

# **Beyond Melatonin** *Dynamic Light Systems for Health + Wellness* | Designers Light Forum



**Paul Pickard**

Chief Strategy Officer, Lighting Technology – Korrus, Inc.

7 MARCH 2023



## Continuing Education Credit

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*Questions related to specific materials, methods, and services will be addressed at the conclusion of this presentation*



## Course Material

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- Brief Review of Light and Human Circadian Response
- EML, CS, CP and new research on light-adapted responses
- Evaluation of Dynamic Light Systems for Circadian Impact
- Evaluation of Dynamic Light Systems ability to adapt to future research
- Light for health BEYOND Melatonin: Blue + Long Red/Infrared
- The Power of Light for Health

### Upon completion, participants will be able to:

**1.**

Demonstrate working knowledge of the limitations of current Circadian metrics

**2.**

Examine dynamic lighting system spectra for Circadian efficacy across multiple metrics

**3.**

Evaluate flexibility of dynamic systems for future research and discovery in Circadian + non-Circadian human health

**4.**

Possess a basic understanding of non-Circadian benefits of light and potential use-cases



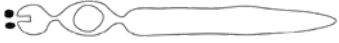

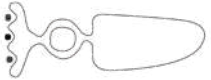



# Light + Human Circadian Response

*A Brief Review*

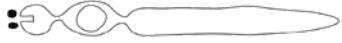

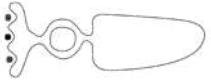

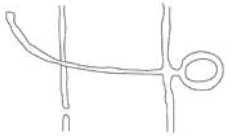



## When light hits our eye...

Retinal Cell Type	Primary Cell Function
Rod 	B&W Night Vision 
Cone 	Color Visualization 



## When light hits our eye... It affects our circadian rhythm

Retinal Cell Type	Primary Cell Function
Rod	B&W Night Vision
	
Cone	Color Visualization
	
ipRGC	Circadian System Governance
	



# The Modern Dilemma with Light

100s of Thousands of Years



Nighttime Light  
Exposure



Long Dark Nights  
(.001 – 10 Lux)



# The Modern Dilemma with Light

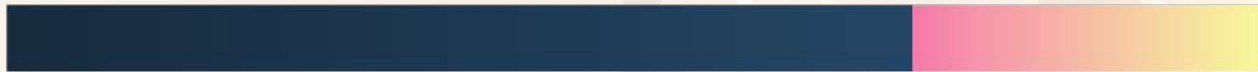
100s of Thousands of Years



Nighttime Light  
Exposure



Sunrise/Sunset Light  
Exposure



Long Dark Nights  
(.001 – 10 Lux)

Quick Dim Transition  
(10 – 1K Lux)



# The Modern Dilemma with Light

100s of Thousands of Years



Nighttime Light  
Exposure



Sunrise/Sunset Light  
Exposure



Daytime Light  
Exposure



Long Dark Nights  
(.001 – 10 Lux)

Quick Dim Transition  
(10 – 1K Lux)

Long Bright Day  
(1K – 10K Lux)



# The Modern Dilemma with Light

<100 Years



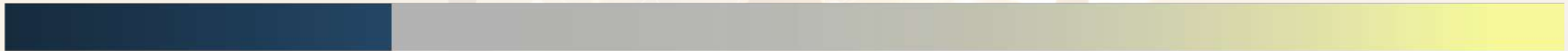
Nighttime Light Exposure



Artificial Light Exposure



Daytime Light Exposure



Shorter Dark Nights  
(.001 - 10 Lux)

Long Dim Day  
(10 - 1K Lux)

Limited Exposure to Bright  
(1K - 10K Lux)



# **EML, CS, and CP**

*The Impact Of New Research On Light-mediated Responses*



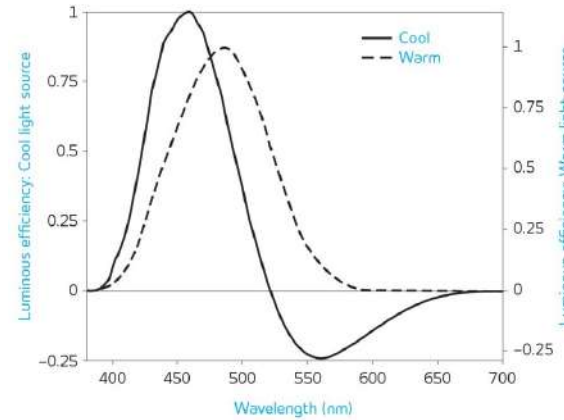
# How do we “solve” for lack of natural light?

## Problem:

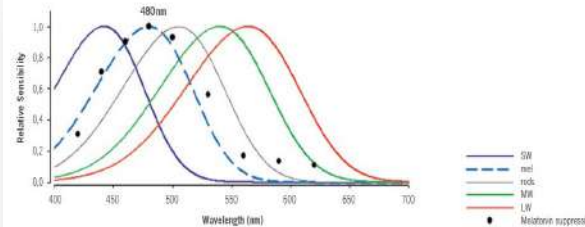
- Day: Can't replicate outdoor intensities indoors
- Night: Unlikely to convince homeowners to use candlelight

## Solution:

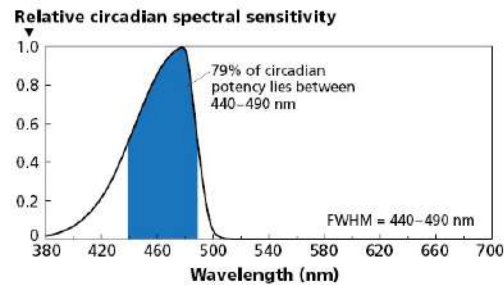
- We can manipulate spectra to help compensate



**CS** (Circadian Stimulus)  
Lighting Research Center  
CS > 0.3 morning  
CS < 0.1 evening  
Prioritize  $E_V/E_H$



**EML** (Equivalent Melanopic Lux)  
Lucas Group / WELL Building V2  
275 vertical EML 9A-1P (Tier 2)



**CP** (Circadian Potency)  
Greater than 20% blue light during daytime  
Less than 2% blue light at night

NOTE: The most well-known Circadian metrics are based on research on dark-adapted individuals

# Acknowledging Limitations Of Dark-Adapted Research

Circadian responses to light are different between dark-adapted and light-mediated individuals.

Most research measures dark-adapted individuals and their responses for up to 1-2 hours beyond initial light exposure.

New research notes the differences in spectral response for Melatonin suppression over extended periods of time (6+ hours.)

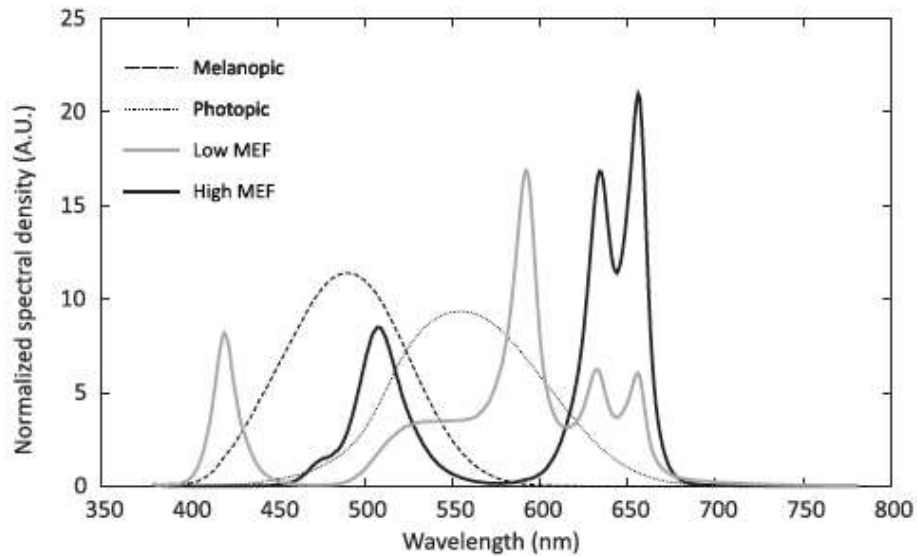
A light source that does NOT suppress Melatonin production after a day's worth of light exposure may still suppress Melatonin if turned on in the middle of the night

The screenshot shows a PNAS research article page. At the top, the PNAS logo is visible. The article title is "The spectral sensitivity of human circadian phase resetting and melatonin suppression to light changes dynamically with light duration". Below the title, the authors are listed: Melissa A. St. Hilaire, Maria L. Ámundadóttir, Shadiab A. Rahman, and Steven W. Lockley. The article is categorized as "RESEARCH ARTICLE" and "NEUROSCIENCE". The publication date is "December 12, 2022". The article number is "119 (51) e2205301119". The DOI is "https://doi.org/10.1073/pnas.2205301119". There is a "VIEW RELATED CONTENT" button and a "GET ACCESS" button. The article abstract is visible, starting with "Using data from 100 healthy young participants studied during a 9-d inpatient protocol, we constructed analytic action spectra for melatonin suppression and circadian phase resetting in response to 6.5-h monochromatic light exposures and fit these action spectra with linear combinations of melanopsin (ipRGC), short-wavelength (S), and combined long and medium-wavelength (L+M) cone functions. First, we demonstrate that melatonin suppression is driven approximately equally by S and L+M cones in the first quarter of light exposure and melanopsin only over longer durations. Second, we demonstrate that S cones may contribute significantly to the overall phase resetting given the nonlinear relationship between light duration and magnitude of resetting. These findings indicate that the spectral sensitivity of circadian light responses changes over time."



# Recent Research On White Light

## Demonstrating the significant importance of blue light on melatonin production



> J Biol Rhythms. 2018 Aug;33(4):420-431. doi: 10.1177/0748730418784041. Epub 2018 Jul 9.

### Spectral Tuning of White Light Allows for Strong Reduction in Melatonin Suppression without Changing Illumination Level or Color Temperature

Jan L Souman<sup>1</sup>, Tobias Borra<sup>1</sup>, Iris de Goijer<sup>1,2</sup>, Luc J M Schlangen<sup>1</sup>, Björn N S Vlaskamp<sup>3</sup>, Marcel P Lucassen<sup>1</sup>

Affiliations + expand  
PMID: 29984614 DOI: 10.1177/0748730418784041

#### Abstract

Studies with monochromatic light stimuli have shown that the action spectrum for melatonin suppression exhibits its highest sensitivity at short wavelengths, around 460 to 480 nm. Other studies have demonstrated that filtering out the short wavelengths from white light reduces melatonin suppression. However, this filtering of short wavelengths was generally confounded with reduced light intensity and/or changes in color temperature. Moreover, it changed the appearance from white light to yellow/orange, rendering it unusable for many practical applications. Here, we show that selectively tuning a polychromatic white light spectrum, compensating for the reduction in spectral power between 450 and 500 nm by enhancing power at even shorter wavelengths, can produce greatly different effects on melatonin production, without changes in illuminance or color temperature. On different evenings, 15 participants were exposed to 3 h of white light with either low or high power between 450 and 500 nm, and the effects on salivary melatonin levels and alertness were compared with those during a dim light baseline. Exposure to the spectrum with low power between 450 and 500 nm, but high power at even shorter wavelengths, did not suppress melatonin compared with dim light, despite a large difference in illuminance (175 vs. <5 lux). In contrast, exposure to the spectrum with high power between 450 and 500 nm (also 175 lux) resulted in almost 50% melatonin suppression. For alertness, no significant differences between the 3 conditions were observed. These results open up new opportunities for lighting applications that allow for the use of electrical lighting without disturbance of melatonin production.

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## **Case Study** (1-yr assessment) Mission Critical 24/7 Control Room of Global Energy Company

### **Key Insights**

- **50% reduction** in employees with excessive sleepiness
- **50% increase** in employees alert and fresh at 5AM
- **67% reduction** in employees reporting frequent mistakes
- **28% reduction** in employees who classify as obese or overweight



## Scientific Consensus Survey

Leading researchers are galvanizing around a common scientific understanding

A survey of 248 scientists who have published a total of 2,697 peer-reviewed scientific articles on circadian clocks and light, reached 24 conclusions including:

- Evidence supports the widespread introduction of circadian lighting that dynamically adjusts light intensity and blue content throughout the day and night for optimal circadian entrainment and health
- Critical wavelengths for (daytime) circadian entrainment are 460–495nm, with blue light near the sensitivity peak of the ipRGC melanopic receptors
- LED lights with high 460-495nm blue content should carry the warning label “may be harmful if used at night.”

The screenshot shows a webpage from LEDucation Magazine. The main article is titled "Surveyed scientists stand behind current research for practical circadian lighting application" by Carrie Meadows, dated Jan. 30, 2023. The article text states: "Survey of circadian scientists concludes there is 'sufficient evidence to support the widespread introduction of circadian lighting that adjusts light intensity and blue content across day and night.'" Below the text is a large infographic with a blue background and white text. The infographic contains the following text: "Energy efficiency should not be prioritized over circadian health", "Normal indoor intensity range of 50-500 lx", "SURVEYED SCIENTISTS AGREE ARTIFICIAL LIGHT SHOULD BE OPTIMIZED FOR CIRCADIAN HEALTH", "Optimize lighting with personalized solutions", and "Respondents published an average of 11 articles". To the right of the infographic is a sidebar with a green header "Showcase your smart lighting technology and solutions" and a logo for "Smart LightingTech UAE 14th-15th March 2023 | Abu Dhabi, UAE". Below the infographic is a section titled "LATEST IN LIGHTING FOR HEALTH & WELLBEING" with several article teasers, including "Light Bites: What's happening in programs and associations — Feb. 15, 2023" and "Sales and profits down at ams Osram. Can micro LEDs help reverse things?". At the bottom of the page is a logo for "LEDs MAGAZINE" and a large "LEDucation.org" watermark.





## The Truth About Blue

There is an abundance of misleading information about risks associated with blue light.

Adequate blue light exposure during the day is just as important as limiting blue light exposure at night.

*Our circadian system relies on exposure to the right light at the right time.*





# **Dynamic Light Systems**

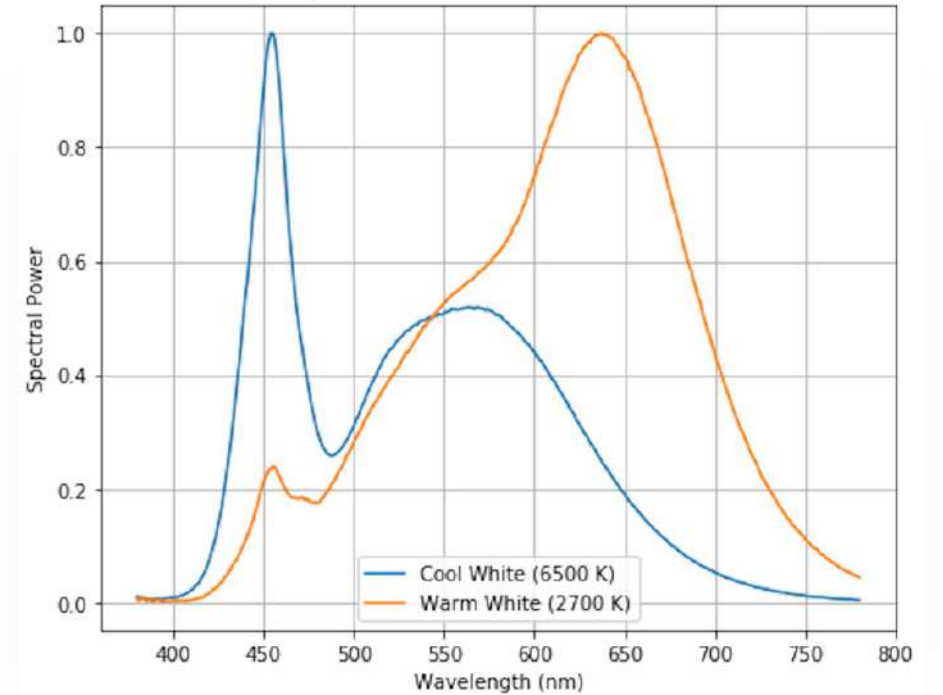
*Evaluating Circadian Impact*



## Standard Tunable White (TW)

CCT: 2700K-6500K

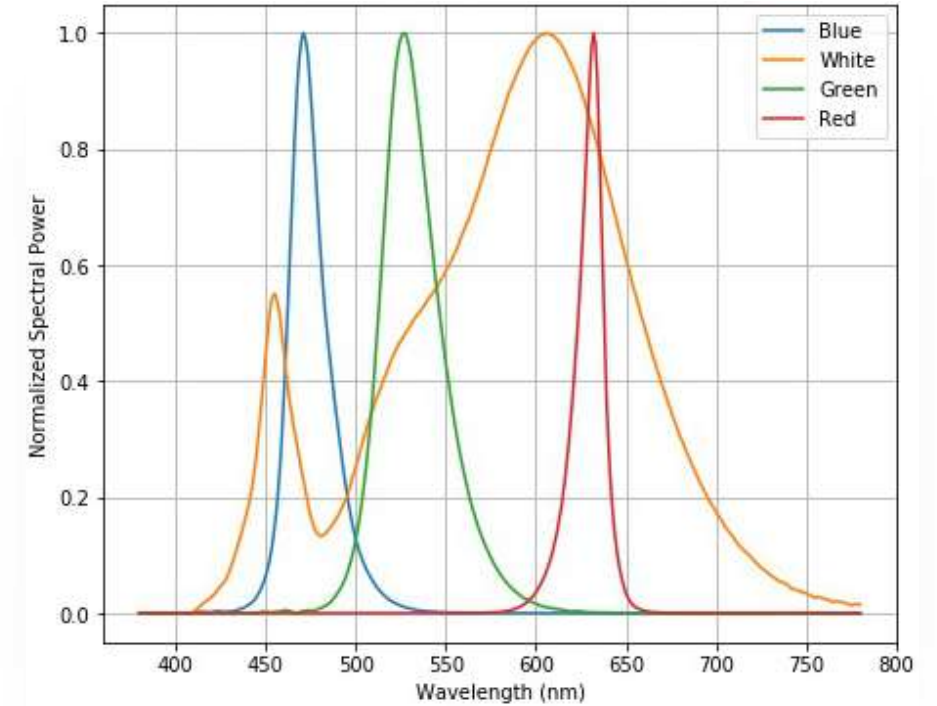
<b>TW</b>	
% reduction blue Cool/Warm	68%
% blue @ 2700K	8.84%
EML Ratio	2.11



## 4-Channel System (RGBW)

CCT: 2700K-6500K

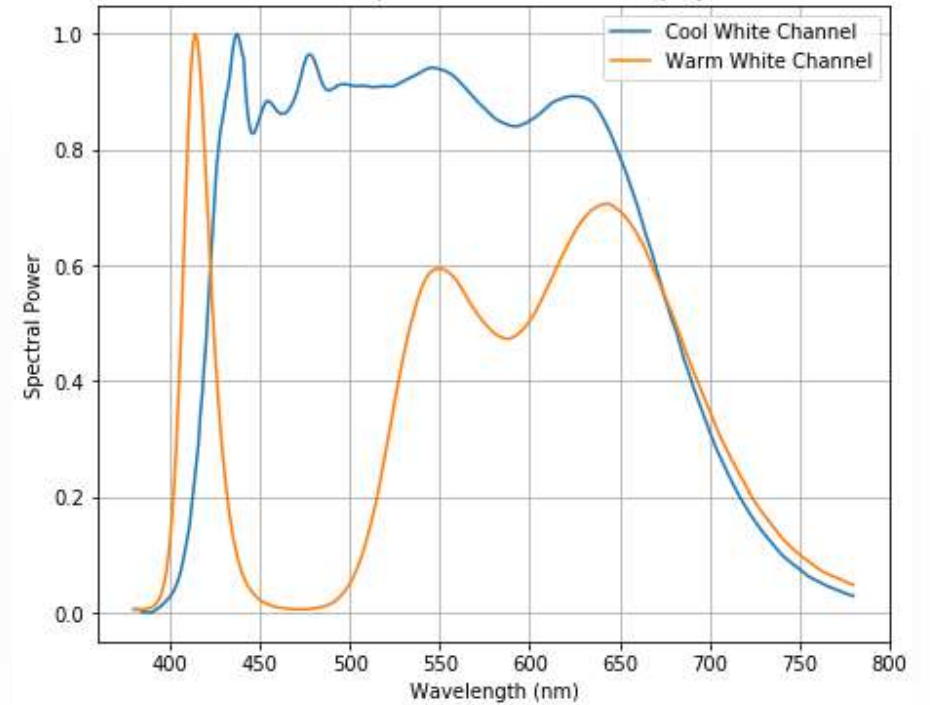
	<b>TW</b>	<b>RGBW</b>
% reduction blue Cool/Warm	68%	70%
% blue @ 2700K	8.84%	7.55%
EML Ratio	2.11	1.68



## Enhanced Tunable White (ETW)

CCT: 2700K-5700K

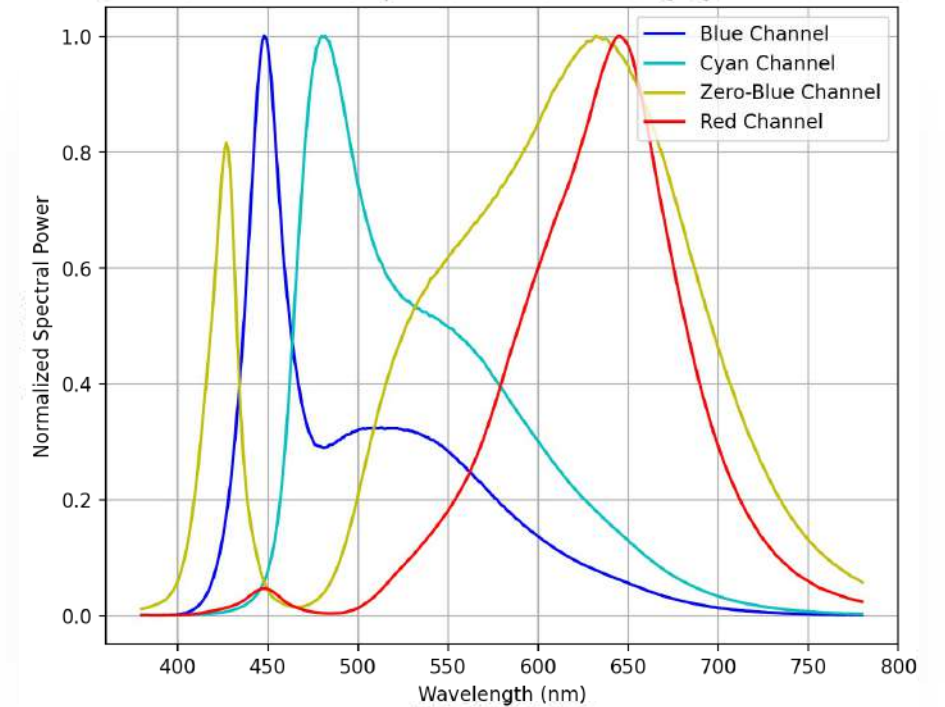
	<b>TW</b>	<b>RGBW</b>	<b>ETW</b>
% reduction blue Cool/Warm	68%	70%	92%
% blue @ 2700K	8.84%	7.55%	1.58%
EML Ratio	2.11	1.68	2.62



## Enhanced 4-Channel Systems

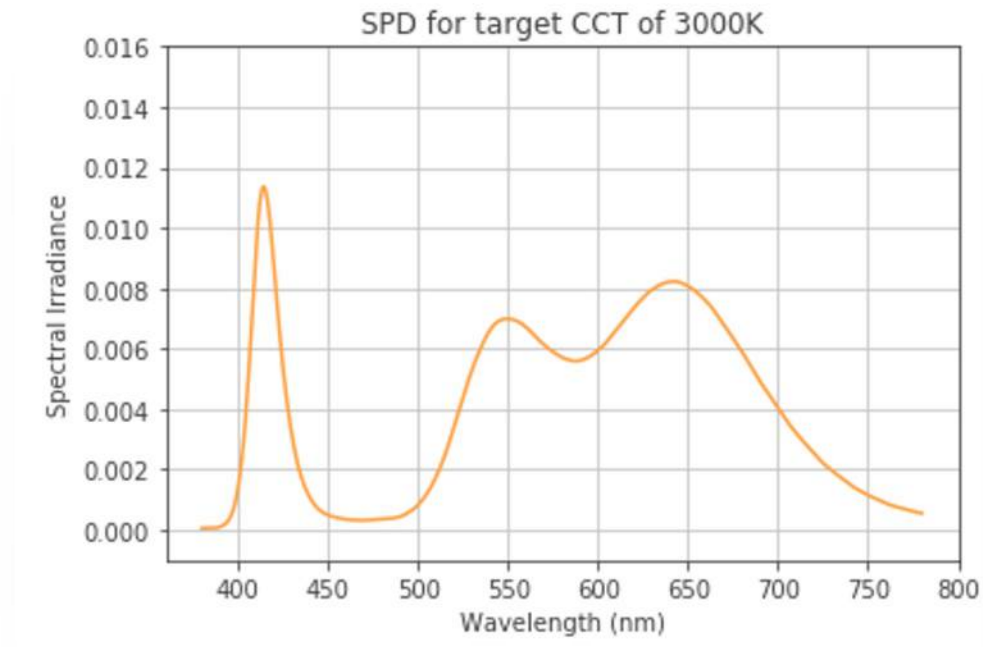
CCT: 2700K-5700K

	2700-6500K		2700K-5700K	
	<b>TW</b>	<b>RGBW</b>	<b>ETW</b>	<b>4CH</b>
% reduction blue Cool/Warm	68%	70%	92%	93%
% blue @ 2700K	8.84%	7.55%	1.58%	1.73%
EML Ratio	2.11	1.68	2.62	3.01

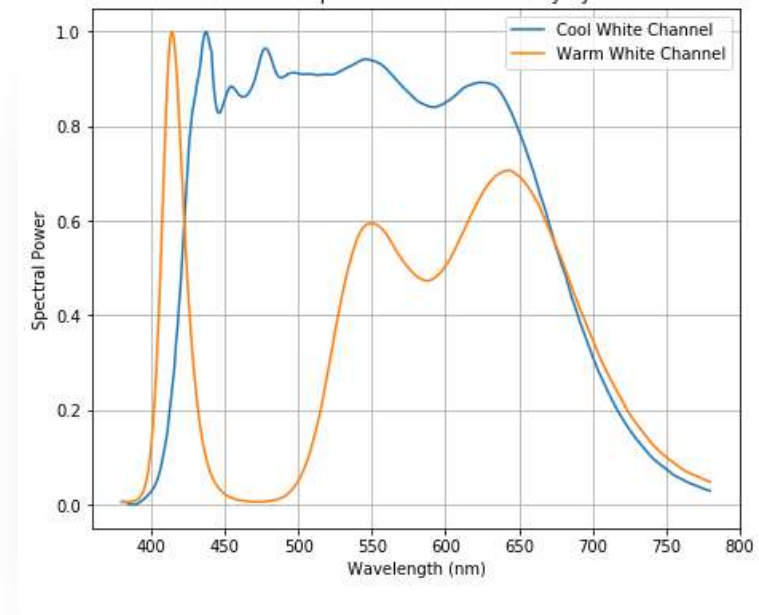


## A Deeper Look: Enhanced Tunable White

Good performance but limited adaptability

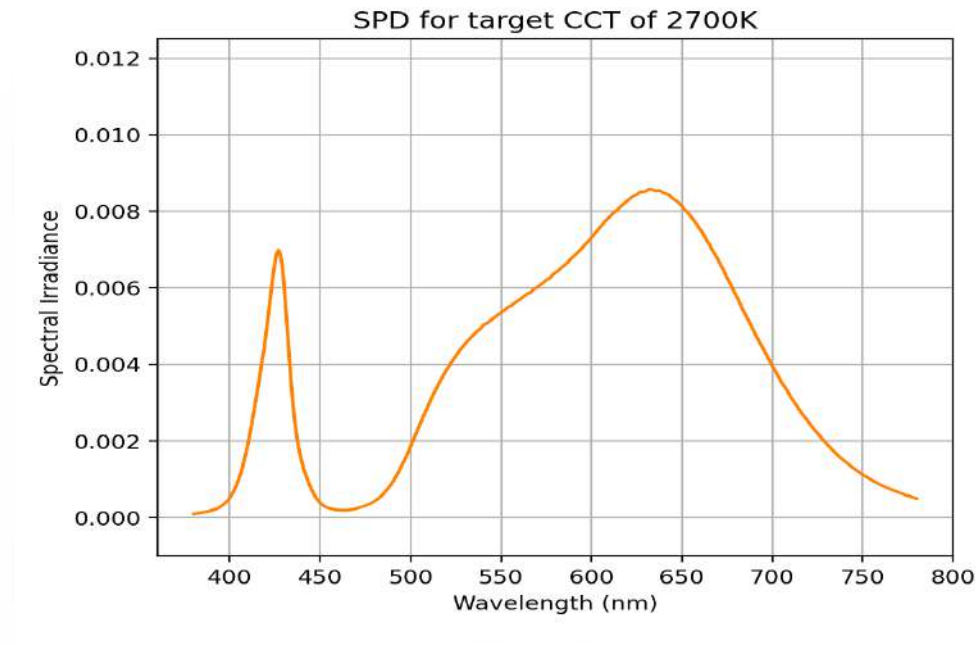


Enhanced Tunable White  
CCT: 2700K-5700K

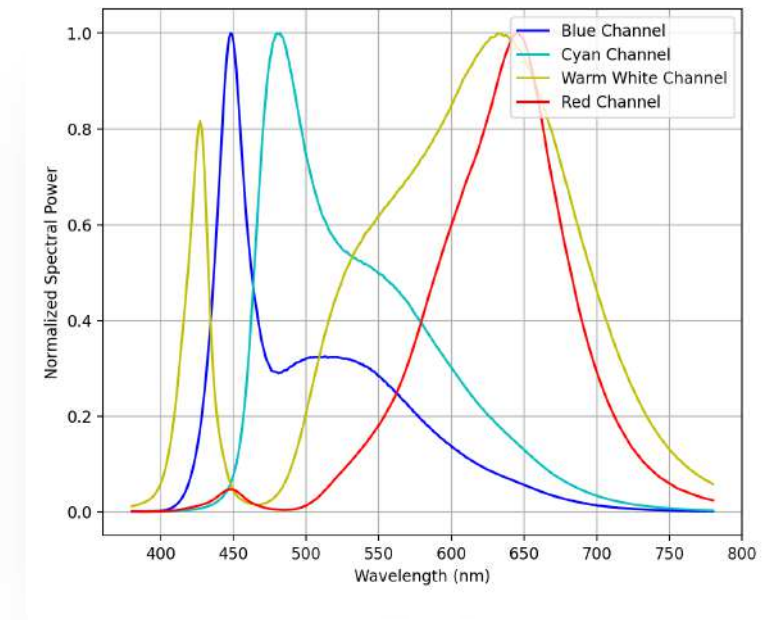


## A Deeper Look: 4 Channel Systems

Broad versatility covers any need or application



4 Channel Systems  
CCT: 2700K-5700K







# **Beyond Melatonin**

*Light for Health*



# Light's Impact On Human Health

- **Improves learning and cognitive response**
- Improves mood, alertness, visual comfort
- Therapeutic Photobiomodulation (PBM) and Long Red + NIR

ORIGINAL RESEARCH article

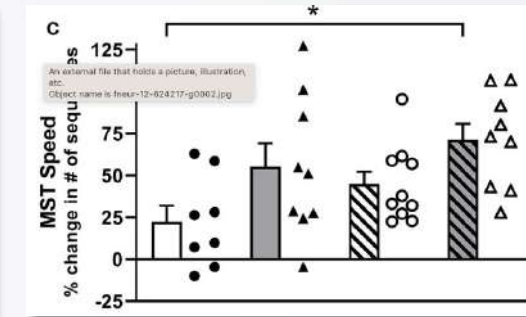
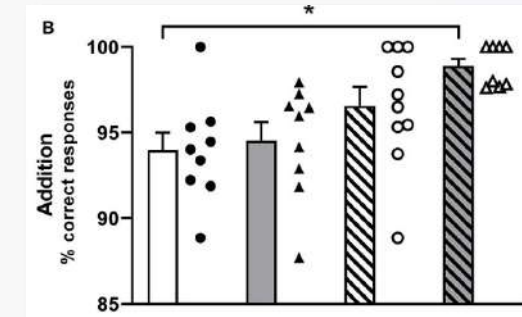
Front. Neurol., 22 February 2021  
Sec. Sleep Disorders  
Volume 12 - 2021 |  
<https://doi.org/10.3389/fneur.2021.624217>

This article is part of the Research Topic  
Translation and Processing of Light by the Non-Image Forming Visual System – Context, Mechanisms and Applications  
[View all 17 Articles >](#)

## Daytime Exposure to Short Wavelength-Enriched Light Improves Cognitive Performance in Sleep-Restricted College-Aged Adults

Leilah K. Grant<sup>1,2</sup>, Brianne A. Kent<sup>1,2</sup>, Matthew D. Mayer<sup>1</sup>,  
Robert Stickgold<sup>3,4</sup>, Steven W. Lockley<sup>1,2</sup> and Shadab A. Rahman<sup>1,2\*</sup>

<sup>3</sup> Division of Sleep and Circadian Disorders, Departments of Medicine and Neurology, Brigham and Women's Hospital, Boston, MA, United States





## Light's Impact On Human Health



- **Improves learning and cognitive response**
- Improves mood, alertness, visual comfort
- Therapeutic Photobiomodulation (PBM) and Long Red + NIR



### Effects of four workplace lighting technologies on perception, cognition and affective state

Breanne K. Hawes<sup>a</sup>, Tad T. Brunyé<sup>a d</sup>  , Caroline R. Mahoney<sup>a d</sup>,  
John M. Sullivan<sup>c</sup>, Christian D. Aall<sup>b</sup>

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[https://doi.](https://doi.org/10.1016/j.ergon.2011.11.011)

"We note that both of these effects appeared to be approximately linear; that is, not only did the LED technology reduce depression and increase arousal, but it did so most at the highest color temperatures," the researchers explain. "This result directly supports research suggesting a positive association between increased color temperature and enhanced mood and arousal states."

Additionally, participants reported feeling more alert and less fatigued with higher color temperature lights. A regression analysis revealed that lighting influenced mood, which reliably predicted cognitive task performance. That is, under the highest color temperature LED light, participants reported the most positive mood as well as the fastest cognitive performance.



# Light's Impact On Human Health

- Improves learning and cognitive response
- **Improves mood, alertness, visual comfort**
- Therapeutic Photobiomodulation (PBM) and Long Red + NIR

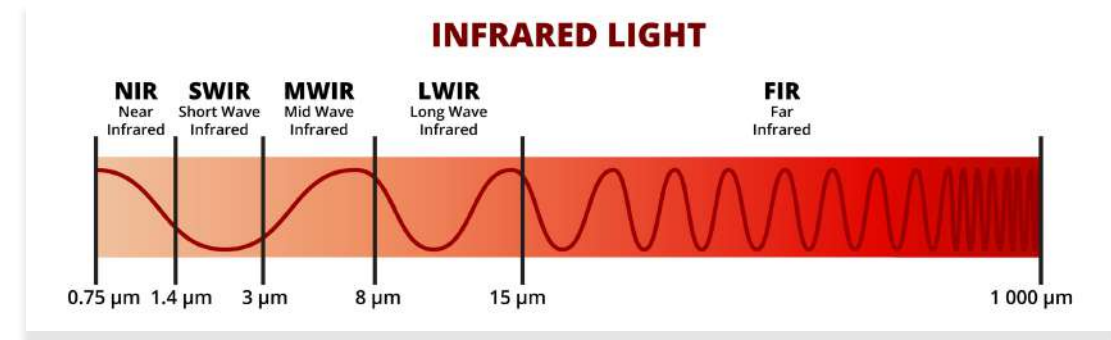
The screenshot shows a research article page from the Society of Light and Lighting journal. The page title is "Effect of daylight LED on visual comfort, melatonin, mood, waking performance". The authors listed are C Cajochen, PhD, M Freyburger, PhD, et al., and J Weibel, MS. The article is from Volume 51, Issue 7, published online on March 24, 2019. The page includes a "Restricted access" notice, a "Contents" menu, and a "Get access" button. The abstract text is partially visible, discussing LED light sources and their effects on human responses.

significantly different. Delta EEG activity (0.75–4.5 Hz) was significantly higher after daylight-LED than conventional-LED exposure during the post-light exposure night. We have evidence that a daylight-LED solution has beneficial effects on visual comfort, daytime alertness, mood and sleep intensity in healthy volunteers.



## Light's Impact On Human Health

- Improves learning and cognitive response
- Improves mood, alertness, visual comfort
- **Therapeutic Photobiomodulation (PBM) and Long Red + NIR**



# Long Red + Near InfraRed (NIR) How does it work?

- May use Cytochrome c oxidase as a photoreceptor
- May cause beneficial changes in cellular interfacial water layers (IWL), especially when subject to pulsed light
- Improves cellular “respiration” – facilitates oxygen cycle in the cellular mitochondria
- Upregulates ATP (adenosine triphosphate) in mammalian cells
  - ATP is the energy currency of cells, as also is a messenger molecule
- Downregulates ROS (reactive oxygen species) in oxidatively stressed cells

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Home / Vol 7, Supplement 1 (March 27, 2019): Annals of Translational Medicine / Mitochondrial cytochrome c oxidase is not the primary acceptor for

Editorial Commentary [Check for updates](#)

**Mitochondrial cytochrome c oxidase is not the primary acceptor for near infrared light – it is mitochondrial bound water: the principles of low-level light therapy**

Andrei P. Sommer  
Ulm, Baden-Württemberg, Germany  
Correspondence to: Andrei P. Sommer, 89075 Ulm, Baden-Württemberg, Germany. Email: andrei.sommer@alumni.uni-ulm.de.

Submitted Dec 28, 2018. Accepted for publication Jan 16, 2019.  
doi: 10.21037/atm.2019.01.43

“For an understanding of the phenomena the first condition is the introduction of adequate concepts.” —Werner Heisenberg, 1973

**Low level light therapy** Other Section

Low level light therapy (LLLT) is a growing field in photomedicine: 5,700 citations in PubMed at the date of writing. As a trend, more and more high impact factor journals are publishing papers related to LLLT. The key difference between LLLT (photobiostimulation, photobiomodulation) and other medical laser or light emitting diode (LED) applications is the intensity of the light. Light intensities used in LLLT are moderate and non-destructive (maximum a few kW/m<sup>2</sup>). For instance, the solar constant (full solar spectrum) above the Earth’s atmosphere corresponds to an intensity of 1.360 kW/m<sup>2</sup>. Potential clinical applications of LLLT include but are not limited to, wound healing, stroke, traumatic brain injury, neurodegenerative conditions, cancer, *in vitro* fertilization and pain management. In addition, there are very promising and exciting LLLT applications with enormous potentials in cell-based therapies, for instance, for end-stage liver diseases. Many of these applications exploit the reciprocal interplay between upregulation of mitochondrial adenosine triphosphate (ATP) and downregulation of reactive oxygen species (ROS) in oxidatively stressed cells. According to the mainstream



## Long Red + Near InfraRed (NIR) What does it do?

- **Improves eyesight in certain populations**
- Improves melatonin production
- Improves cognitive function
- Additional benefits

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PubMed.gov  
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> J Gerontol A Biol Sci Med Sci. 2020 Sep 16;75(9):e49–e52. doi: 10.1093/gerona/glaa155.

### Optically Improved Mitochondrial Function Redeems Aged Human Visual Decline

Harpreet Shihmar<sup>1</sup>, Manjot Grewal<sup>1</sup>, Sobha Sivaprasad<sup>1</sup>, Chris Hogg<sup>1</sup>, Victor Chong<sup>2</sup>, Magella Neveu<sup>1</sup>, Glen Jeffery<sup>1</sup>

Affiliations + expand  
PMID: 32596723 DOI: 10.1093/gerona/glaa155

**Abstract**  
The age spectrum of human populations is shifting toward the older with larger proportions suffering physical decline. Mitochondria influence the pace of aging as the energy they provide for cellular function in the form of adenosine triphosphate (ATP) declines with age. Mitochondrial density is greatest in photoreceptors, particularly cones that have high energy demands and mediate color vision. Hence, the retina ages faster than other organs, with a 70% ATP reduction over life and a significant decline in photoreceptor function. Mitochondria have specific light absorbance characteristics influencing their performance. Longer wavelengths spanning 650–>1,000 nm improve mitochondrial complex activity, membrane potential, and ATP production. Here, we use 6: those ag

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PubMed.gov  
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Review > Mitochondrion. 2017 Sep;36:29–35. doi: 10.1016/j.mito.2016.11.009. Epub 2016 Nov 24.

### Visual light effects on mitochondria: The potential implications in relation to glaucoma

Neville N Osborne<sup>1</sup>, Claudia Nuñez-Álvarez<sup>2</sup>, Susana Del Olmo-Aguado<sup>2</sup>, Jesús Merrayo-Lioves<sup>2</sup>

Affiliations + expand  
PMID: 27890822 DOI: 10.1016/j.mito.2016.11.009

**Abstract**  
Light of different wave-lengths have the potential to interact with four major mitochondrial protein complexes that are involved in the generation of ATP. Neurons of the central nervous system have an absolute dependence on mitochondrial generated ATP. Laboratory studies show that short-wave or blue light (400–480nm) that impinges on the retina affect flavin and cytochrome constituents associated with mitochondria to decrease the rate of ATP formation, stimulate ROS and results in cell death. This suggests that blue light could potentially have a negative influence on retinal

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National Center for Biotechnology Information  
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> Photomed Laser Surg. 2008 Jun;26(3):241–5. doi: 10.1089/pho.2007.2132.

### Low-level laser therapy improves vision in patients with age-related macular degeneration

Boris T Ivandic<sup>1</sup>, Tomislav Ivandic

Affiliations + expand  
PMID: 18588438 DOI: 10.1089/pho.2007.2132

**Abstract**  
**Objective:** The objective of this study of a case series was to examine the effects of low-level laser therapy (LLLT) in patients with age-related macular degeneration (AMD).  
**Background data:** AMD affects a large proportion of the elderly population; current therapeutic options for AMD are limited, however.  
**Patients and methods:** In total, 203 patients (90 men and 113 women; mean age 63.4 +/- 5.3 y) with beginning ("dry") or advanced ("wet") forms of AMD (n = 348 eyes) were included in the study. One hundred ninety-three patients (mean age 64.6 +/- 4.3 y; n = 328 eyes) with cataracts (n = 152 eyes) or without cataracts (n = 146 eyes) were treated using 1117 four times (three per



# Long Red + Near InfraRed (NIR) What does it do?

- Improves eyesight in certain populations
- **Improves melatonin production**
- Improves cognitive function
- Additional benefits

## Melatonin Research

Current Archives Announcements About ▾

Home / Archives / Vol 2 No 1 (2019): Melatonin research / Reviews

### Melatonin and the Optics of the Human Body

**Scott Zimmerman**

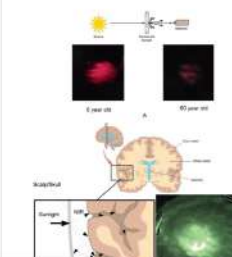
Silas Inc., Basking Ridge, New Jersey, 07920, USA

**Russel J. Reiter**

Department of Cell Systems and Anatomy, UT Health Science Center, San Antonio, Texas

DOI: <https://doi.org/10.32794/mr11250016>

**Keywords:** melatonin, circadian rhythm, free radical, Electron Spin Resonance, LED lighting, sunlight, optical ray tracing, near infrared



Abstract

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National Center for Biotechnology Information

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Randomized Controlled Trial > J Athl Train. 2012 Nov-Dec;47(6):673-8.  
doi: 10.4085/1062-6050-47.6.08.

### Red light and the sleep quality and endurance performance of Chinese female basketball players

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Affiliations + expand

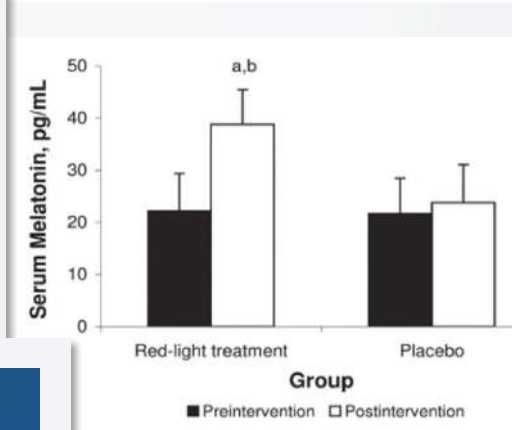
PMID: 23182016 PMCID: PMC3499892 DOI: 10.4085/1062-6050-47.6.08

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#### Abstract

**Context:** Good sleep is an important recovery method for prevention and treatment of overtraining in sport practice. Whether sleep is regulated by melatonin after red-light irradiation in athletes is unknown.

**Objective:** To determine the effect of red light on sleep quality and endurance performance of Chinese female basketball players.





## Long Red + Near InfraRed (NIR) What does it do?

- Improves eyesight in certain populations
- Improves melatonin production
- **Improves cognitive function**
- Additional benefits





Ageing Research Reviews


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### Can transcranial photobiomodulation improve cognitive function? A systematic review of human studies

Tsz-lok Lee<sup>a</sup>, Zihan Ding<sup>a</sup>, Agnes S. Chan<sup>a, b</sup>  

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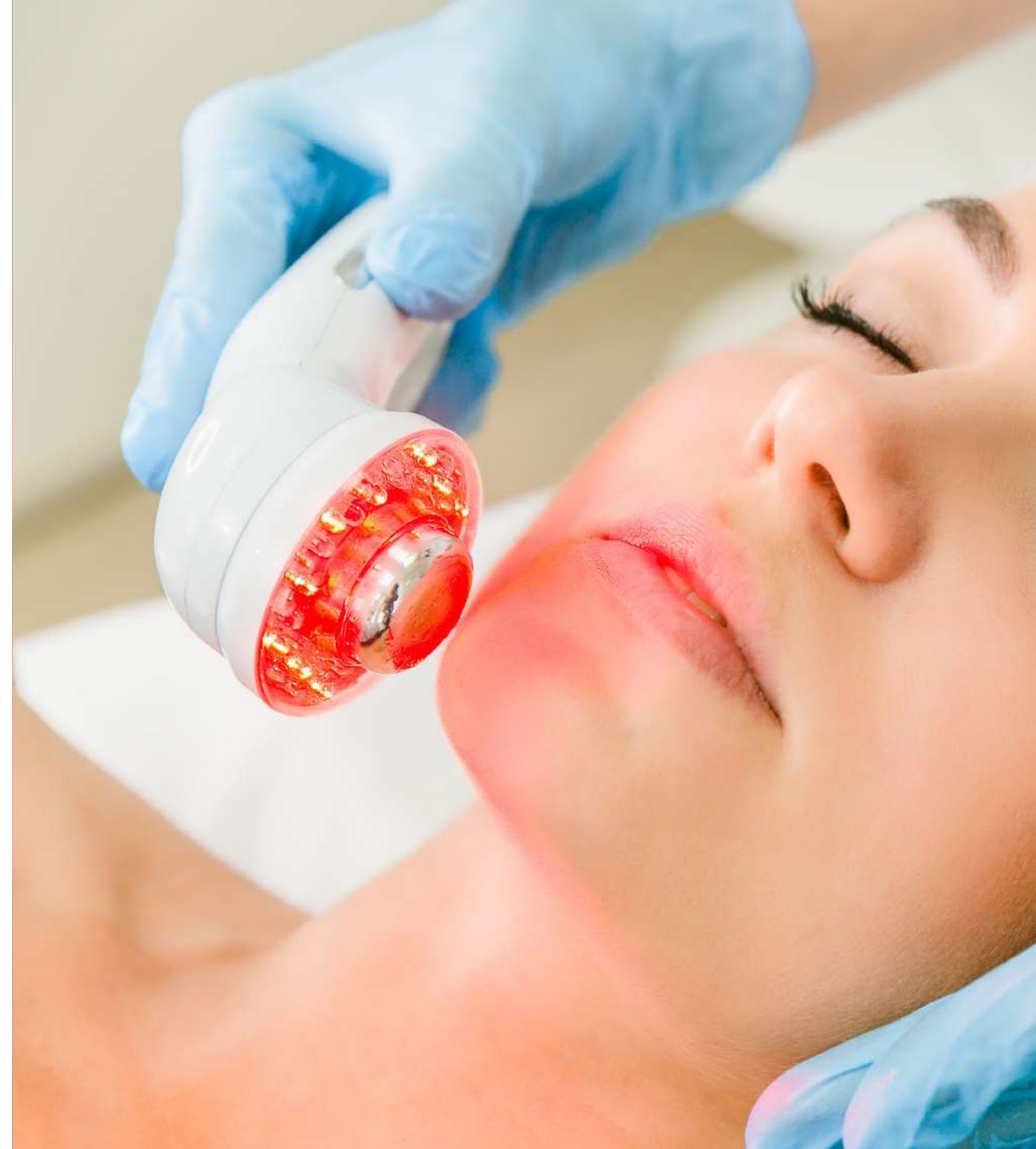
#### Highlights

- Most studies found improvement of cognitive functions after tPBM.
- tPBM is effective in treating dementia and traumatic brain injury.
- Irradiance of 20–25 mW/cm<sup>2</sup> and fluency of 1–10 J/cm<sup>2</sup> were commonly used.



## **Long Red + Near InfraRed (NIR) What does it do?**

- Improves eyesight in certain populations
- Improves melatonin production
- Improves cognitive function
- **Additional benefits**
  - Improves skin conditions
  - Promotes wound healing
  - Promotes hair regrowth
  - Reduces swelling + inflammation
  - ... and more





# Key Takeaways



## What does this mean for lighting?

1. Along with food, H<sub>2</sub>O, air, and exercise – LIGHT is a vital pillar of human health and wellness
2. Scientific research continues to reinforce the connection between light and health. Both intensity AND spectra matter
3. Consensus has formed around the importance of Circadian, but this is only just the beginning
4. Our industry needs to think deeply about the future and “skate to where the puck is going to be”
5. Adoption of flexible dynamic systems is the key to delivering the right light at the right time





This Concludes The American Institute of Architects  
Continuing Education Systems Course

