received a significant light signal such that the change in season did not impact their sleep time.

Conclusion: Office workers entrained to the office lighting

Eating After Dark…

Eating closer to circadian night is associated with significant weight gain
(McHill et al. 2017)

- When we sleep, our bodies enter a mini-hibernation
  - Metabolism shuts down for fasting
- Sending nighttime signals in the workplace would initiate this hibernation process
- If you did this….you should not eat after work.

Image credit: Huffington Post

Until society revolves around the sun, our electric lights should not!

2017 Clinical and Field Studies

- Early morning light given to night owls significantly reduces ADHD symptoms (Fargason et al. 2017)
- Higher daytime circadian signal in the office is associated with better sleep and mood (Figuiero et al. 2017)

There's a big benefit to providing high daytime signals during our biological daytime

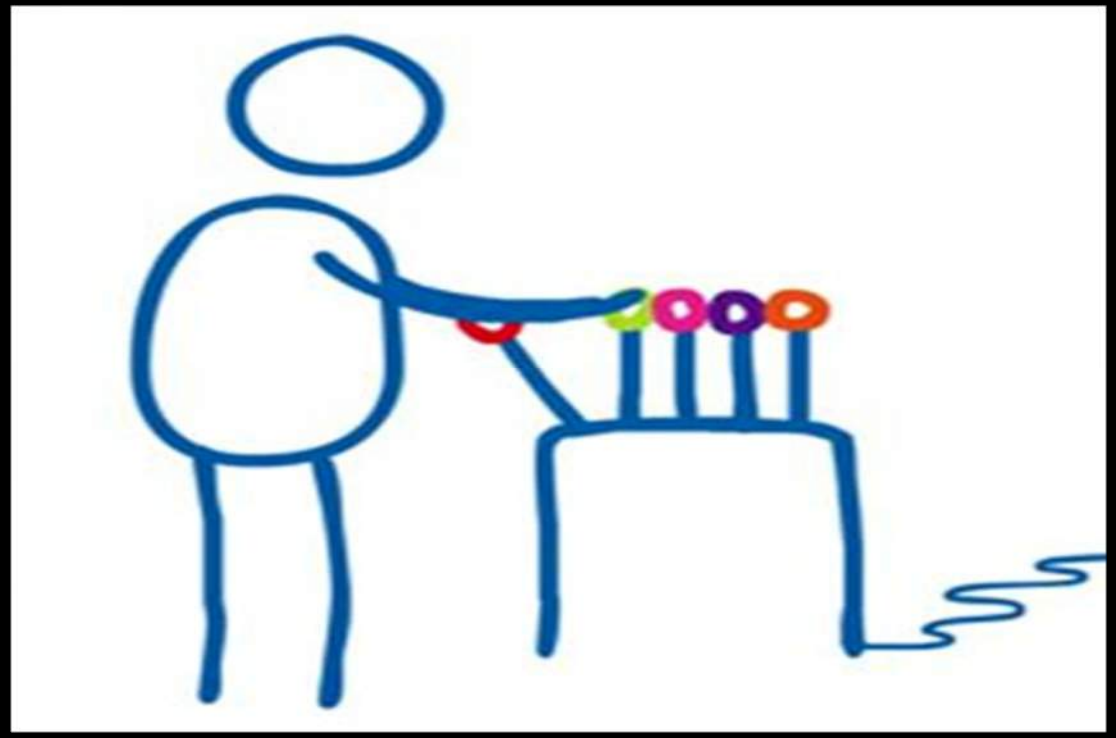
Part 1: Quiz

- What do circadian rhythms regulate?
  - Hormones, metabolism, alertness, sleep, and so much more
    - (43% of genetic expression is circadian – Zhang et al. 2014)
- What is a chronotype?
  - Self selected preference for sleep and wake time
- What is social jet lag?
  - When internal time and social time don’t agree
- Who has social jet lag?
  - 87% of non-shift workers
- Can we synchronize to electric lighting?
  - Yes!
- Should we synchronize to electric lighting?
  - Three (3) possible approaches:
    - support chronotype variance (social time – Simple on/off controls) which we do now.
    - reduce chronotype variance (solar time – advanced controls) expensive / winter really?
    - Support chronotype variance within reason (i.e. daytime from 6am to 8pm) see slides next

Part 2: Techniques

- What factors can be used to maximize or minimize circadian stimulation?
- How can we maximize daytime circadian stimulation?
- How can we minimize nighttime circadian stimulation?
- How can we create a proper dynamic 24-hour scenario?

How do we Affect Circadian Stimulation?



Five Levers:

- Intensity
- Timing
- Light History
- Spatial Distribution
- Spectrum

Spatial Distribution

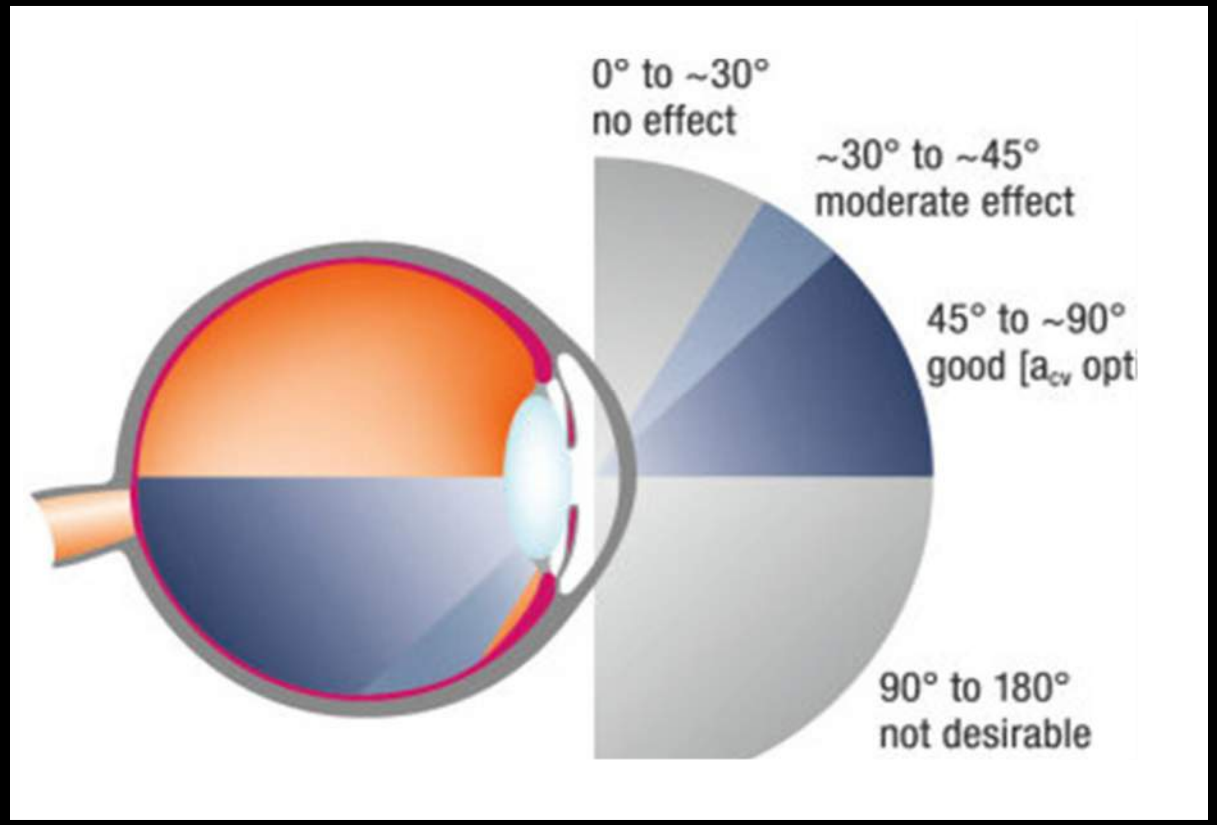


Image credit: www.osram.com

- 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 (taskplane) illuminance may have little effect

Spatial Distribution - SKY

- Light coming from above the horizon is best
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Spatial Distribution - FIRE

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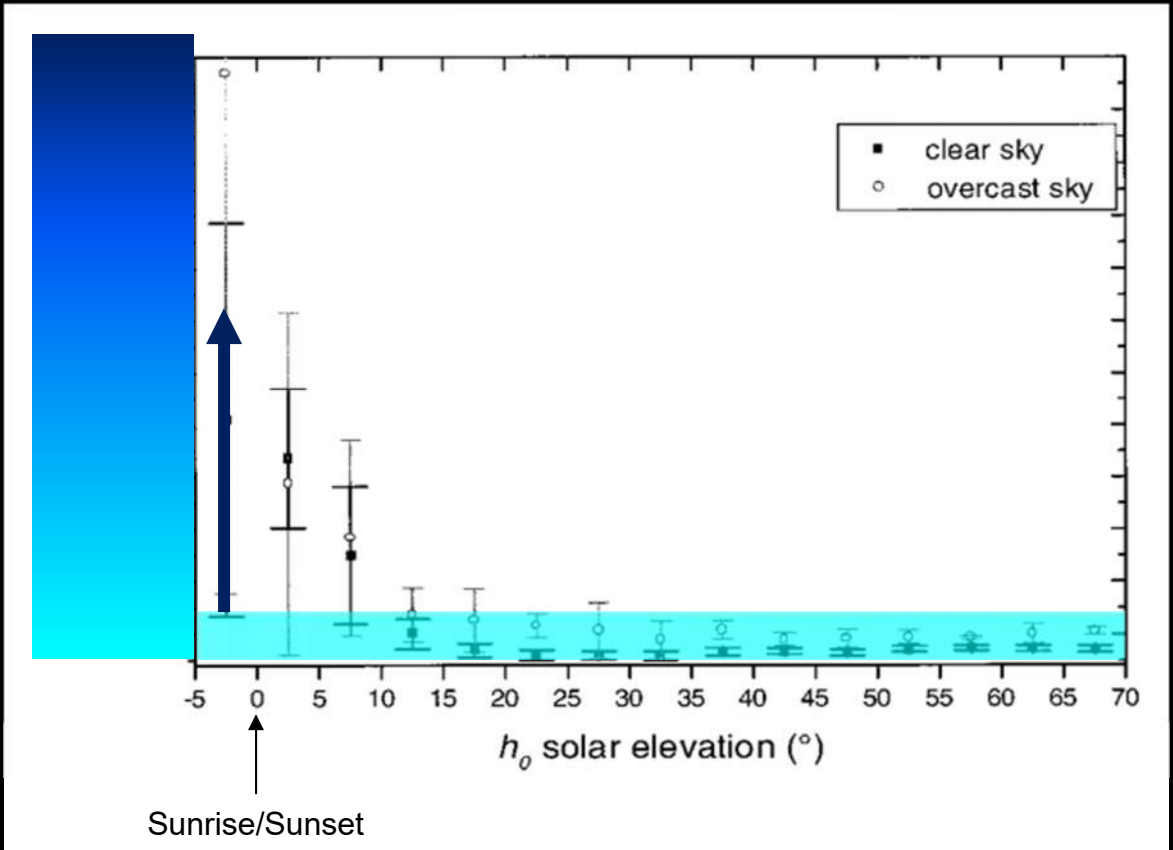
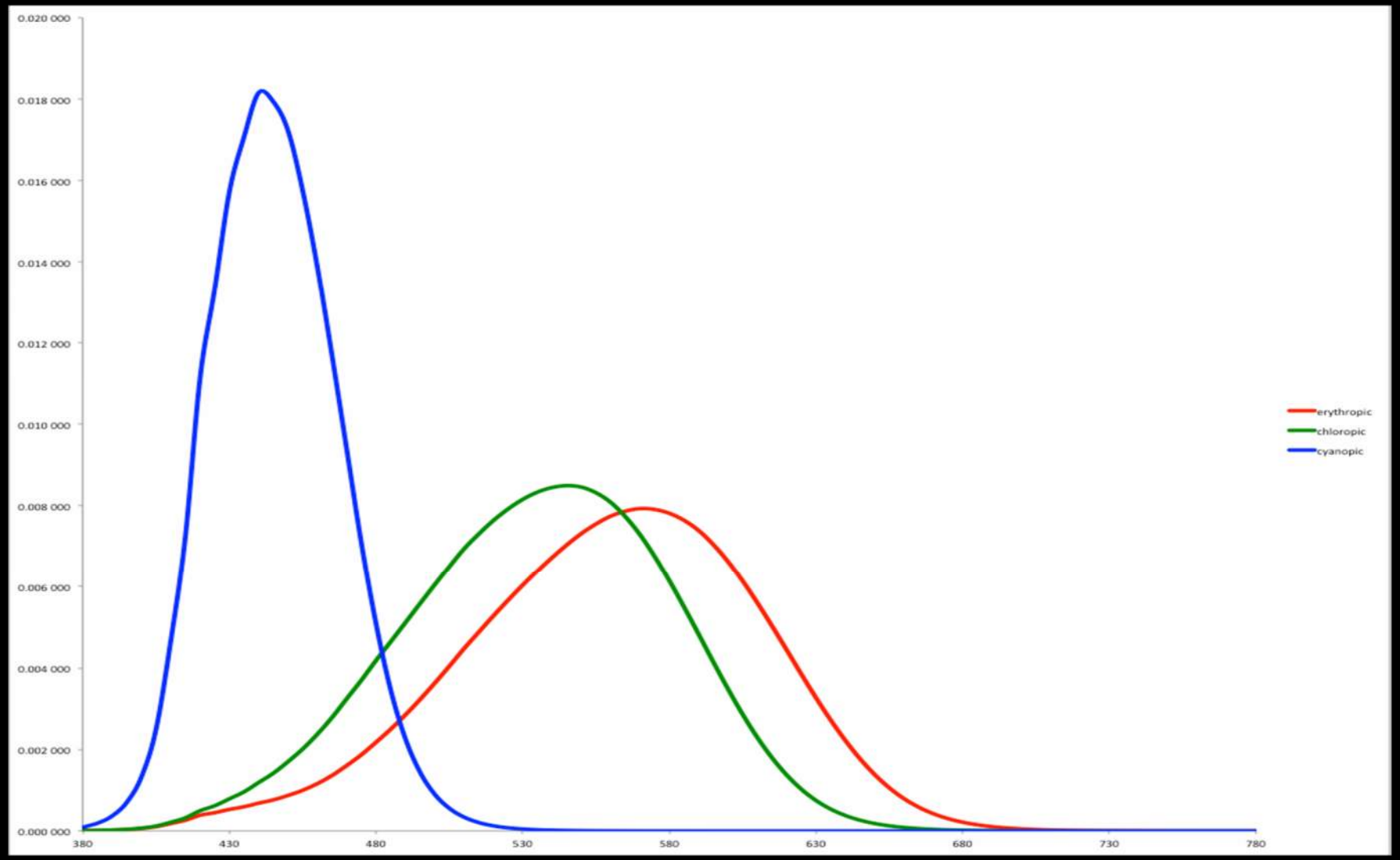
Color Temperature and Intensity



[Hernandez-Andres et al. 2001]

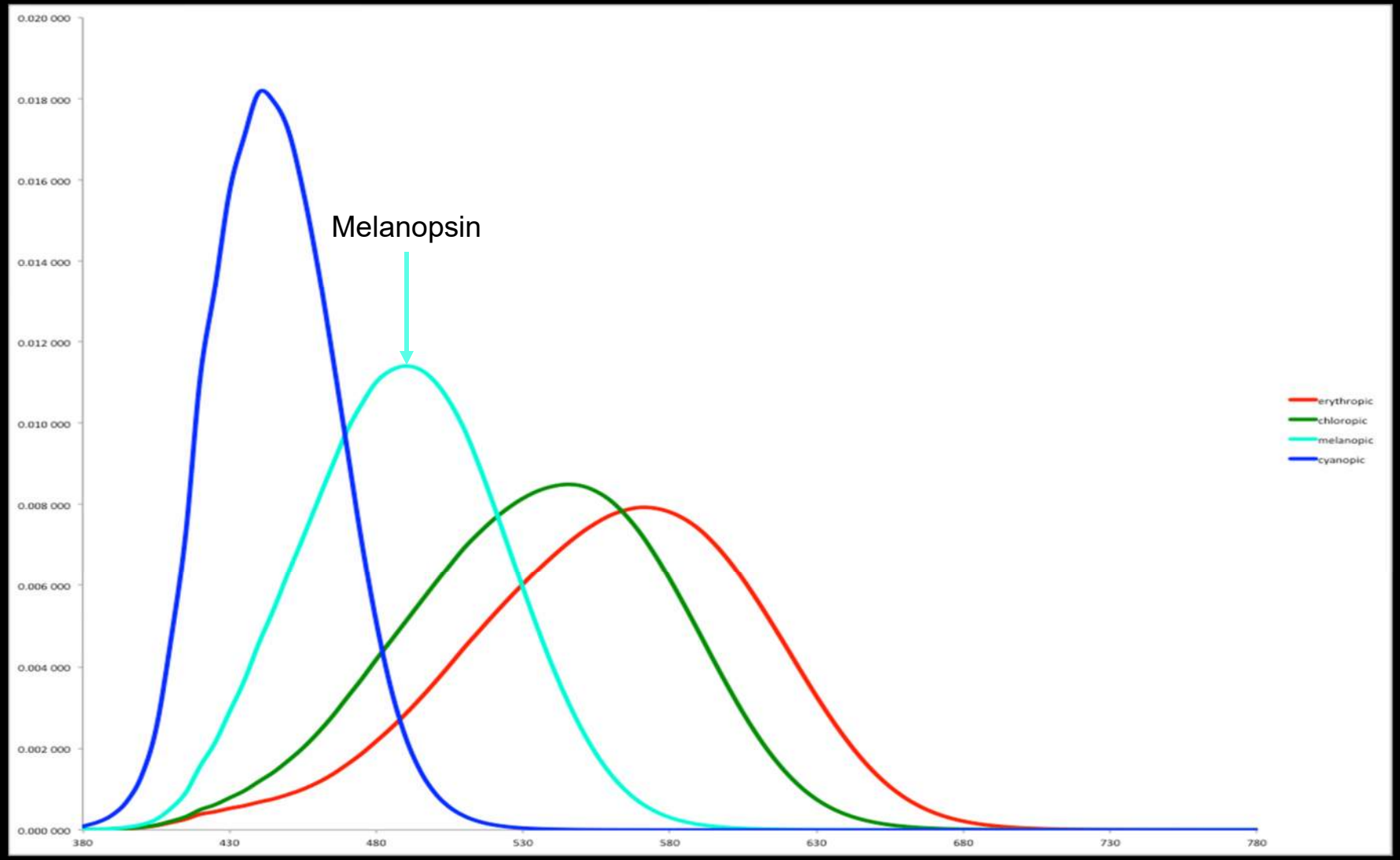
- Daytime color temperature doesn't change much outside of twilight ~ 5500K – 6500K
- Cooler temperature coincides with dramatic reduction in intensity
- High circadian stimulus during the day, low circadian stimulus at night

Cones for Color Vision



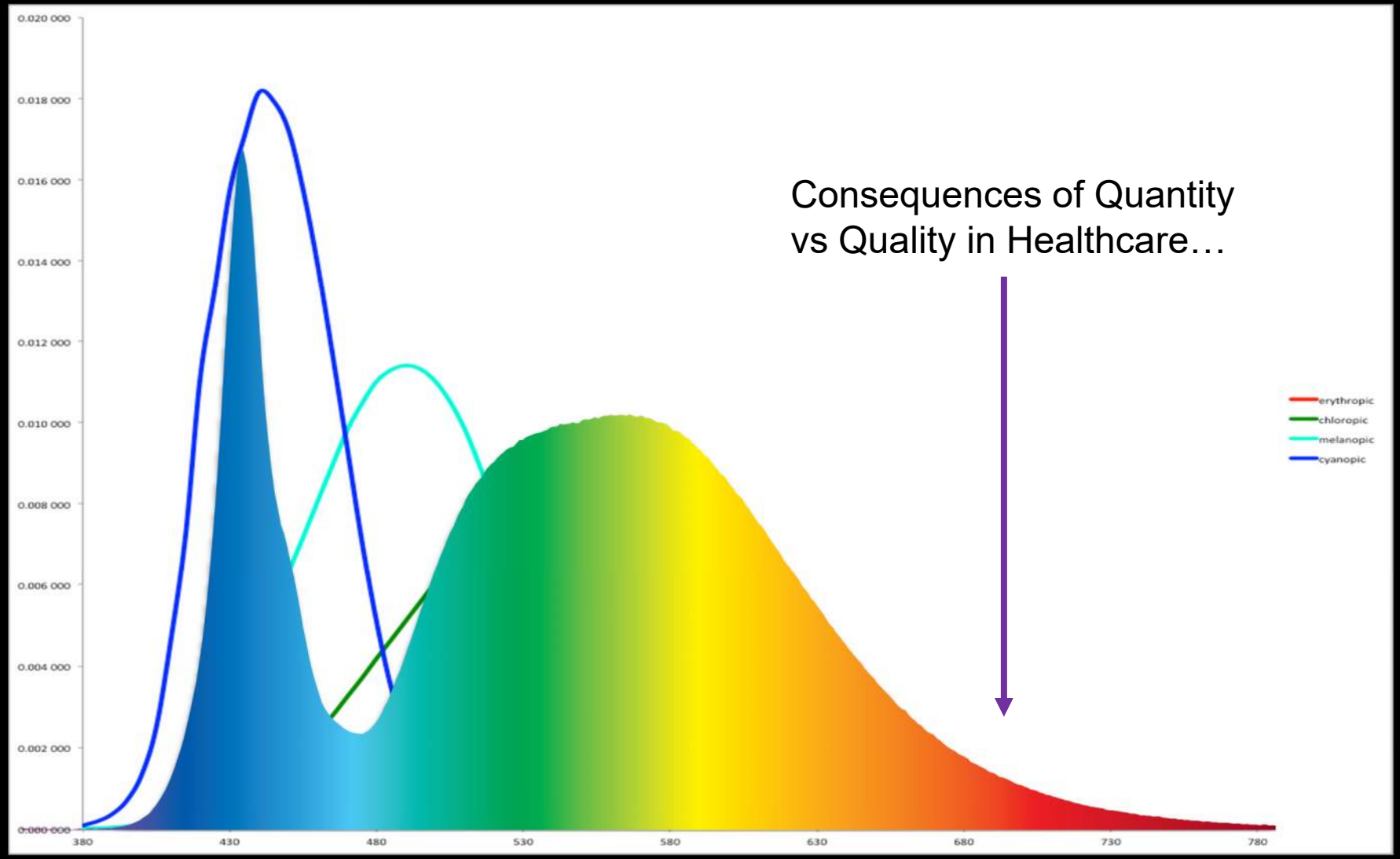
[Lucas et al. 2014, Trends in Neuroscience]

Addition of Melanopsin



[Lucas et al. 2014, Trends in Neuroscience]

5000K “Daylight” LED

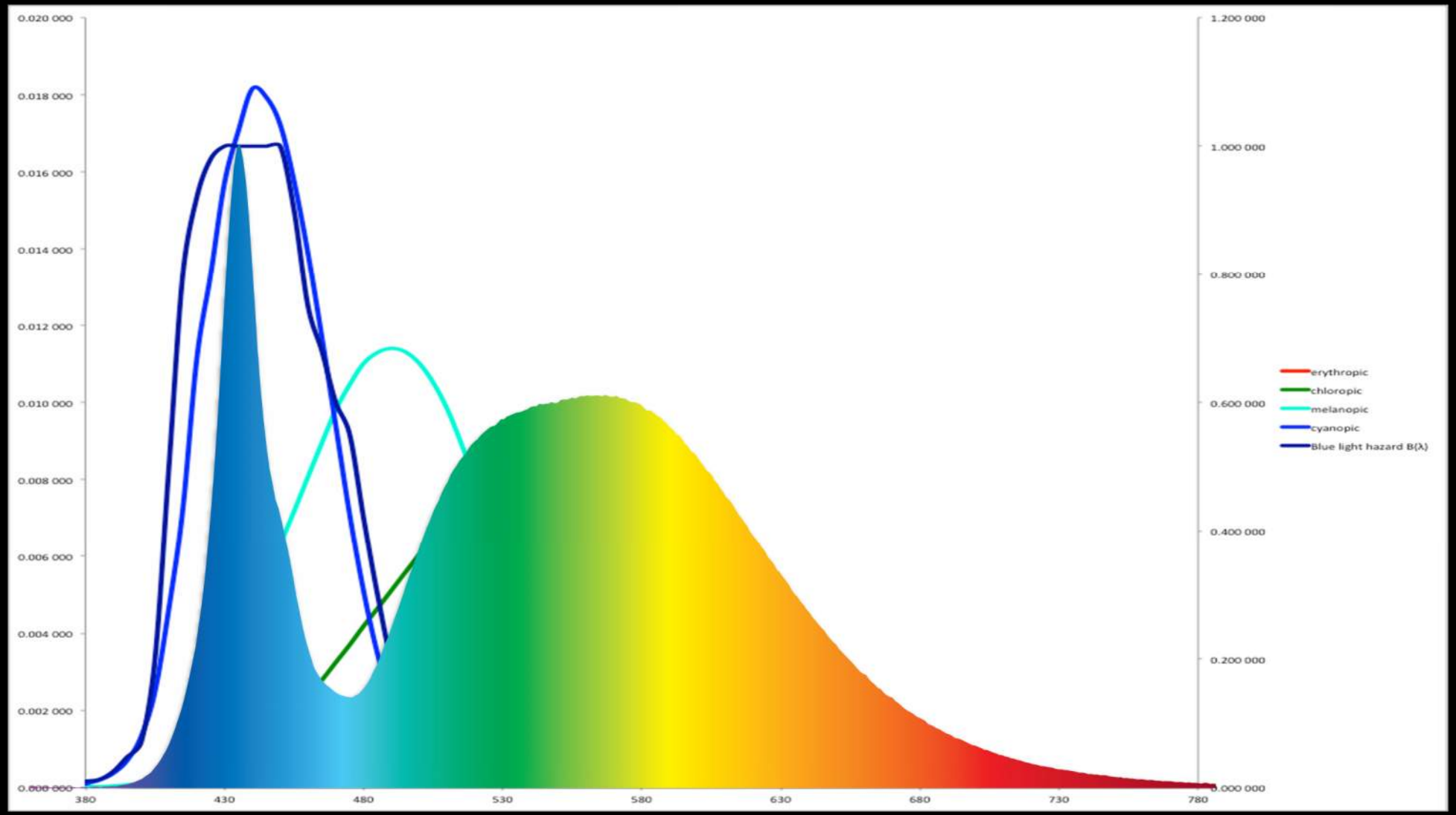


[Lucas et al. 2014, Trends in Neuroscience]

DETECTING Cyanosis

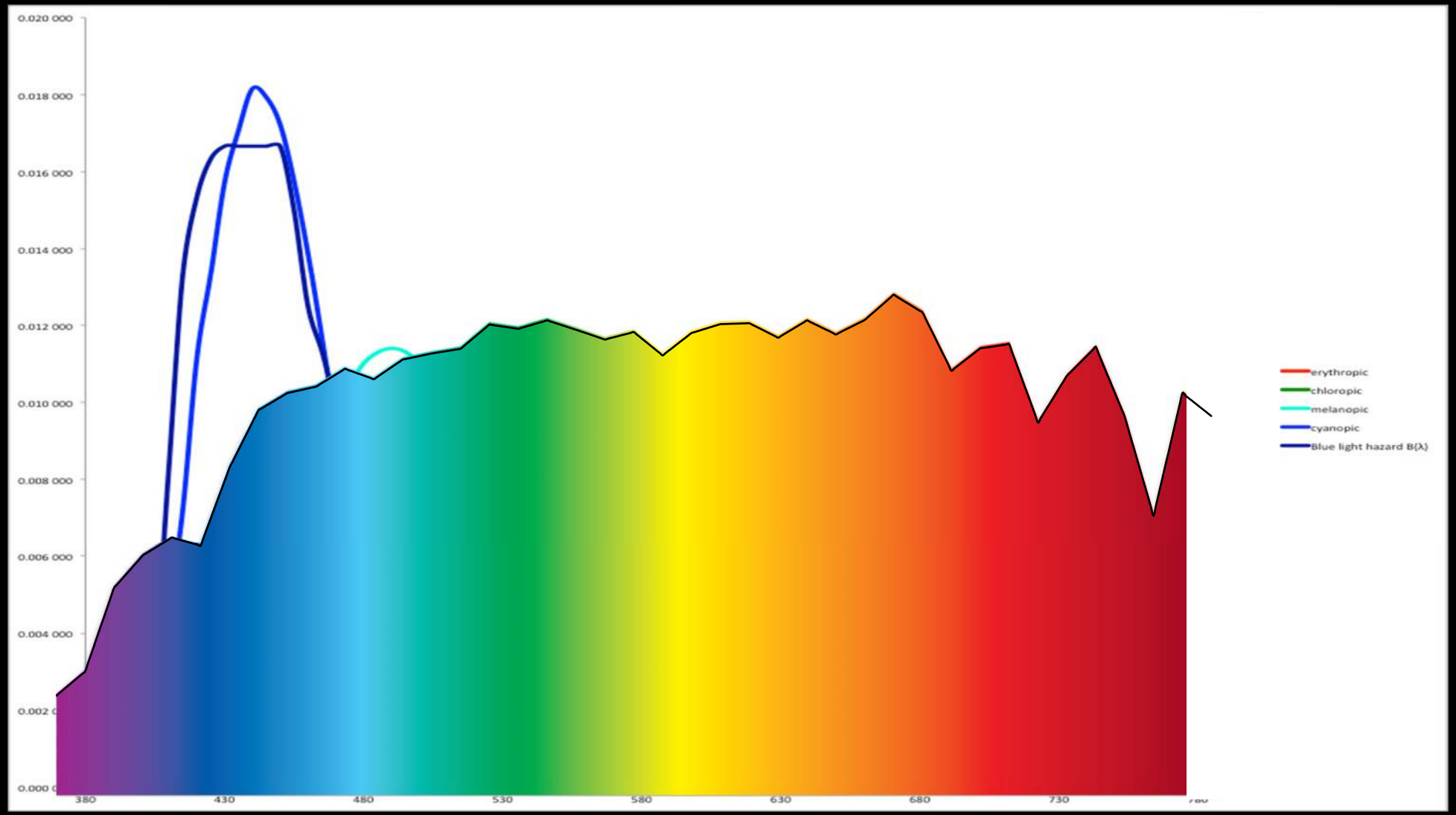
- Bluish coloration of the skin
- Signs of the following:
  - Sepsis
  - Pneumonia
  - Bronchiolitis
  - Pulmonary hypertension
  - Hypoventilation
  - COPD
  - Congenital heart disease
  - Heart disease
  - Hypothermia
  - Arterial obstruction
  - Etc.
- This bluish coloration in the skin is actually an absenc
  - Cyanosis Observation Index quantifies this
    - 3.3 or less is required

‘Bad Blue’ for Reference



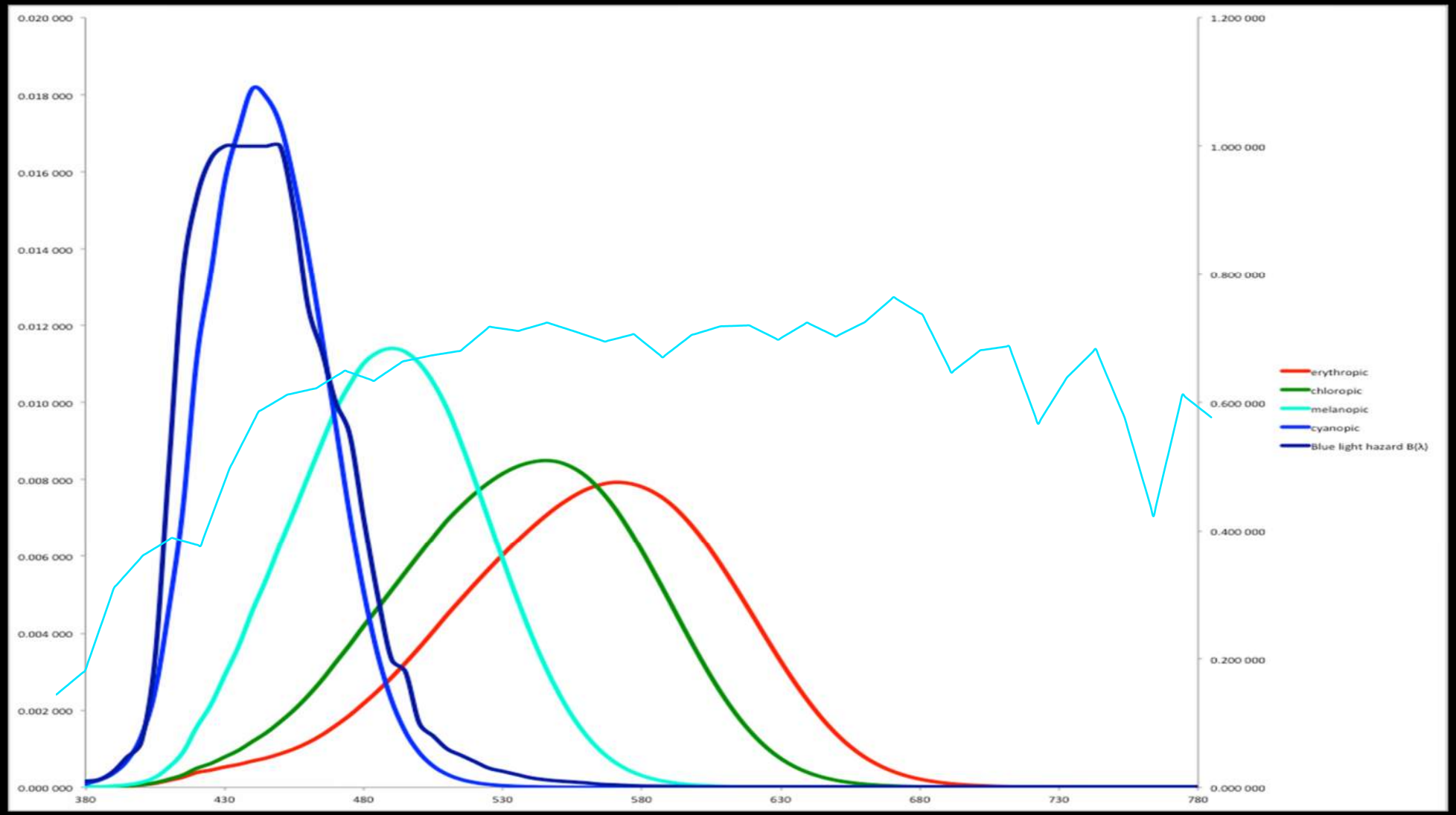
[Lucas et al. 2014, Trends in Neuroscience]

5000K Daylight

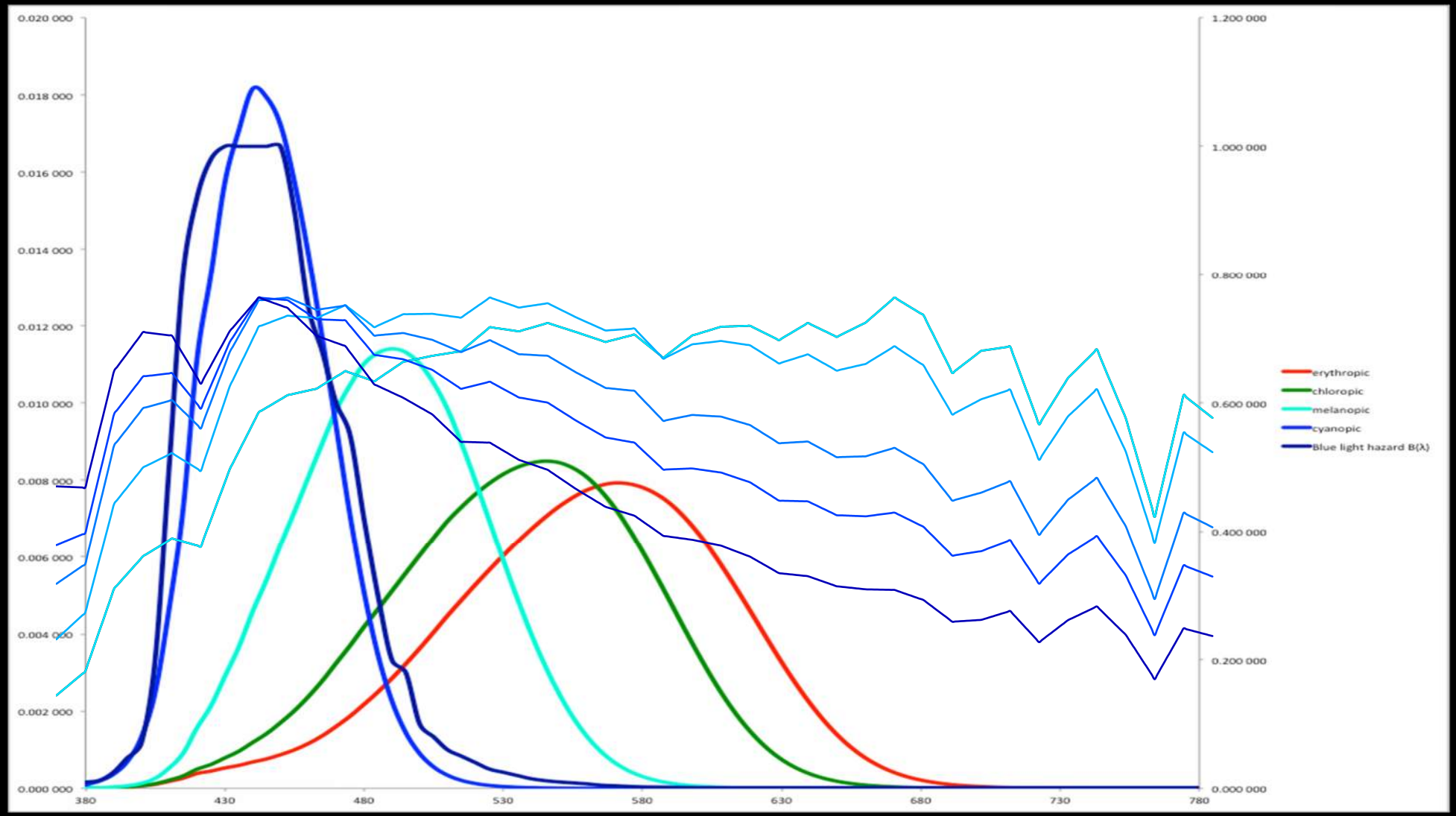


[Lucas et al. 2014, Trends in Neuroscience]

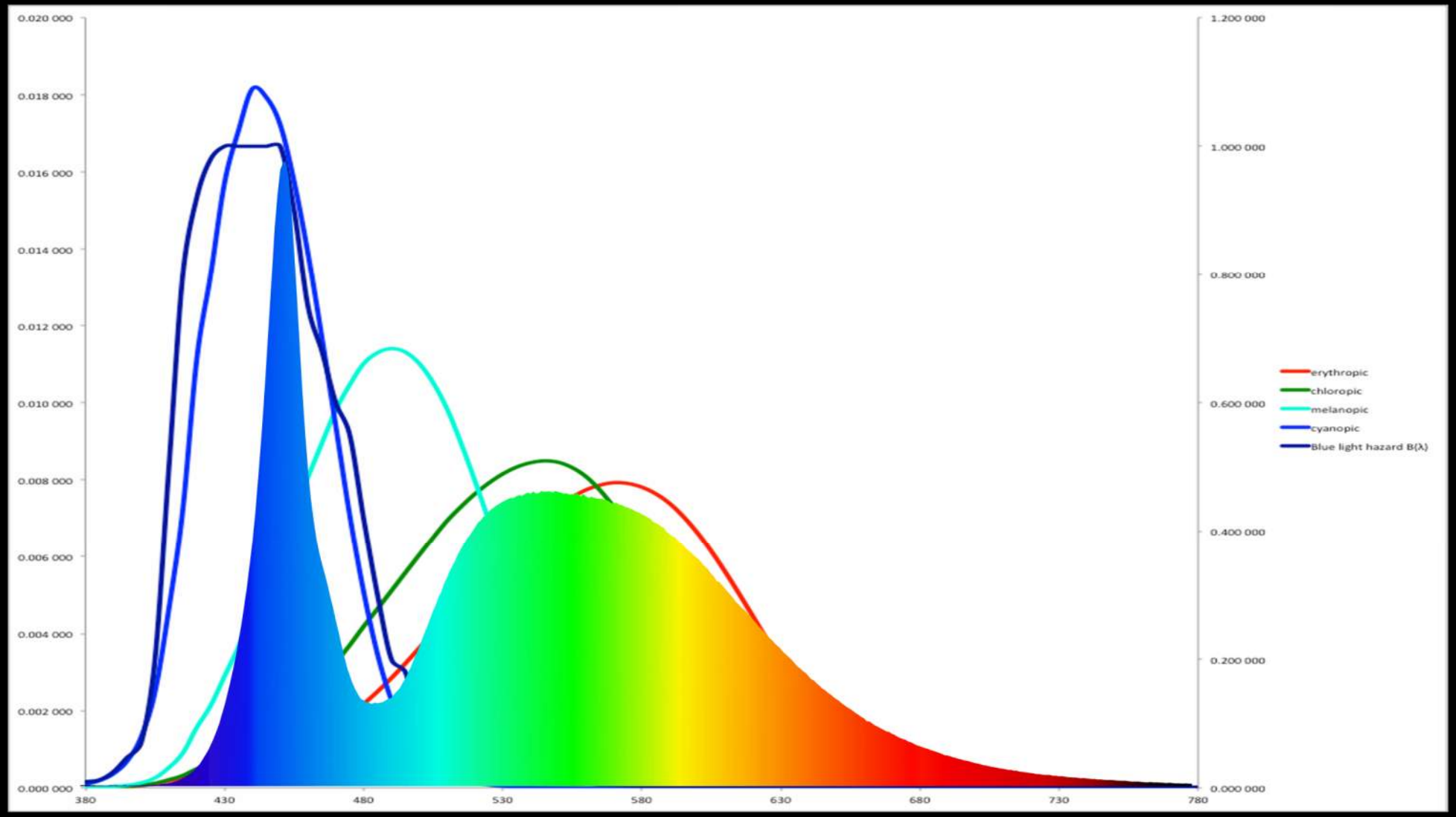
5000K Daylight



5K Daylight – 10K Daylight

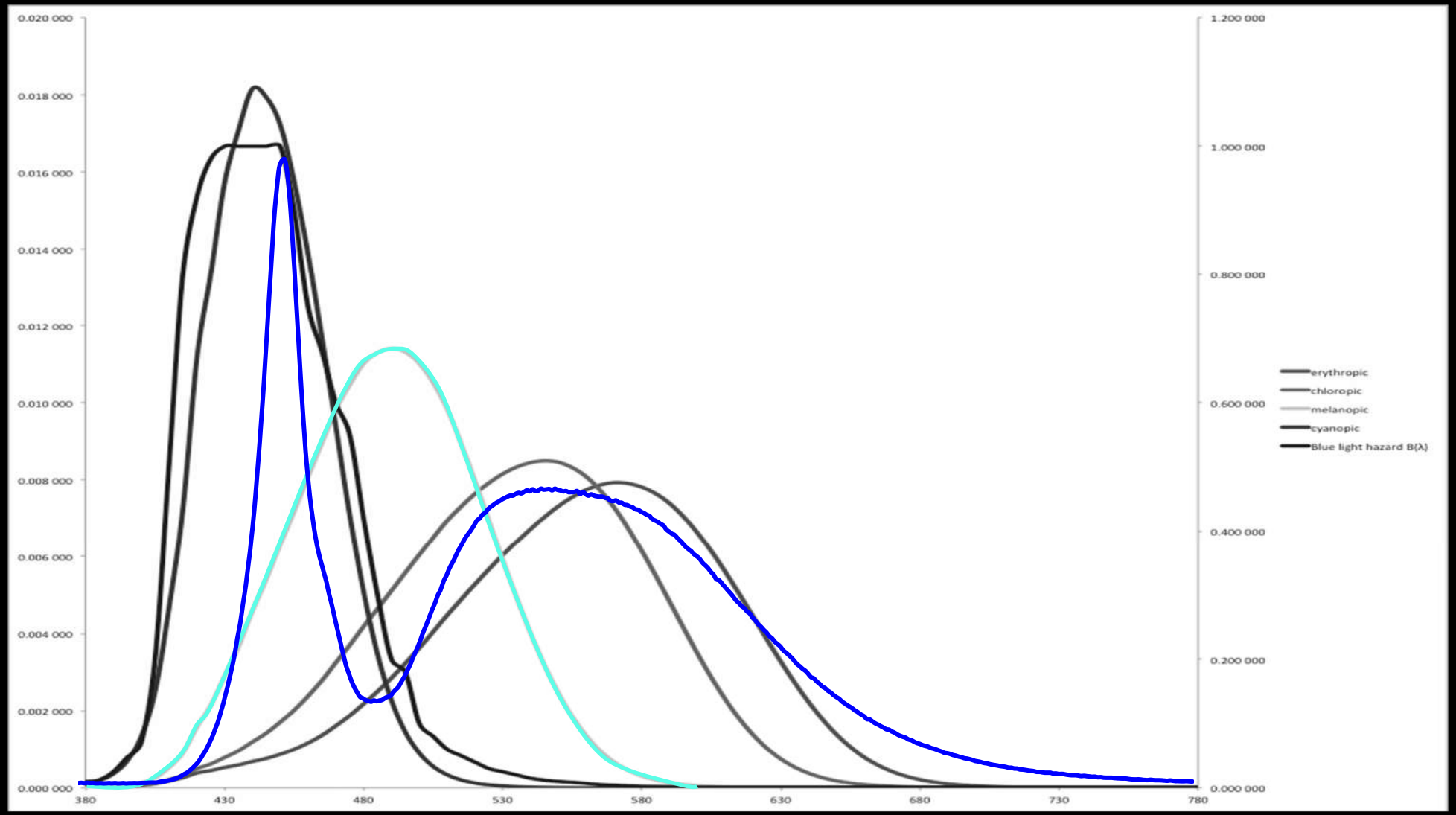


Tunable White LED



[Lucas et al. 2014, Trends in Neuroscience]

6500K LED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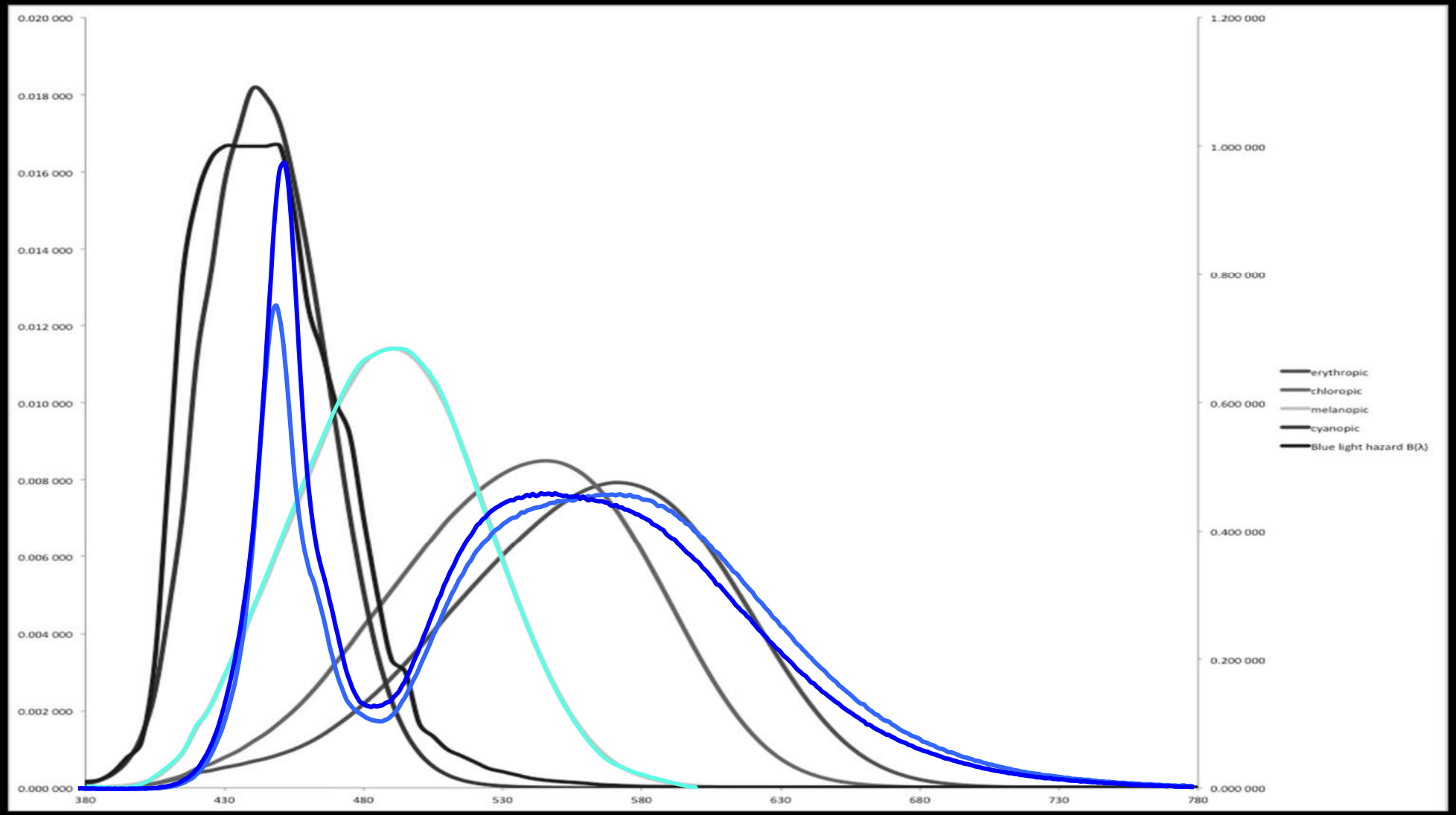
730
780
erythropic
chloropic
melanopic
cyanopic
Blue light hazard B(λ)

5000K LED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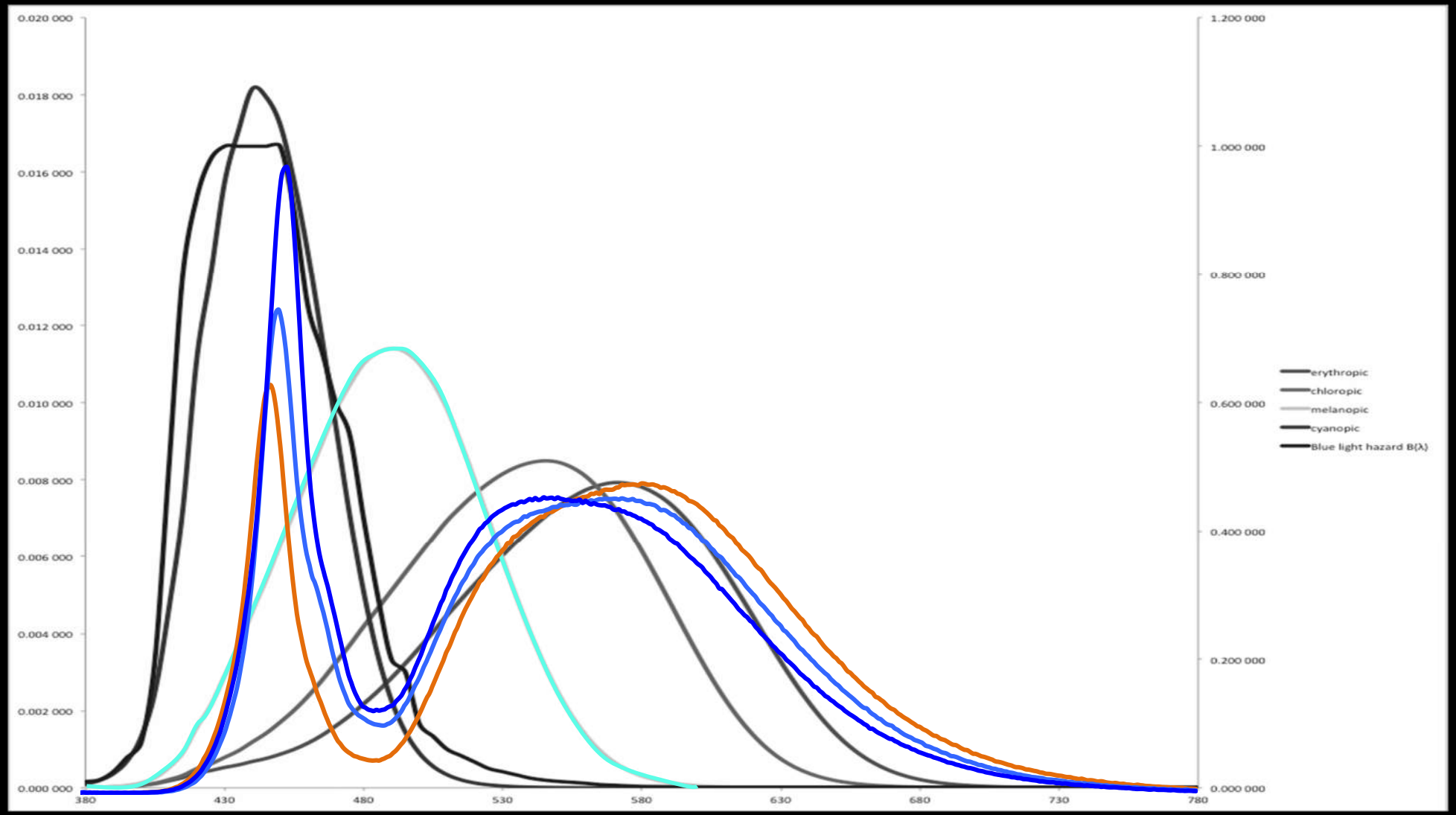
680
730
780
erythropic
chloropic
melanopic
cyanopic
Blue light hazard B(λ)

4000K LED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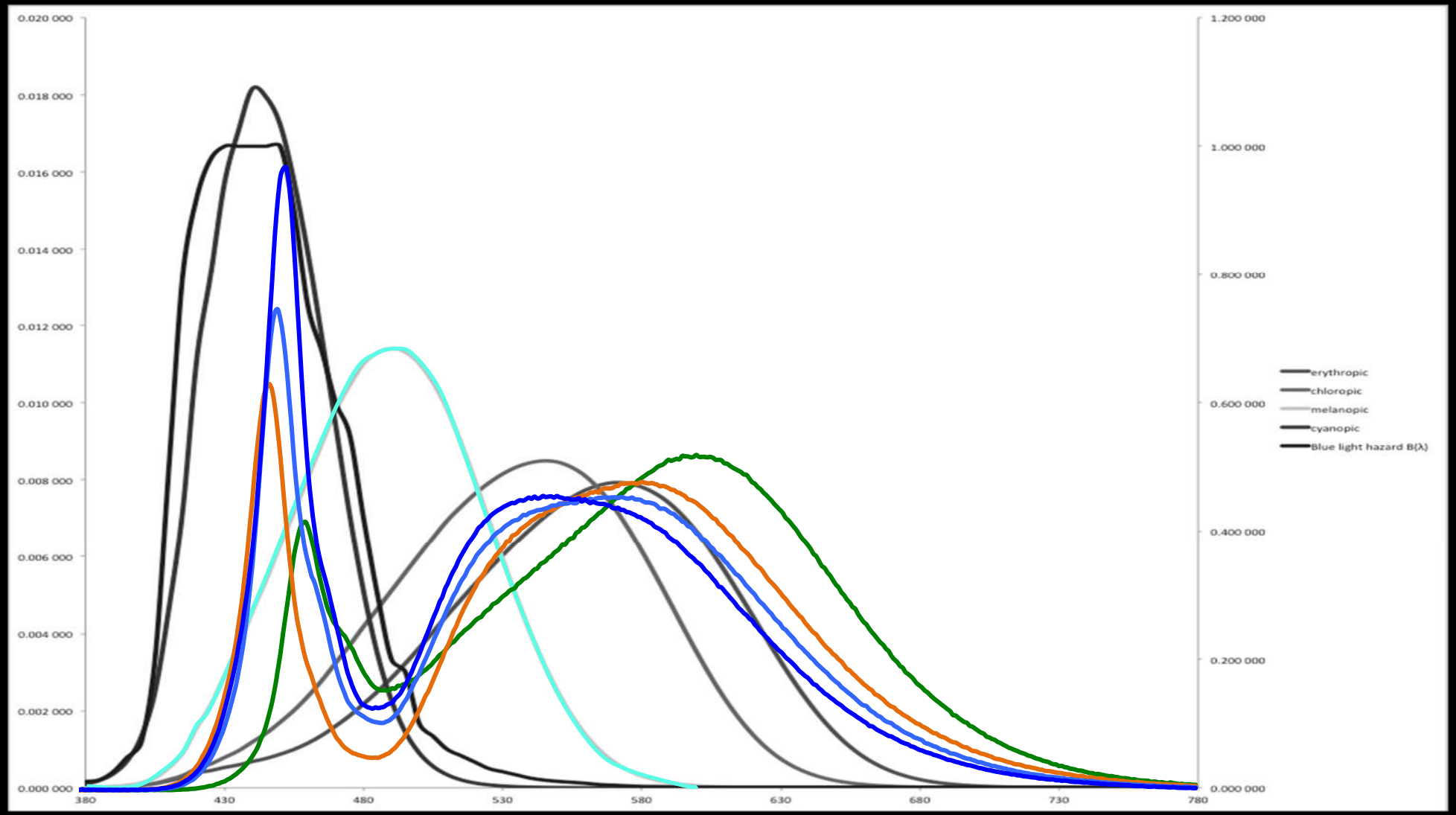
erythropic
chloropic
melanopic
cyanopic
Blue light hazard B(λ)

3500K LED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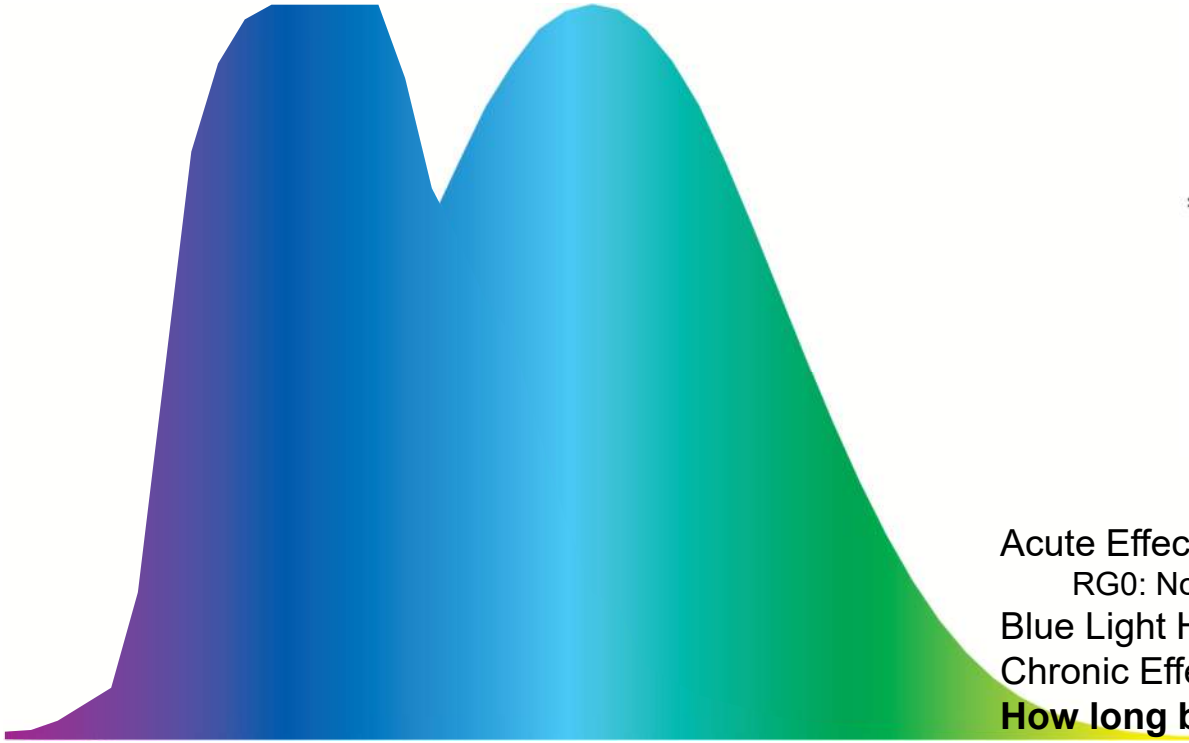
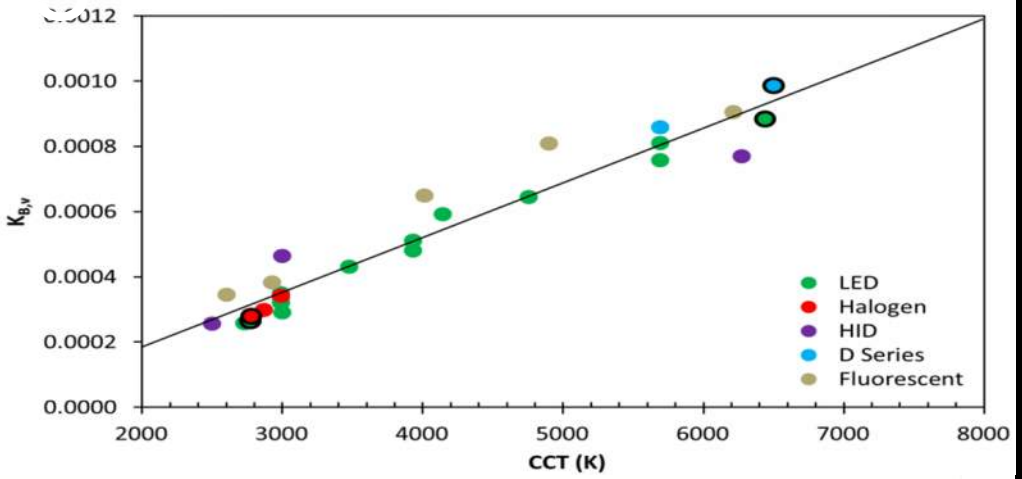
Blue light hazard B(λ)





[DOE: Optical Safety Facts Sheet]

Acute Effects: Photochemical induced injury

RG0: No cause for concern w/exposure less than 2.8h

Blue Light Hazard is strongly correlated to CCT

Chronic Effects: Oxidative Stress

How long before it's a problem? We don't know

And……

- Among the factors that get in the way of long sound sleep is blue light. It turns out blue light can suppress melatonin more than green light, and shifts circadian rhythms by twice as much (three hours vs. 1.5 hours), Harvard Health reported
- By better understanding the interactions of melanopsin and how the eyes react to light, Prof. Panda hopes to find new targets of countering skewed circadian rhythms due to artificial illumination.

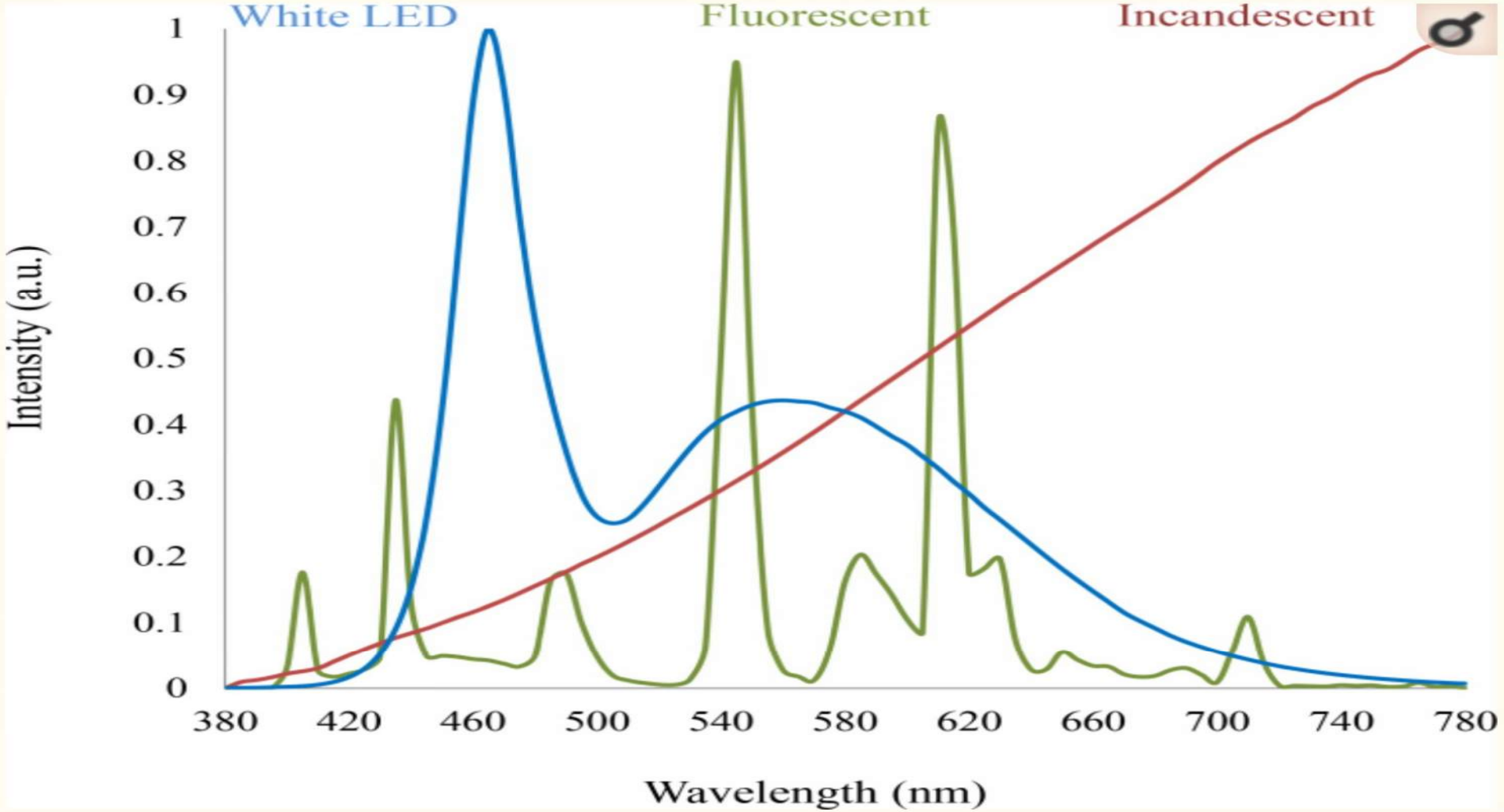
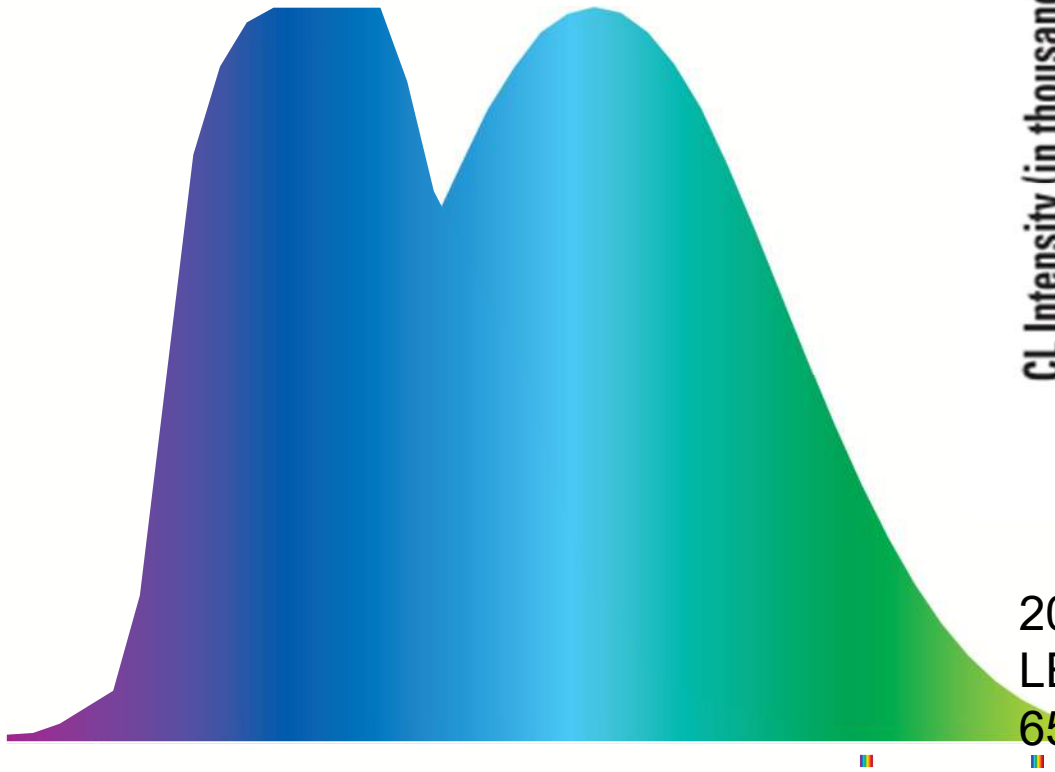
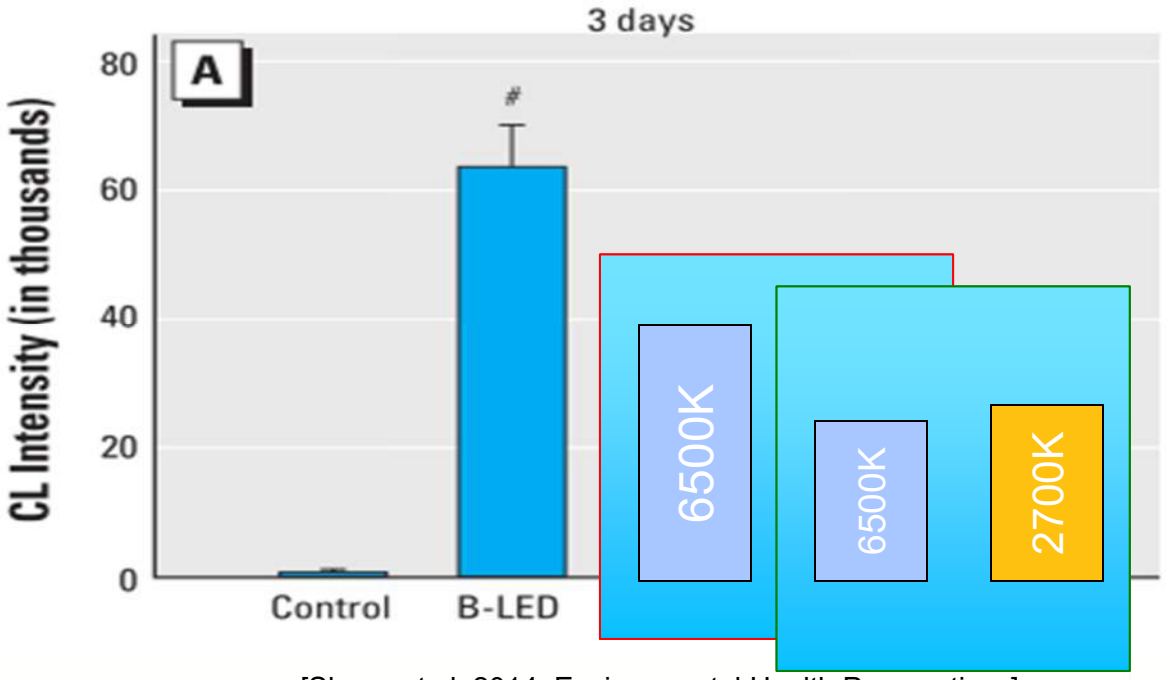


Figure 1

A comparison of the power spectrum of a standard white-light LED, a tricolor fluorescent lamp, and an incandescent source. The radically different power spectrums can look similar when viewed directly by the eye, irrespective of how much blue emission is present.

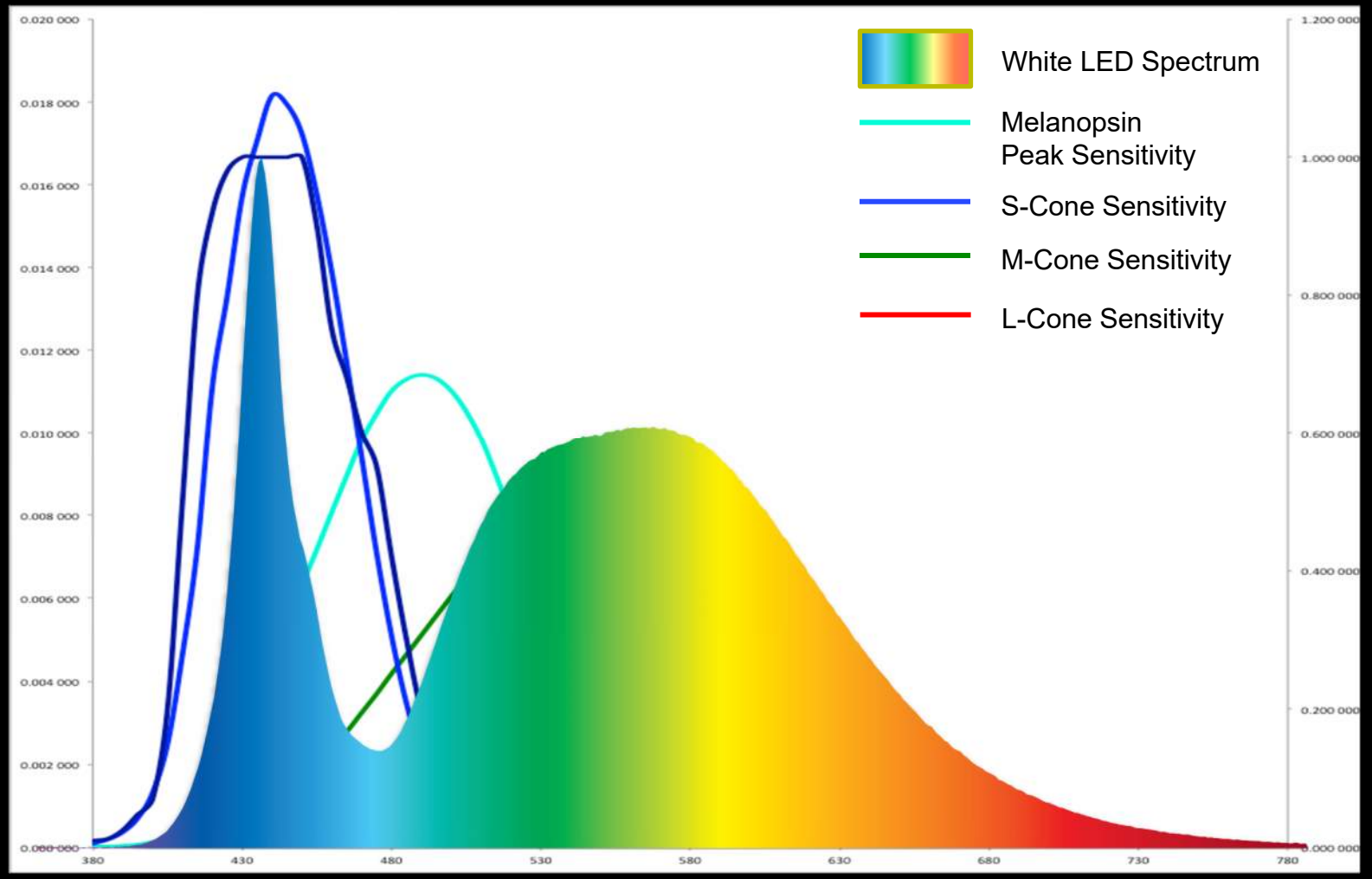




[Shang et al. 2014, Environmental Health Perspectives]

2014 study shows significant difference between 6500K LED and 6500K CFL but not between 2700K CFL and 6500K CFL.

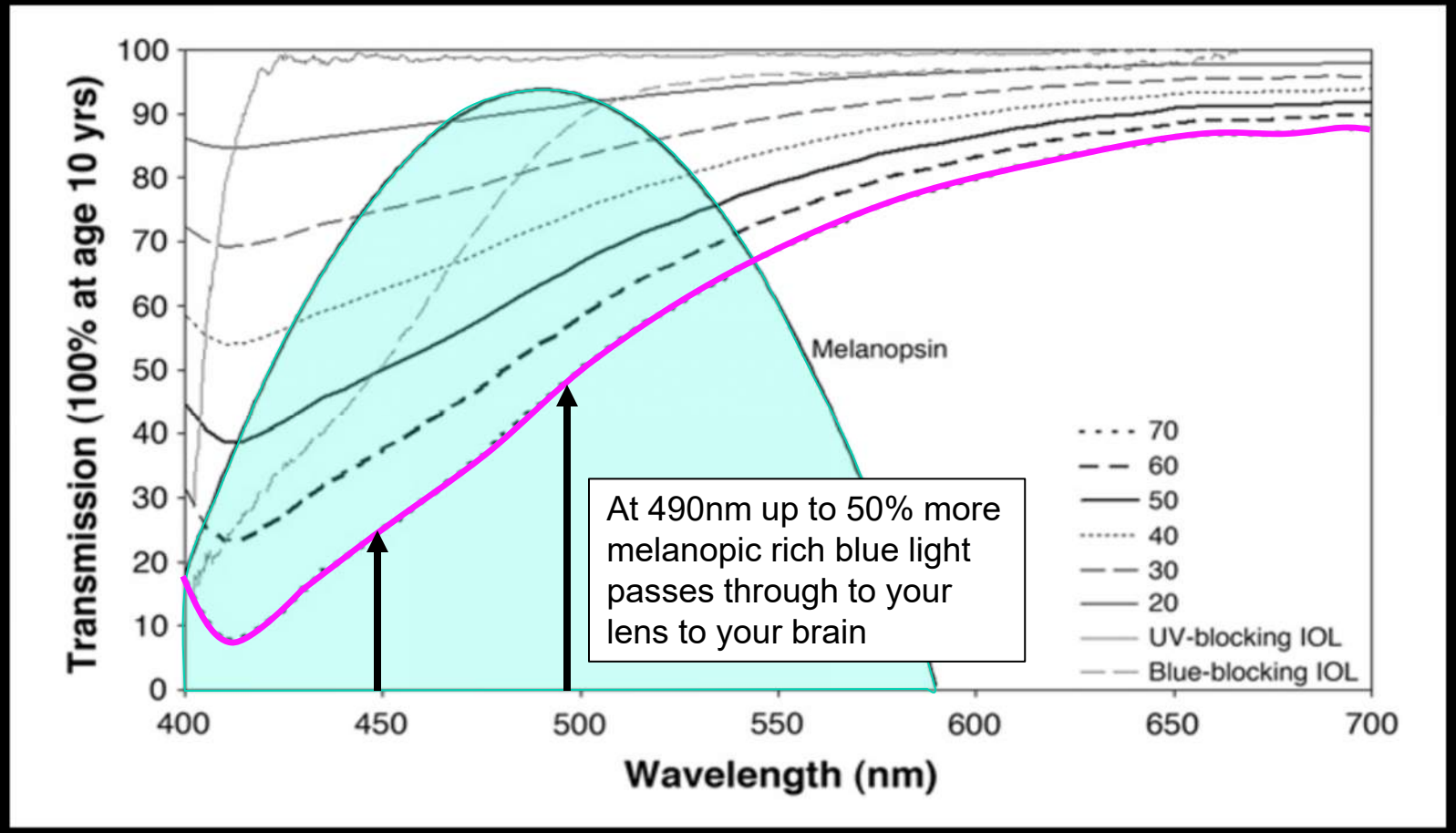
Why would LED have a higher risk?



- Melanopsin drives our pupillary light reflex.
- That reflex is initiated when we receive light that is rich in the sky blue signal
- Traditional LED have a very clear dip in that sky blue region, which means they are lacking in that spectrum
- Traditional LED spectra actually undermine our natural bodies protection mechanism and increase risk of exposure to the bad blue

Other Considerations:

Lens Transmission with Age, secondary protection mechanism?



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

"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"

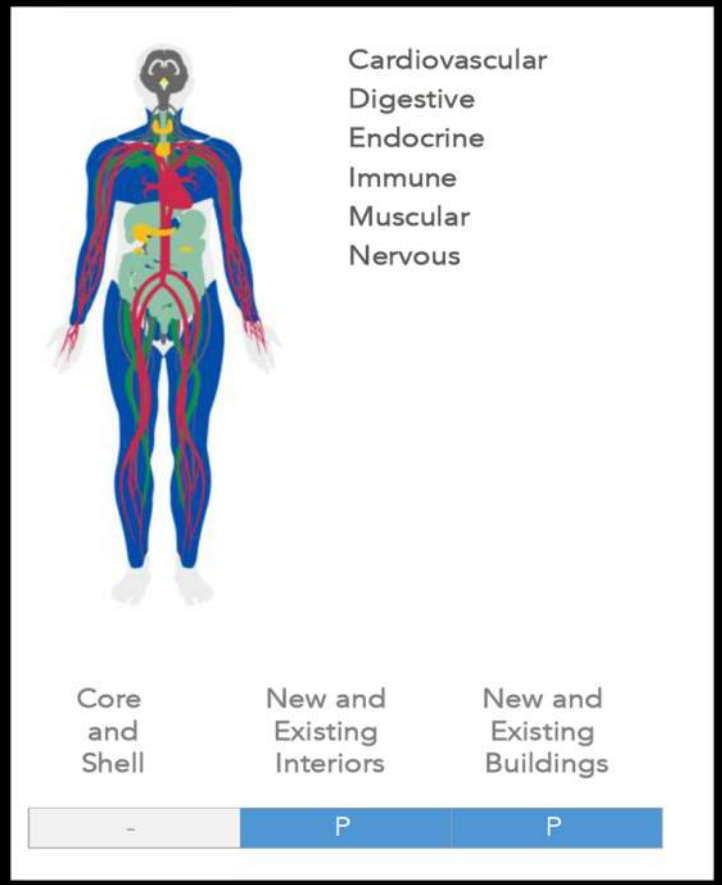
– Behar-Cohen et al. 2011, Progress in Retinal and Eye Research

Standards and Models

- WELL Building Standard
  - v2 released in May 2018
  - Uses a ratio to convert photopic lux to equivalent melanopic lux (EML)
- LRC CS (Circadian Stimulus Model)
  - Requires the use of the LRC calculator and spectral data
  - Uses sub-additivity which is a phenomena that occurs in color vision

WELL Building Standard v2

- WELL Building Standard has adopted melanopic lux in Feature L03 of their Light Concept.
- Feature L03: Circadian Lighting Design
  - At 75% or more of workstations, at least 200 equivalent melanopic lux is present, measured on the vertical plane facing forward, 1.2 m [4 ft] above finished floor (to simulate the view of the occupant). This light level may incorporate daylight, and is present for at least the hours between 9:00 AM and 1:00 PM for every day of the year.
  - For 100% workstations, electric lights provide maintained illuminance on the vertical plane facing forward (to simulate the view of the occupant) of 150 equivalent melanopic lux or greater
  - Melanopic Lux requires use of an EML ratio to convert photopic lux to melanopic lux.

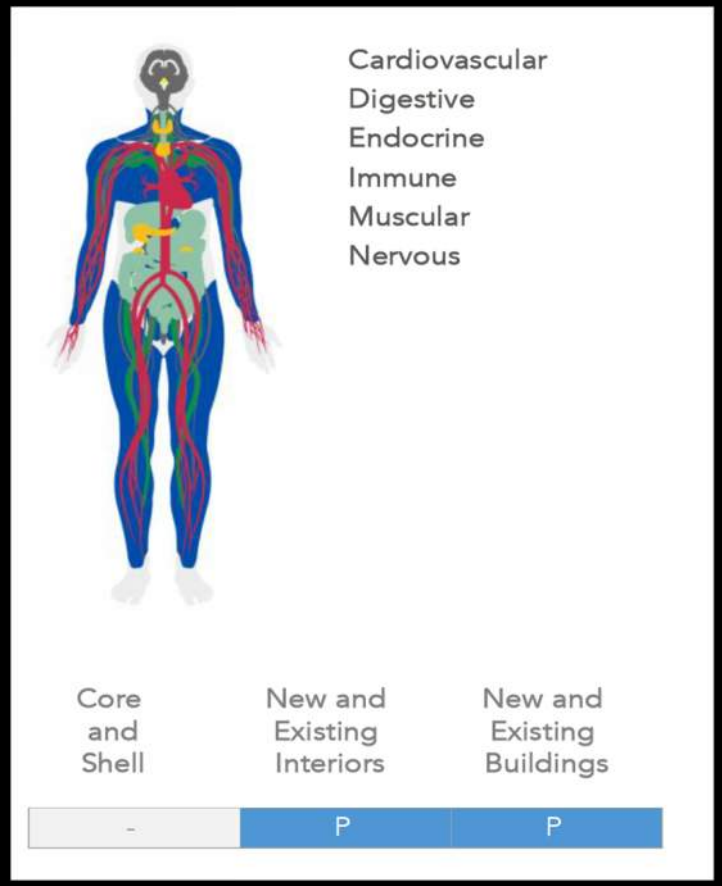


WELL Building Standard v2

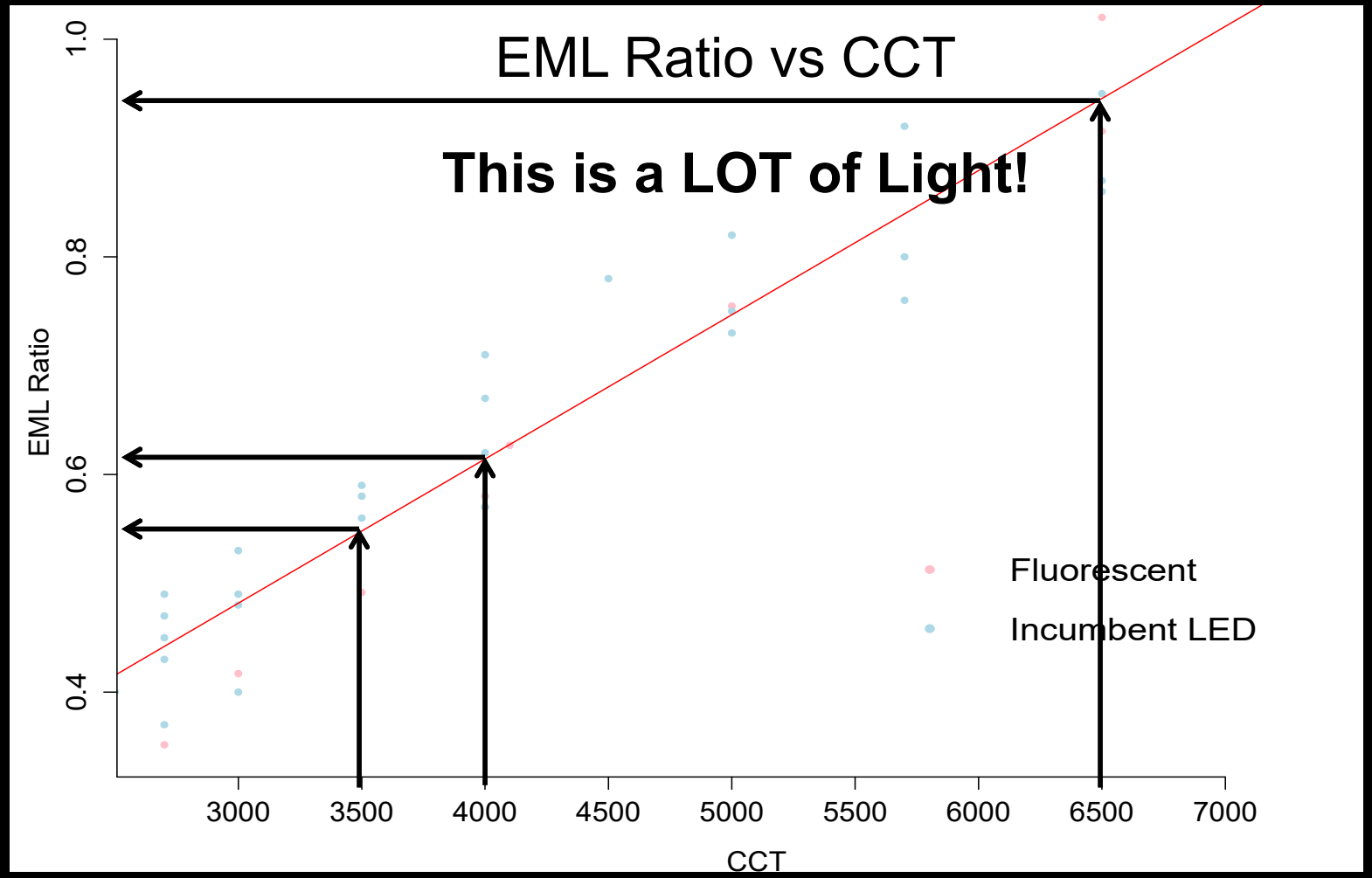
Feature L03: Circadian Lighting Design

- <u>Electric Lighting Only</u>
  - 240 EML (3pts)
  - 150 EML (1pt)
  - (CRI > 50 is 1pt)

- <u>Electric + Daylighting</u>
  - 180 EML (3pts)
  - 120 EML (1pt)
  - *And Meet 2pts from Enhanced Daylight portion in LO5



Melanopic Lux (Legacy LED)



Melanopic Lux =
Photopic Lux * EML Ratio

↑ Design ↑ Spectrum

Ex: WELL v2 Target 240 EML (3pts)

- Customer wants 3500K
- 35K EML ~ 0.55

$$\frac{240}{0.55} = \text{Photopic Lux} * \frac{0.55}{0.55}$$

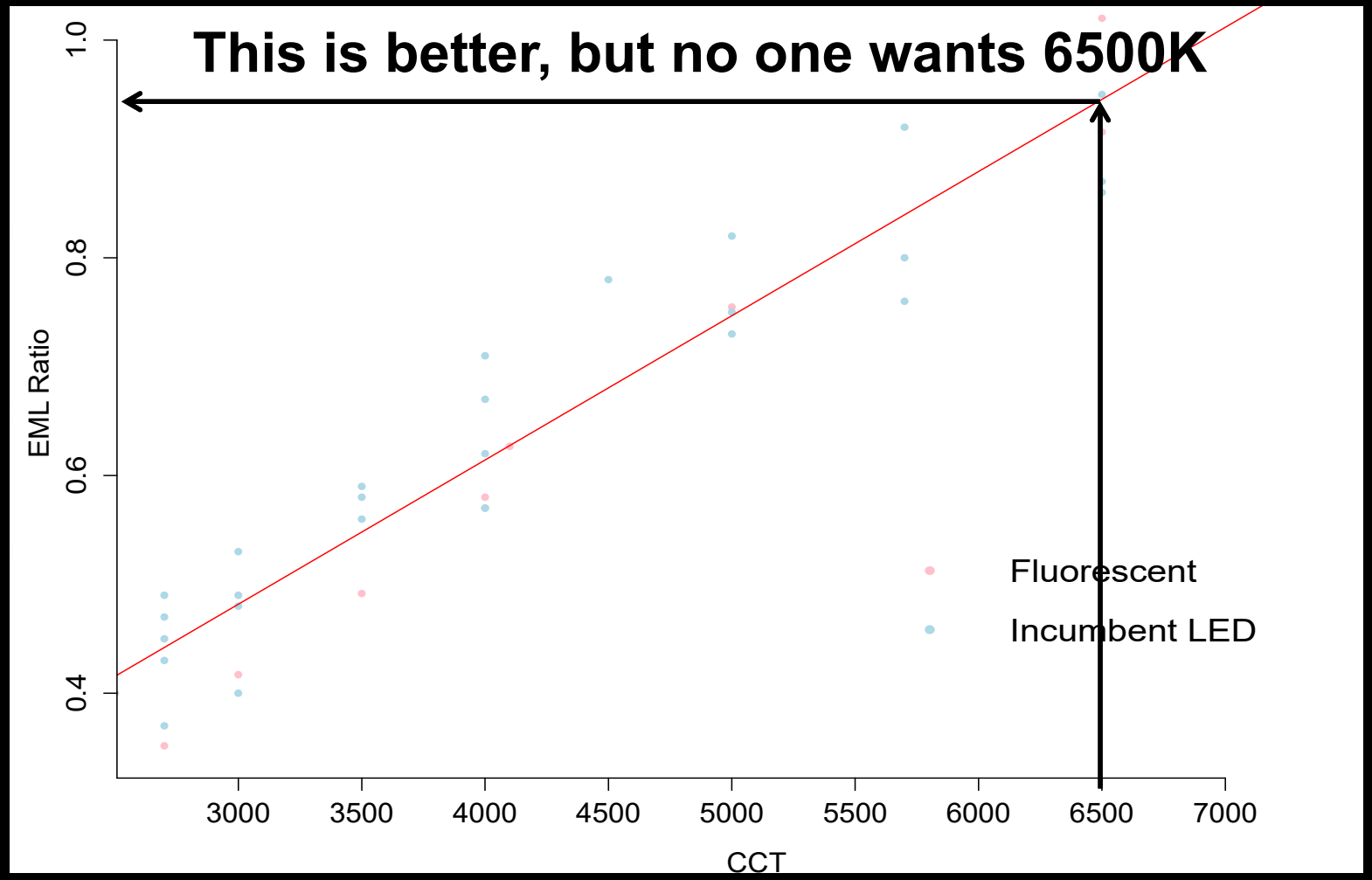
35K: 436lx or ~41fc (vertical at eye)

4K: 393lx or ~37fc (vertical at eye)

65K: 258lx or ~24fc (vertical at eye)

Melanopic Lux (Legacy LED)

EML Ratio vs CCT



Melanopic Lux =
Photopic Lux * EML Ratio

Design — Spectrum

Example:

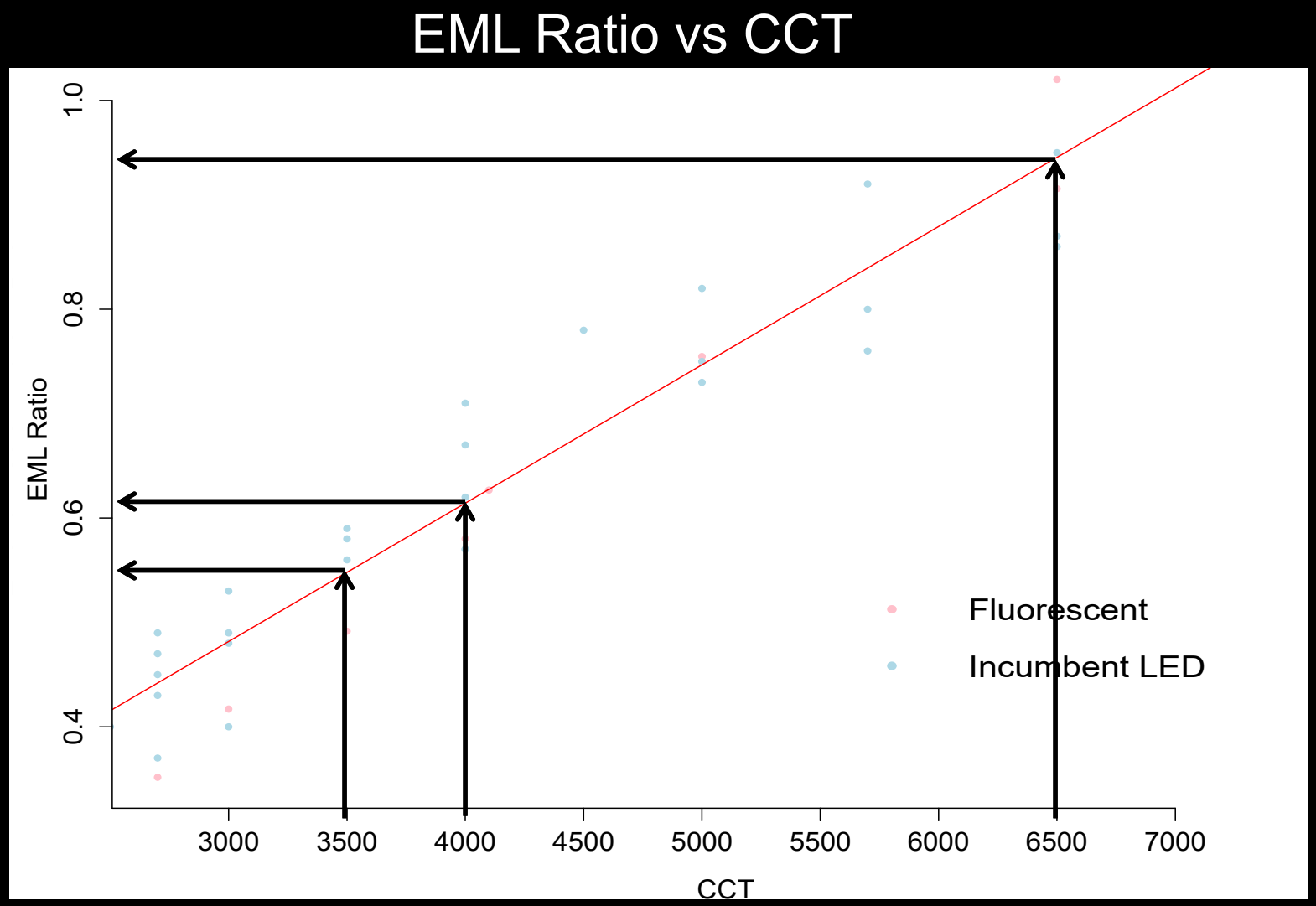
WELL target - 240 vertical melanopic lux requirement

- Customer okay with 6500K
- EML ~ 0.93

$$\frac{240}{0.93} = \text{Photopic Lux} * \frac{0.55}{0.93}$$

258lx or 24fc (vertical at your eye)

Melanopic Lux (Legacy LED)



Melanopic Lux =
Photopic Lux * EML Ratio

↑ Design ↑ Spectrum

Ex: WELL v2 Target 150 EML (1pt)

- Customer wants 3500K
- EML ~ 0.55

$$\frac{150}{0.55} = \text{Photopic Lux} * \frac{0.55}{0.55}$$

35K: 272lx or ~25fc (vertical at eye)

4K: 245lx or ~23fc (vertical at eye)

65K: 161lx or ~15fc (vertical at eye)

What Are Our Design Options?

Keep the color temperature you want – BUT this requires more light output

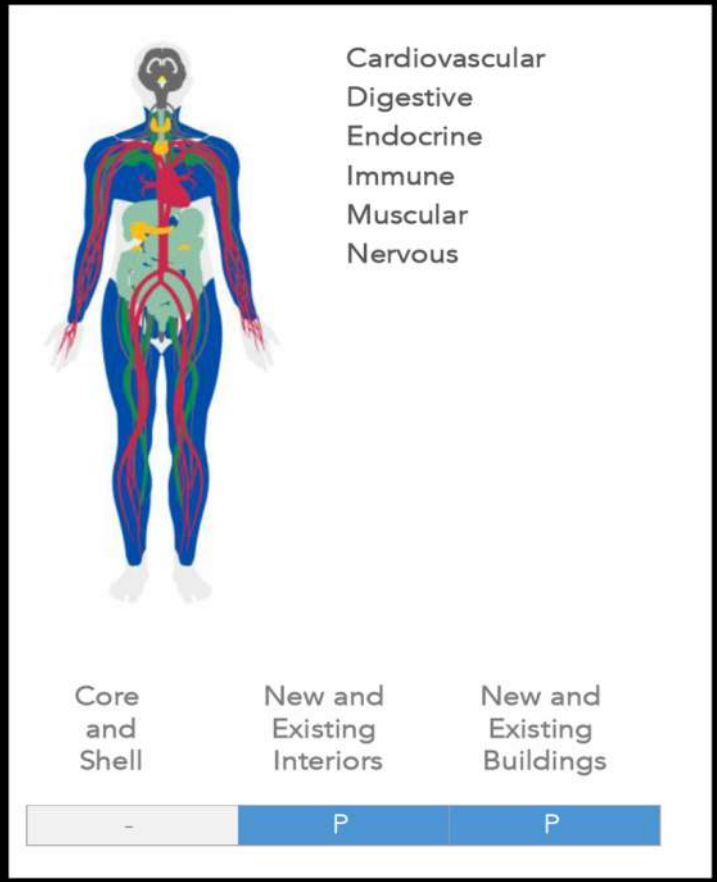
Increasing light output will increase glare

WELL Building Standard v2

- L03: Circadian Lighting Design
  - 120, 150, 180, 240 vertical melanopic lux for a minimum of 4 hours per day.

- L04: Electric Light Glare Control

  Fixtures have a luminance less than 10,000 cd/m^2 between 45 °- 90° from nadir, and/or an intensity of less than 1,000 candela between 45 °- 90° from nadir.



Increase fixture quantity

Might help keep glare down, but increases cost and energy

Specify Cooler Color Temperature to Improve EML Efficacy

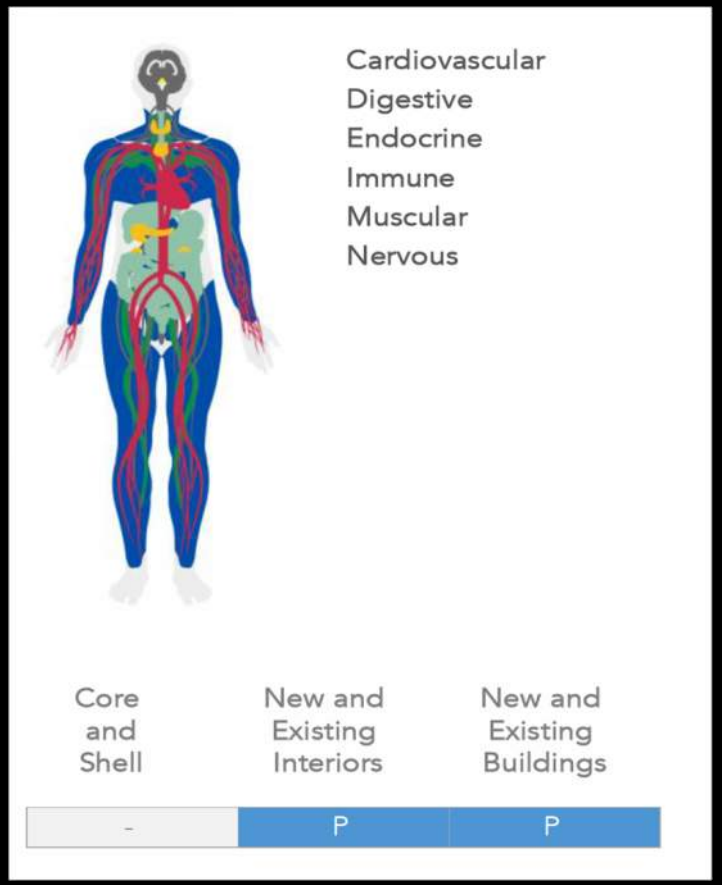
Higher CCT’s Not Desirable in Most Architectural Applications

WELL Building Standard v2

- L03: Circadian Lighting Design
  120, 150, 180, 240 vertical melanopic lux for a minimum of 4 hours per day.

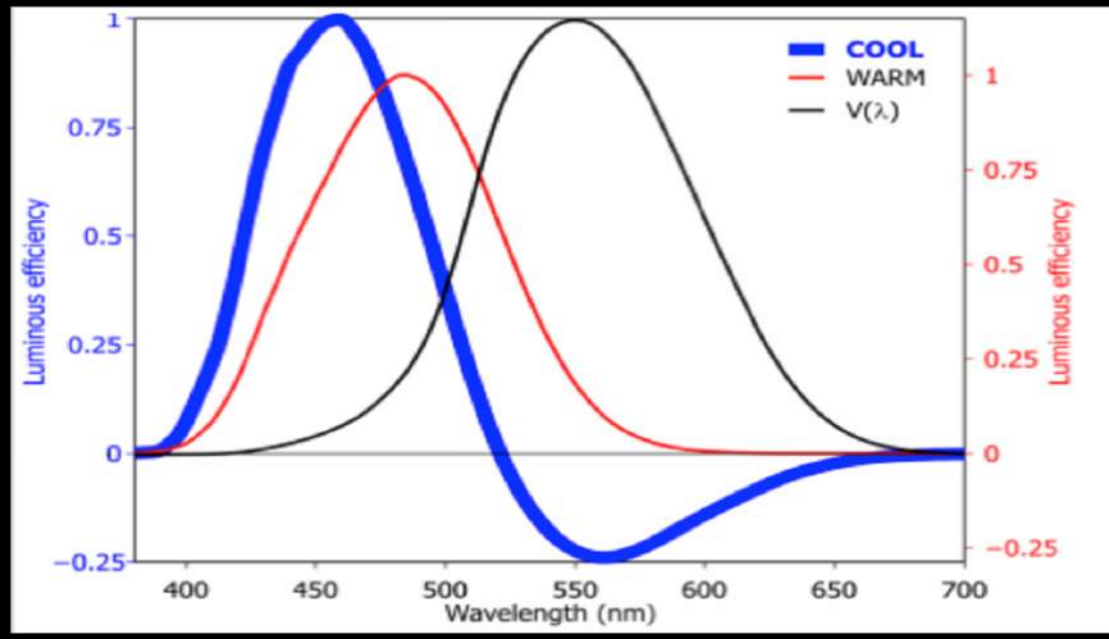
- L04: Electric Light Glare Control
  Fixtures have a luminance less than 10,000 cd/m^2 between 45 °- 90° from nadir, and/or an intensity of less than 1,000 candela between 45 °- 90° from nadir.

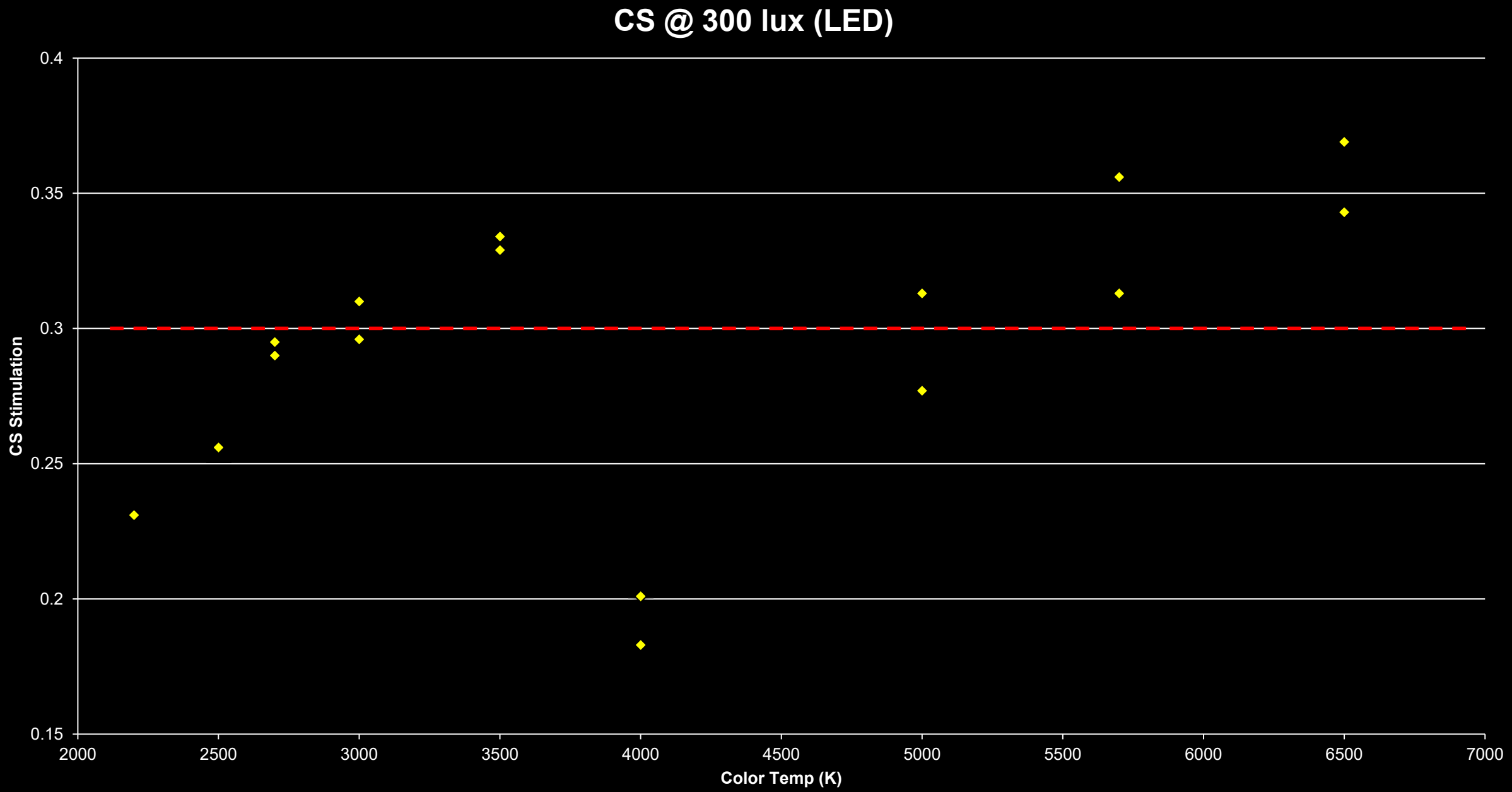
- L07:
  CRI > 90
  CRI > 80 and R9>50
  TM30 requirements too



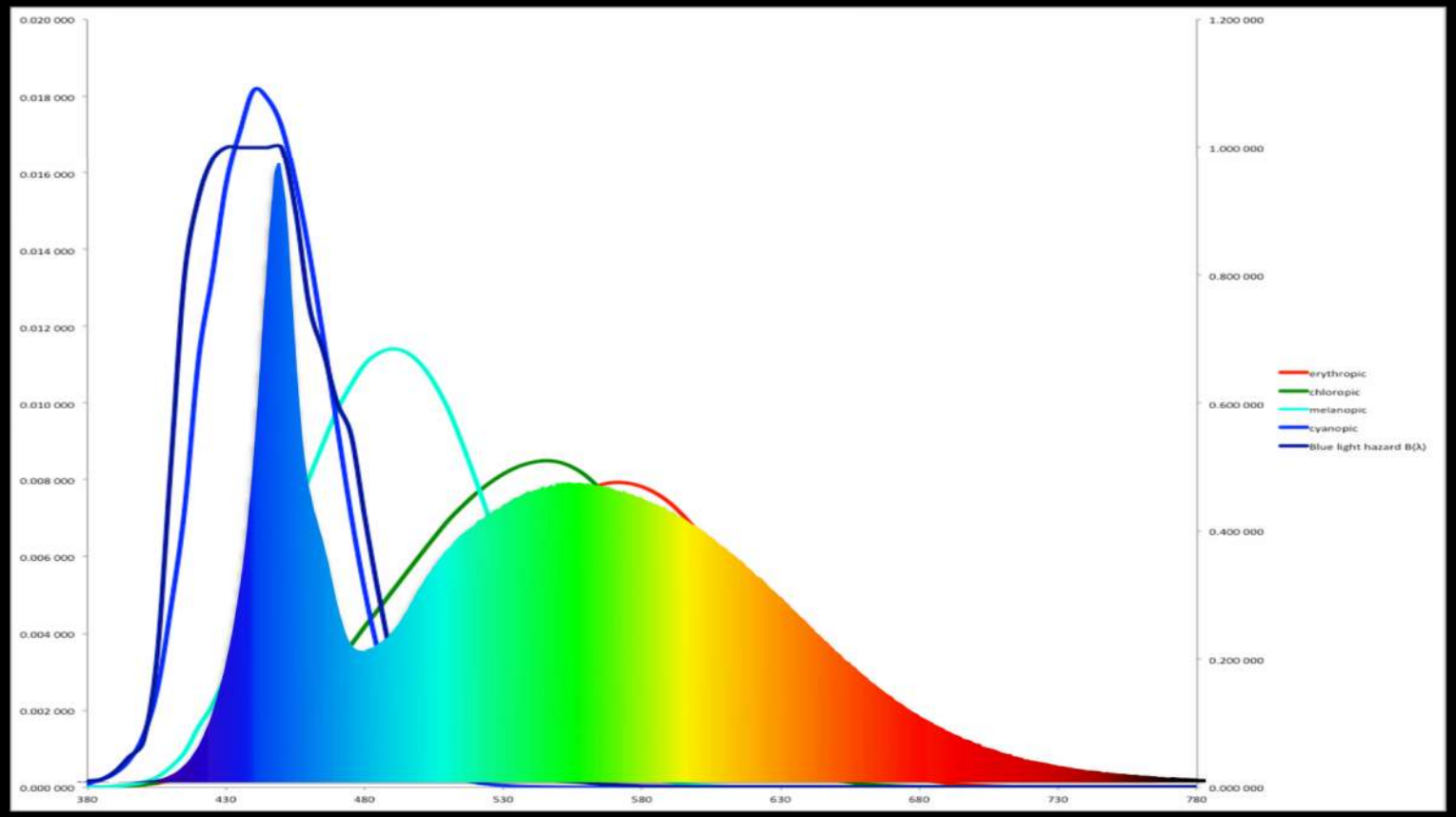
LRC model

- The main difference here is it includes this idea of sub-additivity
- They basically agree at 3500K and warmer
  - 485nm peak versus 490nm
- Recommendation: CS of 0.3 or greater is a good daytime stimulus




CS @ 300 lux (LED)
0.4
0.35
0.3
0.25
0.2
0.15
CS Stimulation
2000
2500
3000
3500
4000
4500
5000
5500
6000
6500
7000
Color Temp (K)

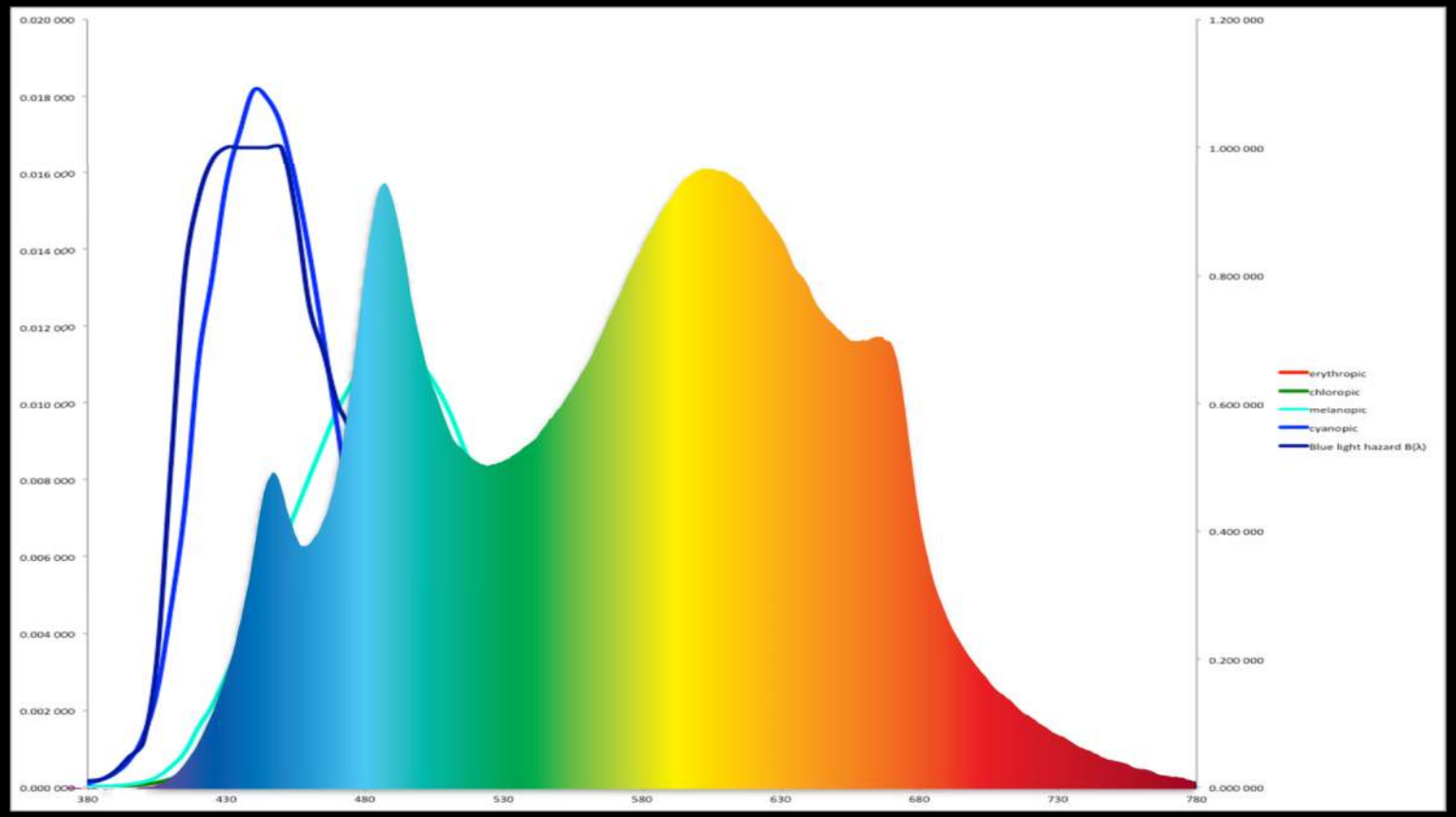
Traditional “Circadian” LED Product



CCT = 6000K
EML ratio = 0.87
R9 = 16

Reimagined Circadian LED

Lighting that is spectrally optimized to provide the circadian stimulation you need,
in a color temperature you want



CCT = 3500K
EML ratio = 0.83
R9 = 95
COI < 3.3

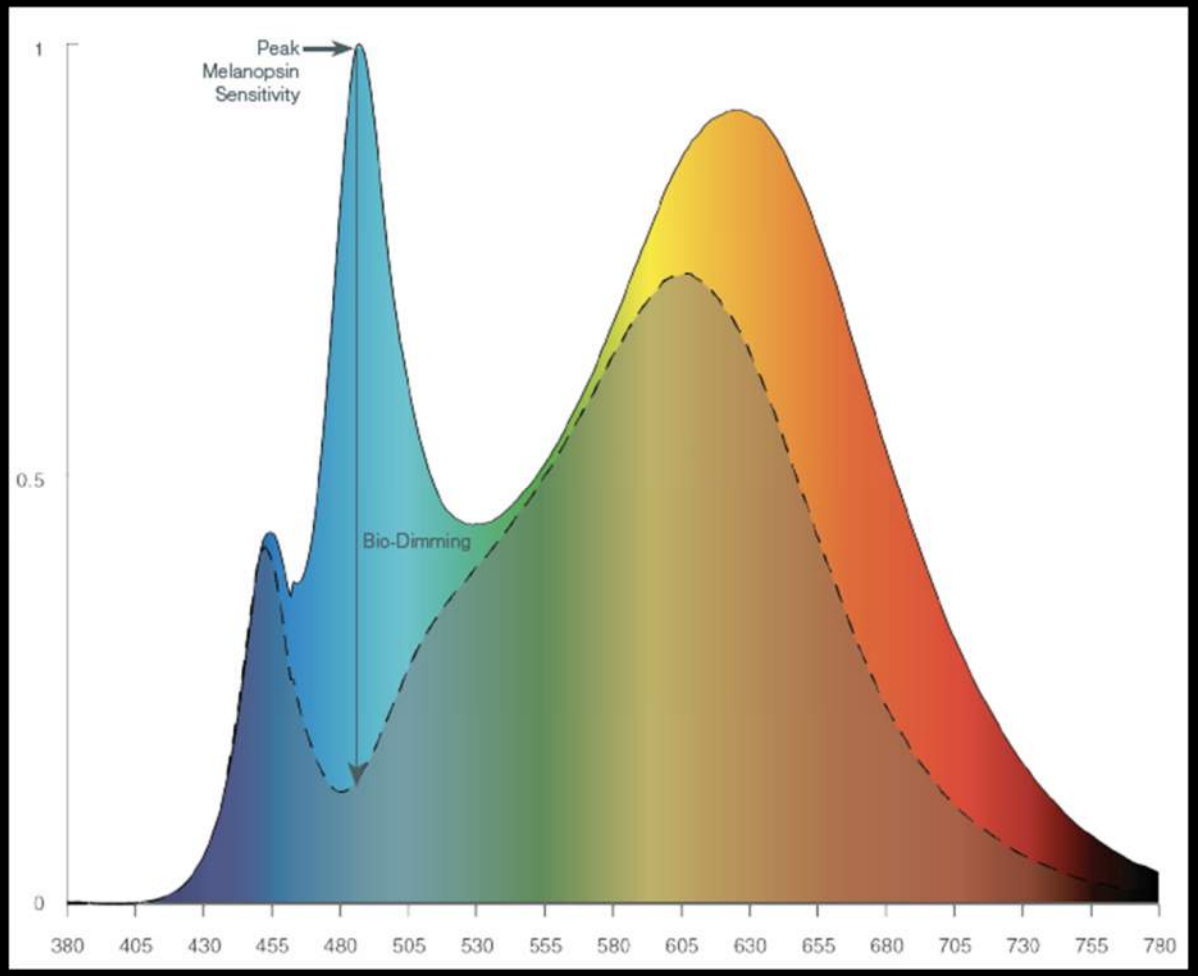
HYBRID VEHICLES & CIRCADIAN LIGHTNG

INSURANCE HERO

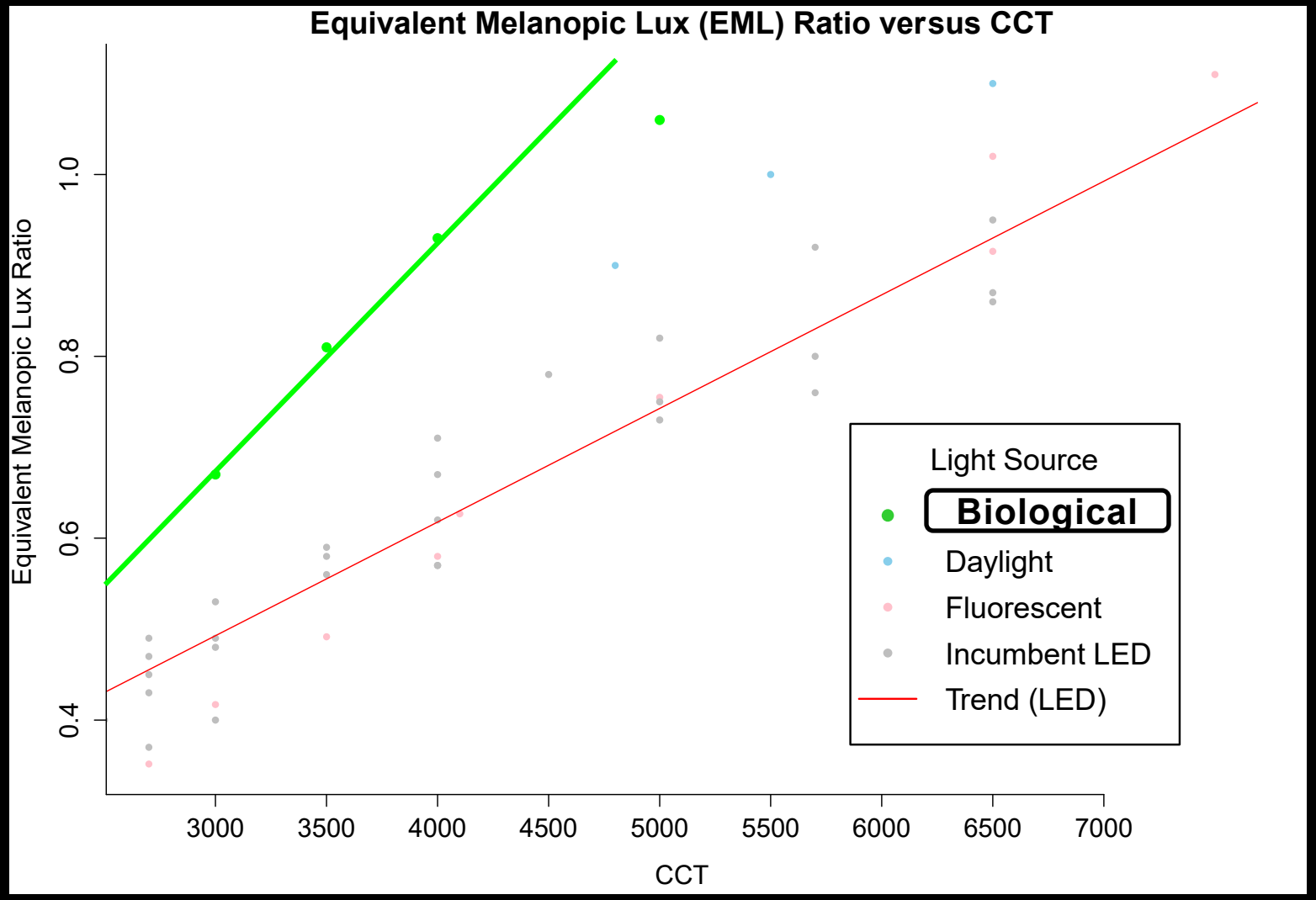
20MPG vs 58MPG
.50EML vs .83EML

What about load shedding / overlit space??

- Are you ‘losing’ the good blue spectrum/melanospin?
- Load shed
- Over lighting to achieve WELL (don’t want to fall short on numbers)



Melanopic Lux Trend of Optimized Spectrum



- Spectrally Optimized lighting has a completely different trend line.
- We can achieve much higher circadian stimulation without sacrificing color preference

Putting It All Together

- During the Day time, light up your “sky”
  - High photopic lux
  - High vertical lux
  - Melanopic rich spectrum

- During the Night time, darken your “sky” and light your “fire”
  - Low vertical lux
  - Melanopic depleted spectrum
  - Focus light on horizontal surfaces

Assisted Living

Daytime

SKY

Horizon

FIRE

Offices

Daytime

SKY

Horizon

FIRE

Do you need color tuning for circadian regulation?

- No
- Color tuning's best known asset is to psychologically tell you "it's getting late"
- Including controls, color tuning can more than double the cost
- More benefit can be had from layering light, using static spectrums that are optimized for biological day or biological night.
  - This is only really necessary in 24-hour applications

Where does simple static spectrum make sense?

Places where you go ONLY during your biological daytime

- **Offices**
  - Wide range of chronotypes
  - Wide range of schedules
- **Classrooms**
  - Kids are more susceptible to blue light hazard
  - High school students are prone to be night owls
- **Assisted Living Facility Community/Daytime Areas**
  - Aging Eye offers unique opportunities
- **Sports locker rooms and gymnasiums**
  - There is a circadian peak to athletic performance

Part 2: Quiz

- Light coming from which direction has the strongest circadian impact?
  - Above the horizon
- Does LED color tuning provide day versus night delineation?
  - Not alone. You need to do more with your lighting design. Dim and change spatial distribution.
- What is the simplest way to help boost our circadian rhythms?
  - By better delineating our biological daytime from our biological night.

Things you can do today

- Install f.lux on your computer and smart phones
  - www.justgetflux.com
  - www.fluxometer.com
- Turn on “night shift” on your iPhone

- Keep your bedroom lights as warm as possible

- Cooler white light in your kitchen and shower (if you shower in the morning)

- Turn on cubicle lights at the office, if applicable

Liability and Misinformation

- Liability starts with misinformation
  - Color tuning is complicated and expensive
    - Requires justification
      - More productivity
      - Better academic performance
      - Better health
    - All of these things are intensity driven and will NOT come with just color tuning
- Whomever promise these things is liable for fulfilling those promises

Liability in Medicine

- It’s all about the language, nothing is certain
  - “is used to treat”
  - “has been shown to”
  - “may reduce”
  - “can help”

- “Circadian stimulating lighting in the office is used to treat an epidemic known as Social Jet Lag”

Should we be manipulating people's biology?

We've been manipulating people's biology

Image credit: The Matrix

Now it's time to stop

THANK YOU!

Ken Esterly / kesterly@bioslighting.com

Robert Soler / rsoler@bioslighting.com

www.bioslighting.com

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