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Designers Lighting Forum

Bursting the Melatonin Bubble: New Perspectives for Human-Centric Lighting

Dr Shelley James

20 March 2024

Credit(s) earned on completion of this course will be reported to AIA CES for AIA members. Certificates of Completion for both AIA members and non-AIA members are available upon request.

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

Learning Objectives

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

1. Know how the non-visual pathway was discovered and current understanding of the main variables and mechanisms involved in circadian and other neuroendocrine and behavioural responses so that participants can understand the framework for current regulations and standards.

2. Know how new research is challenging established models of non-visual response, with particular reference to the melatonin pathway and its role in circadian entrainment and mood regulation so that participants can interpret lighting standards and regulations more effectively.

3. Know the role of non-visual photic inputs, environmental, genetic and cultural cues in circadian entrainment and mood regulation so that participants can contribute more effectively to sustainable interdisciplinary design solutions.

4. Know how these principles offer a framework for 'integrative' lighting design in three key sectors: healthcare, education and social housing so that participants can understand the implications of this understanding for their own practice.

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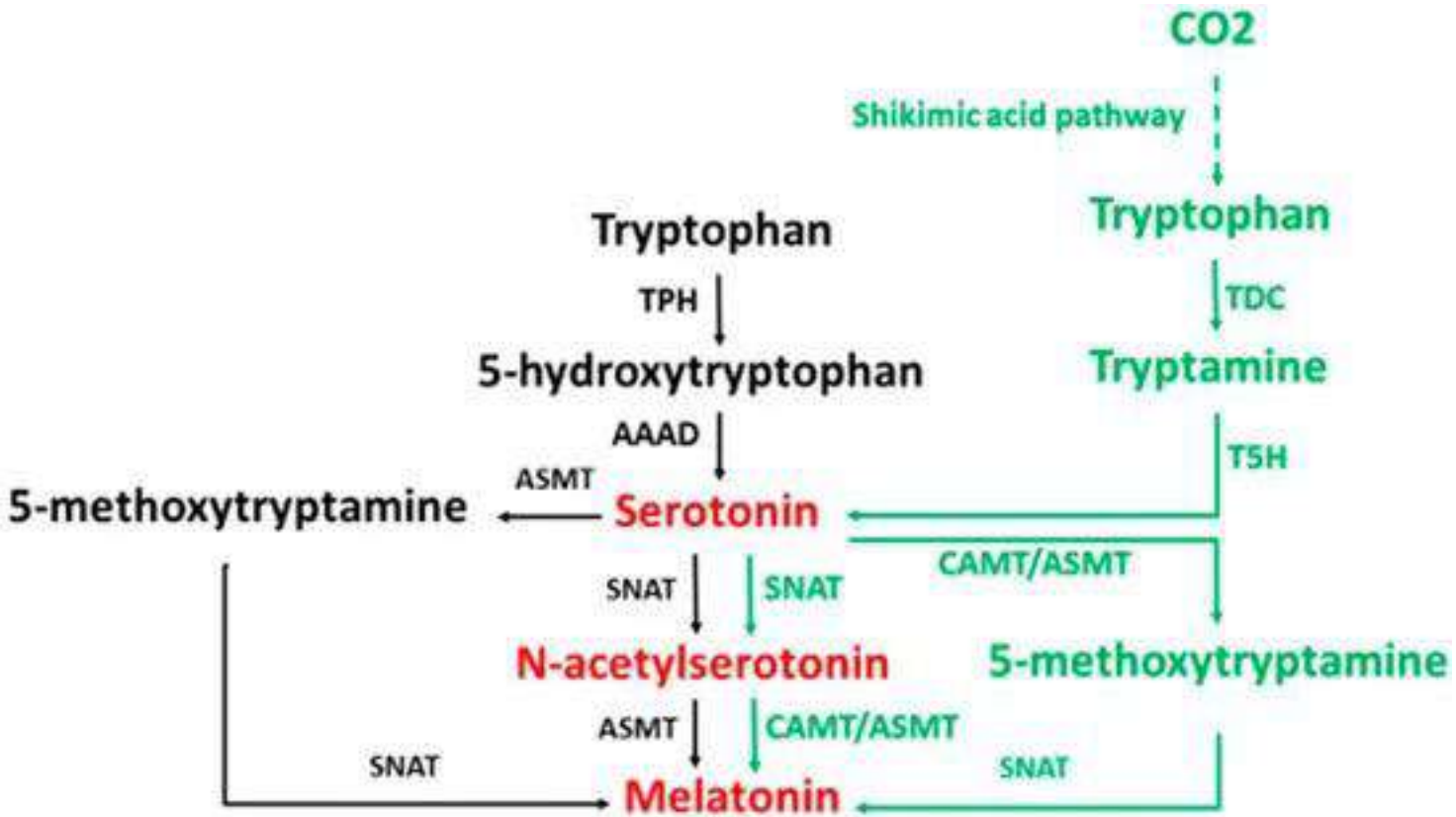
Learning Outcome 1

Know how the non-visual pathway was discovered and current understanding of the main variables and mechanisms involved in circadian and other neuroendocrine and behavioural responses so that participants can understand the framework for current regulations and standards.



Tan, D.-X., Manchester, L. C., Esteban-Zubero, E., Zhou, Z., & Reiter, R. J. (2015). Melatonin as a Potent and Inducible Endogenous Antioxidant: Synthesis and Metabolism. *Molecules*, *20*(10), 18886-18906. https://www.mdpi.com/1420-3049/20/10/18886

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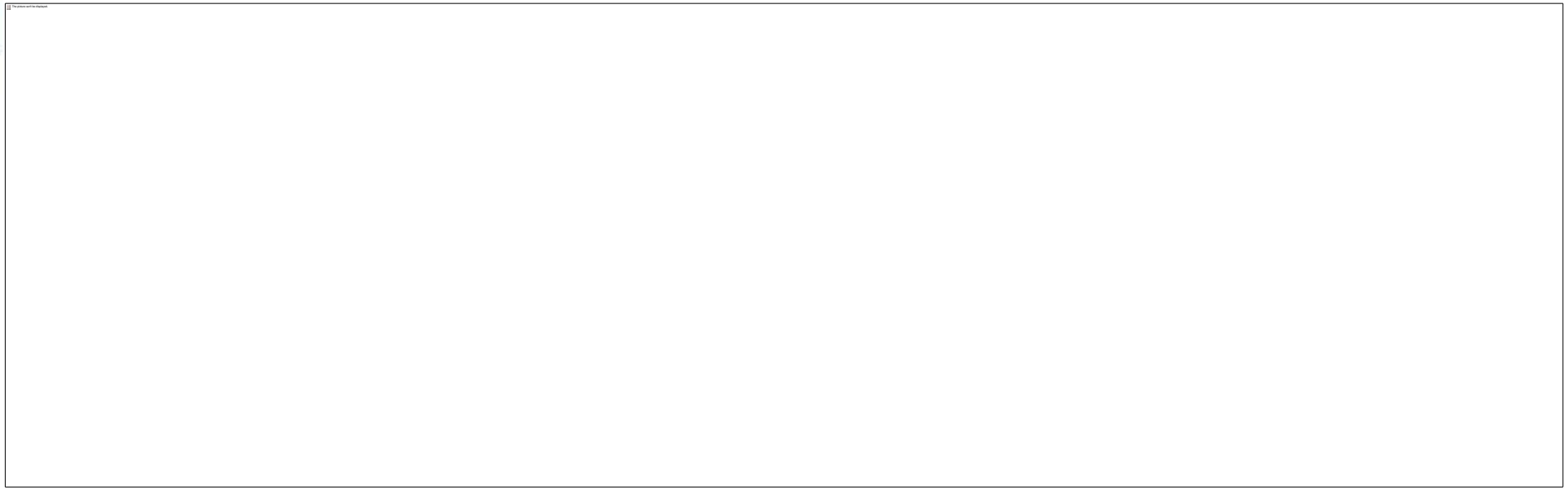

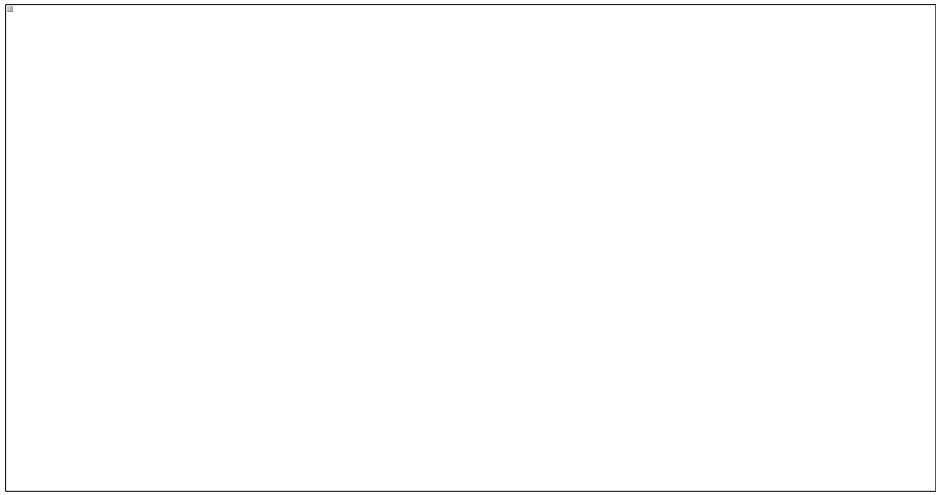

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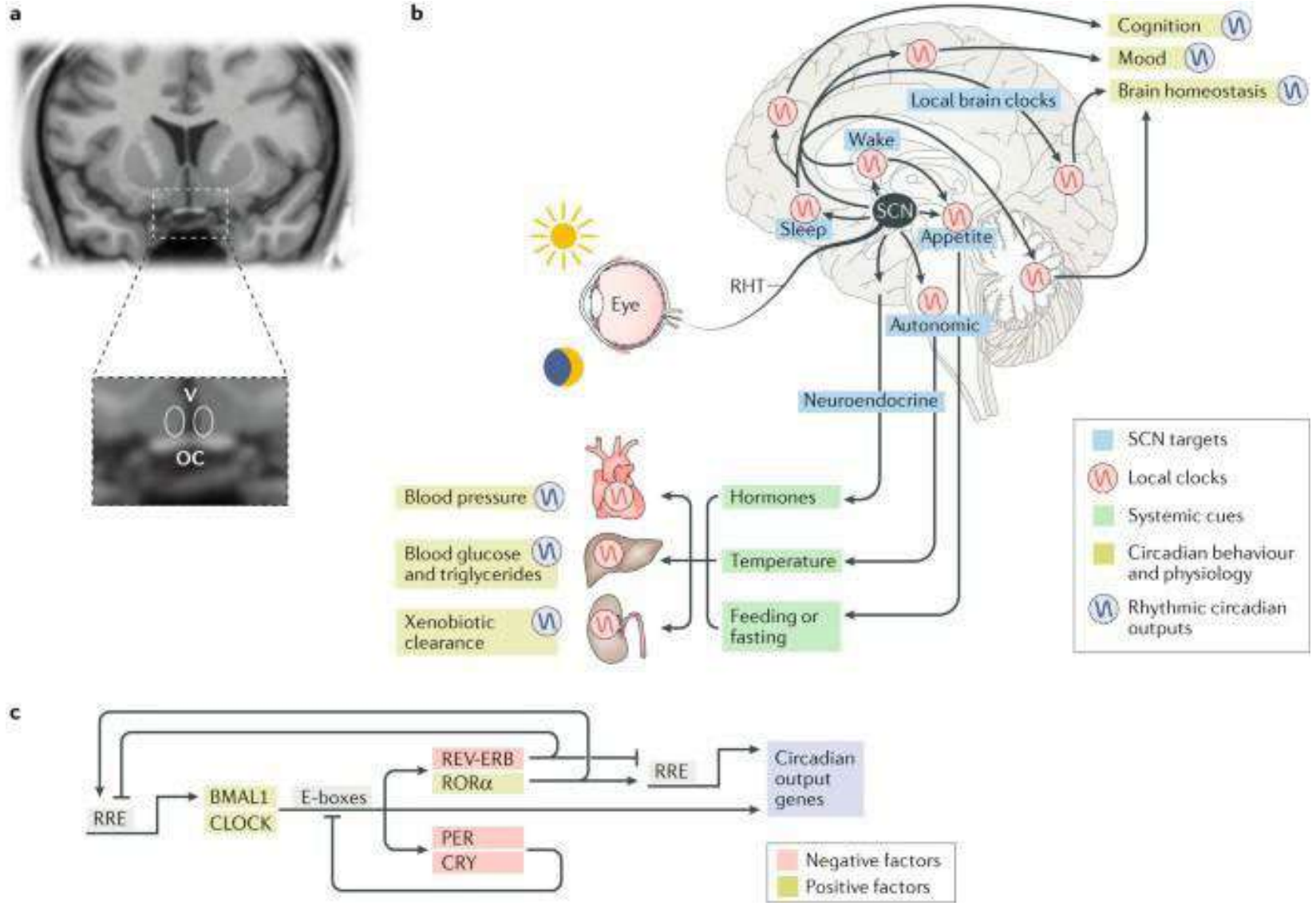

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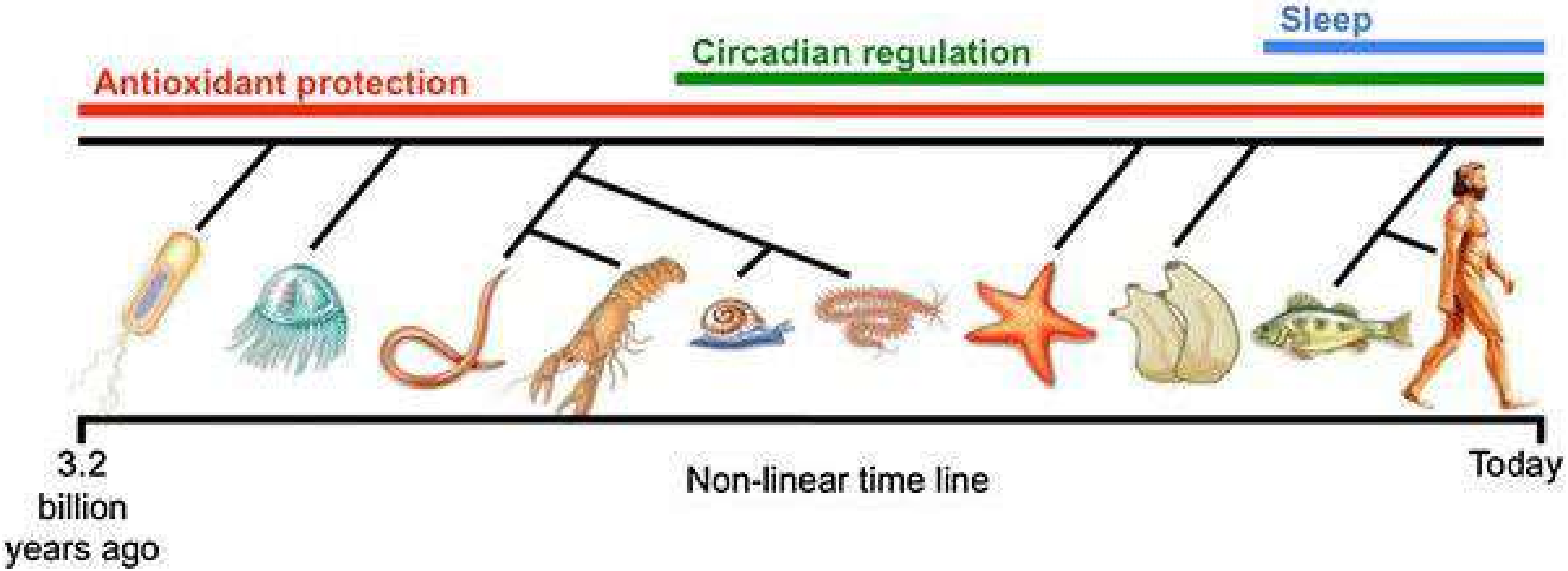

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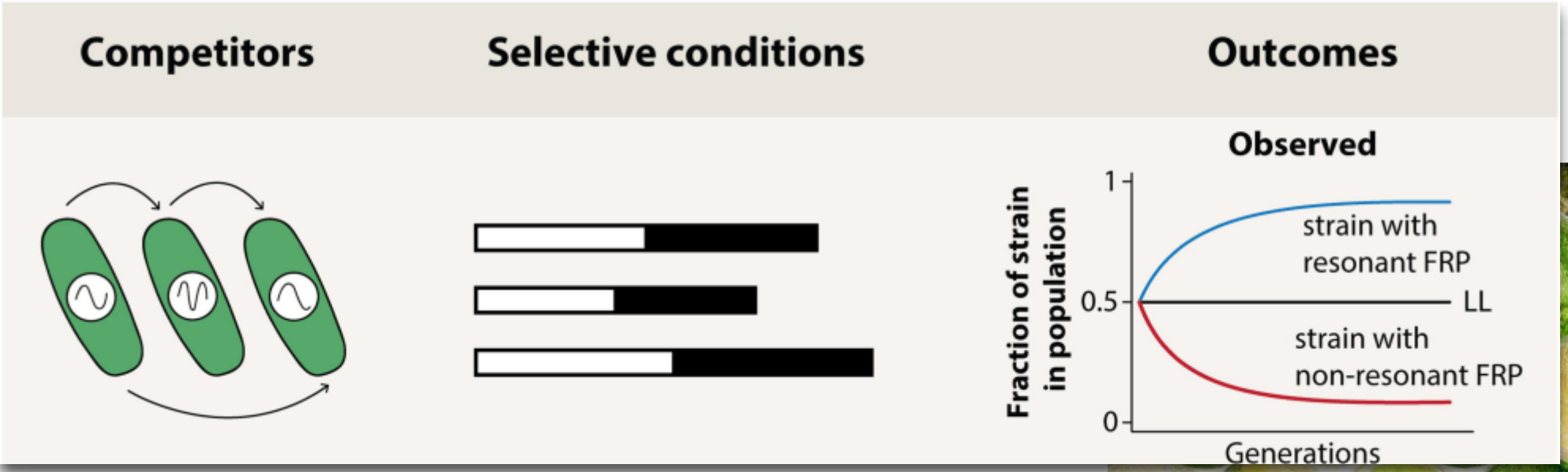

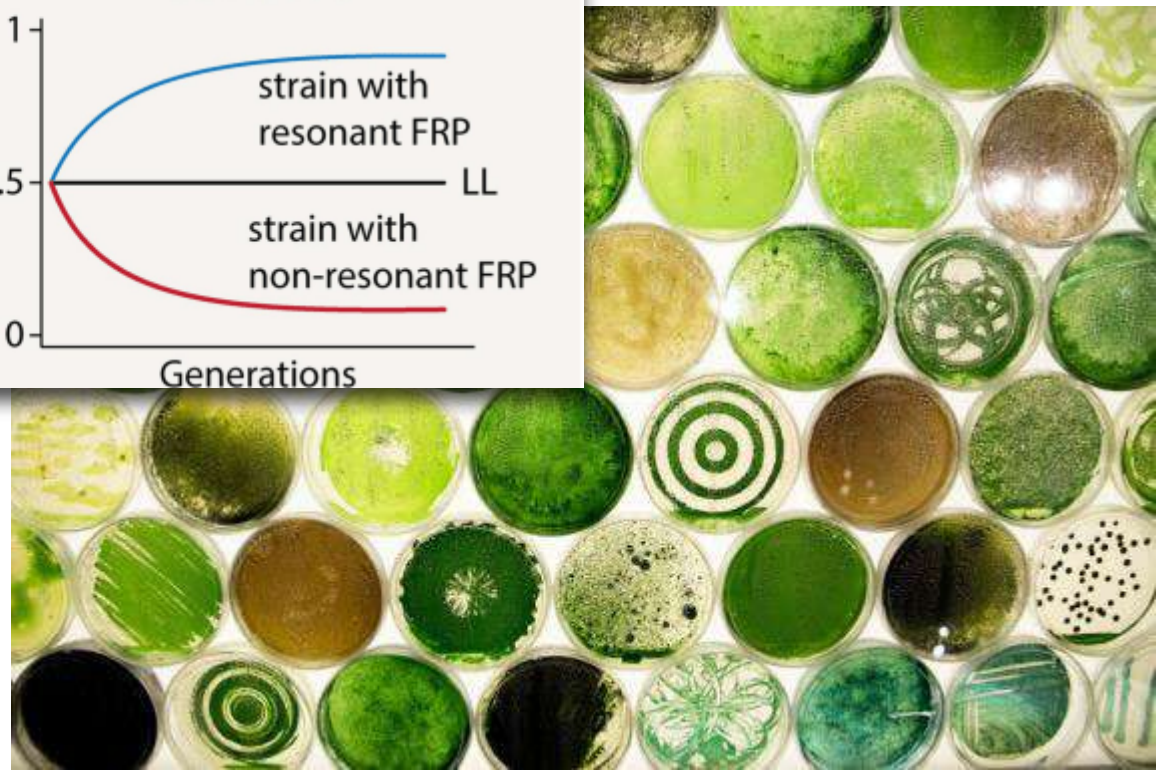

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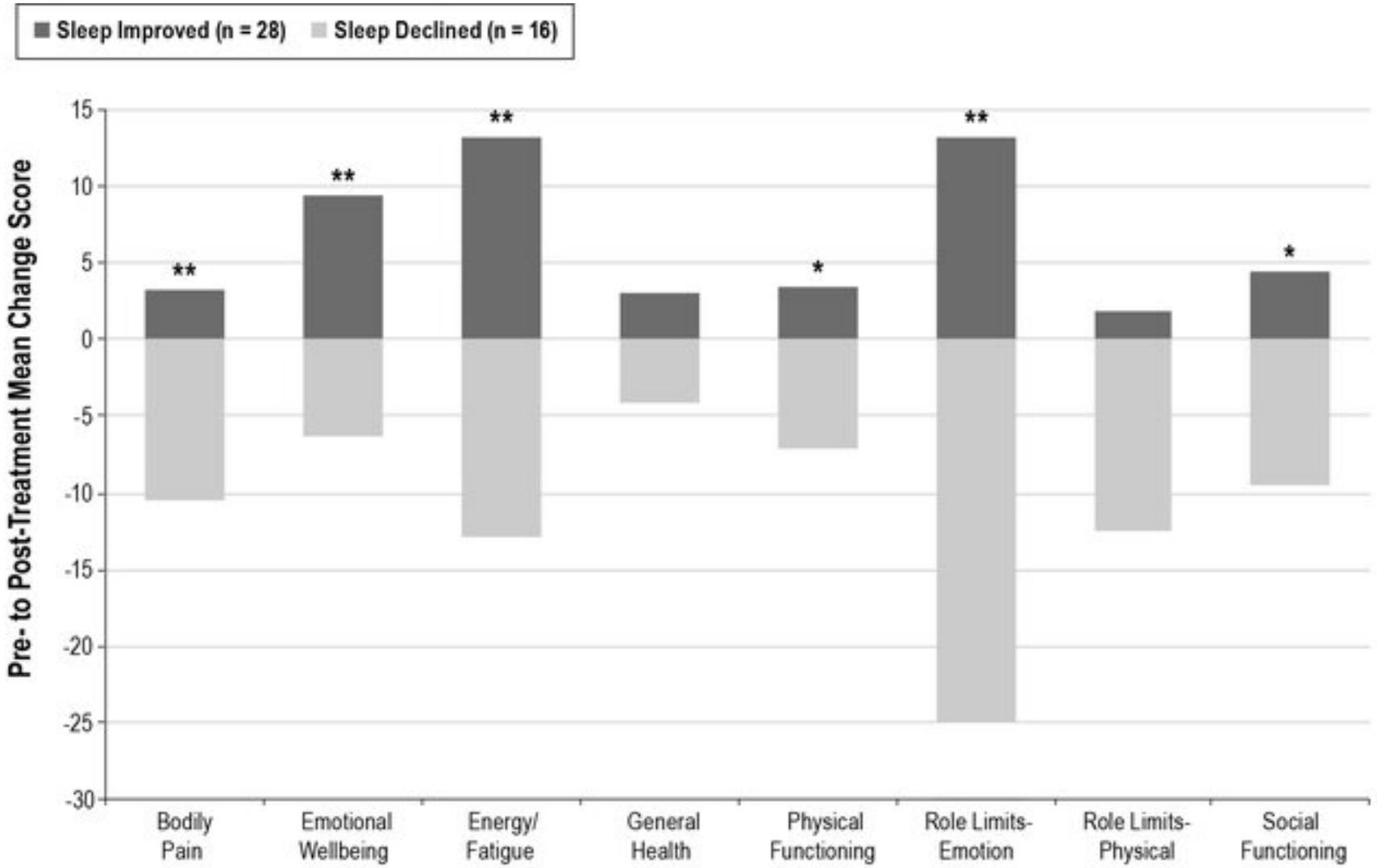
Better sleep = better quality of life



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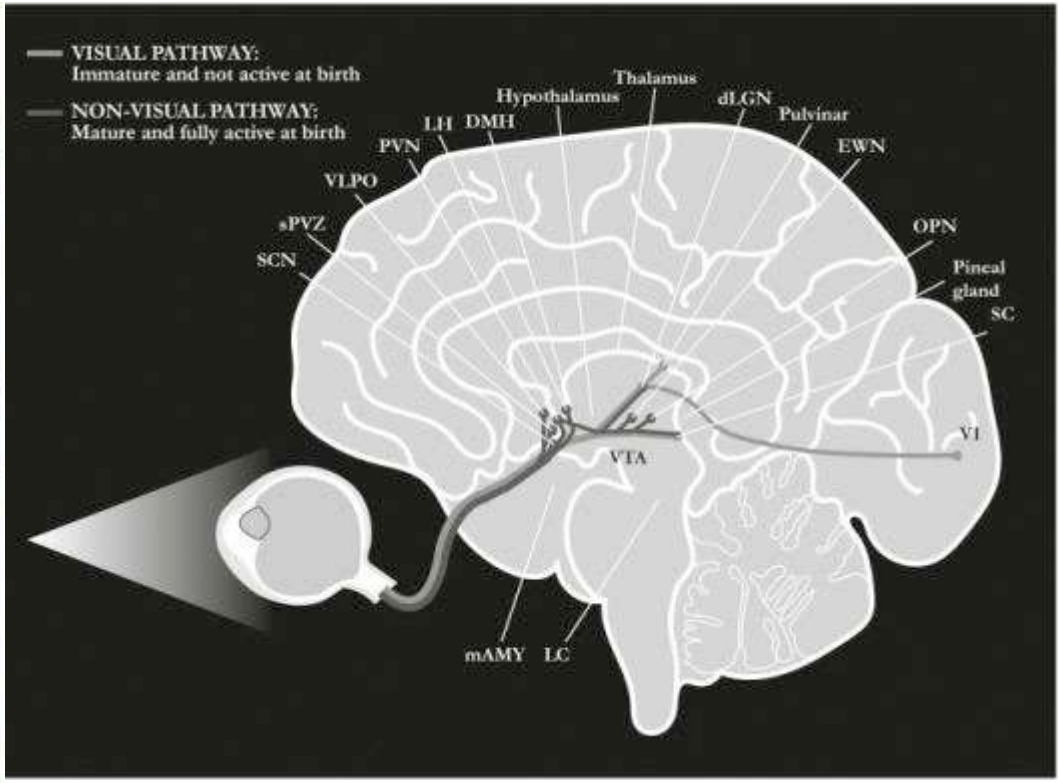

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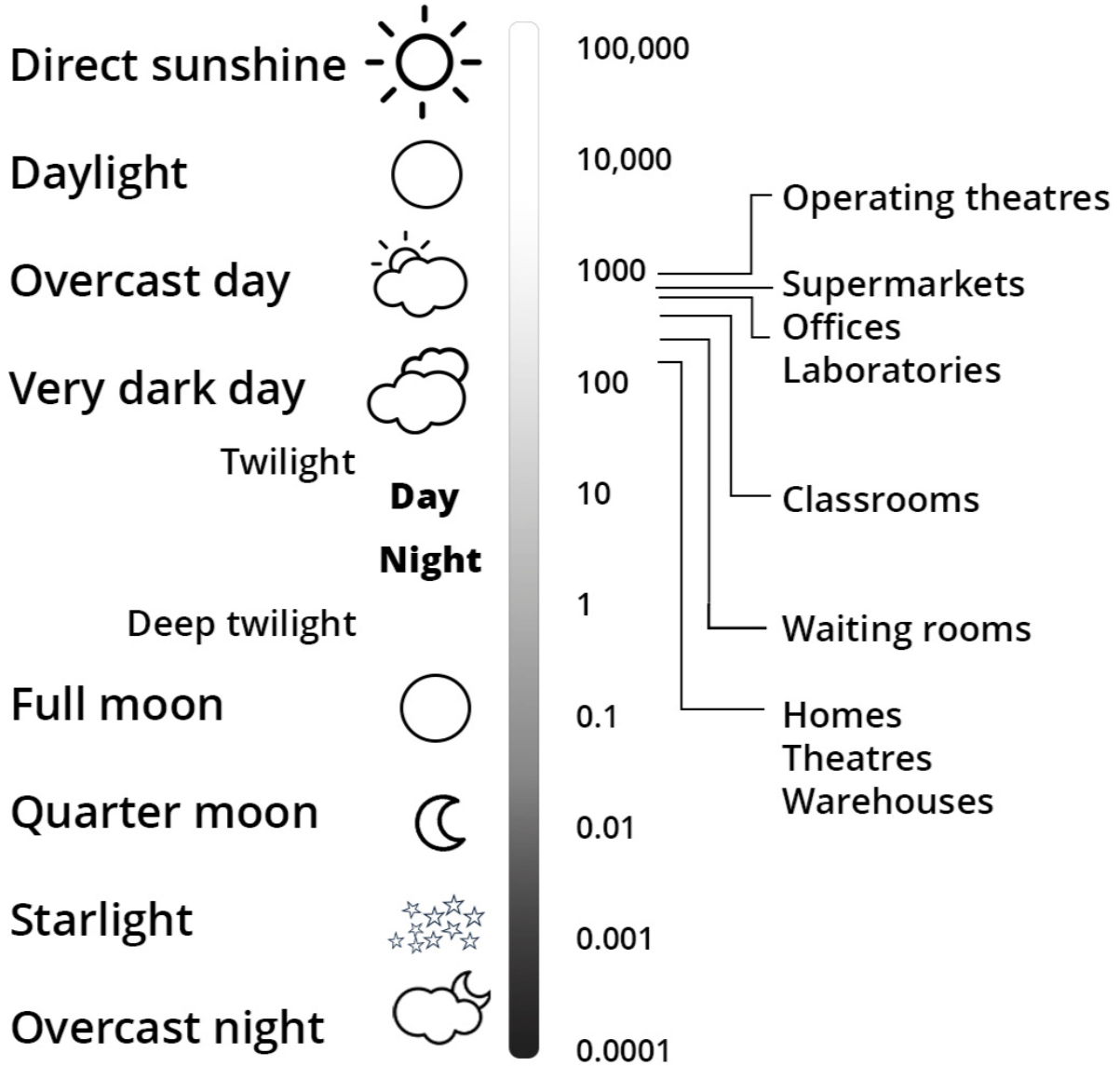

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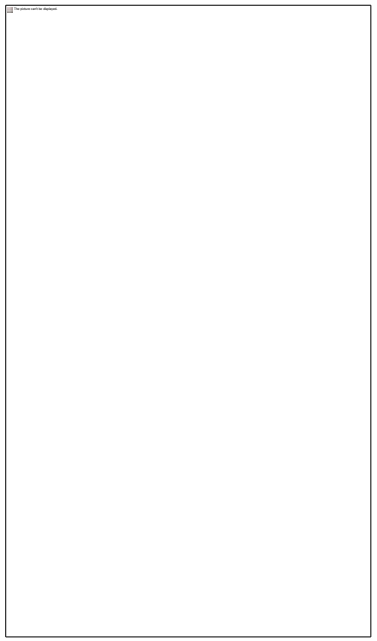
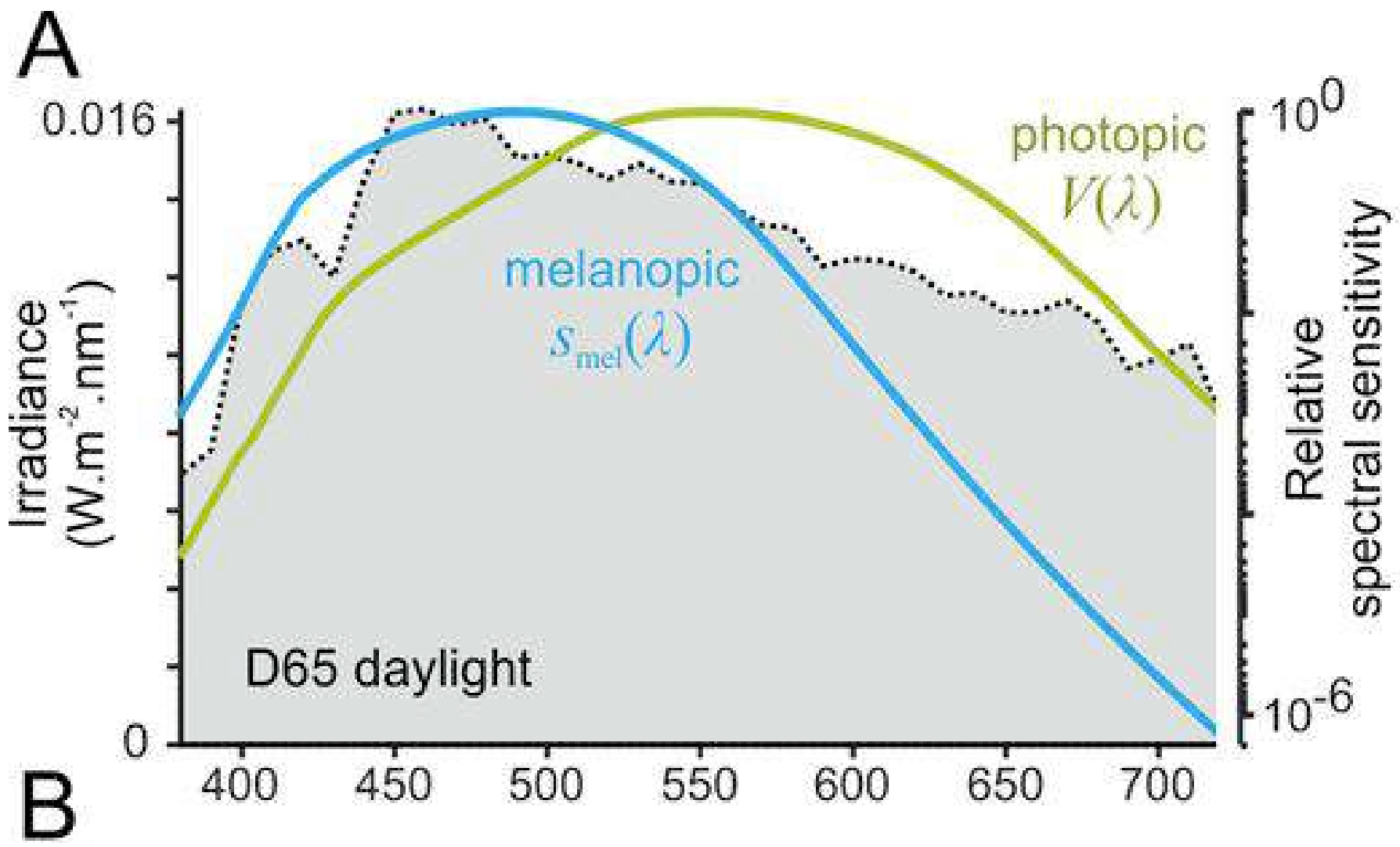
Measuring melanopic response…

- Blue =melanopic action (smel(λ)
- Green - photopic efficiencyV(λ
- Grey - standard daylight D65





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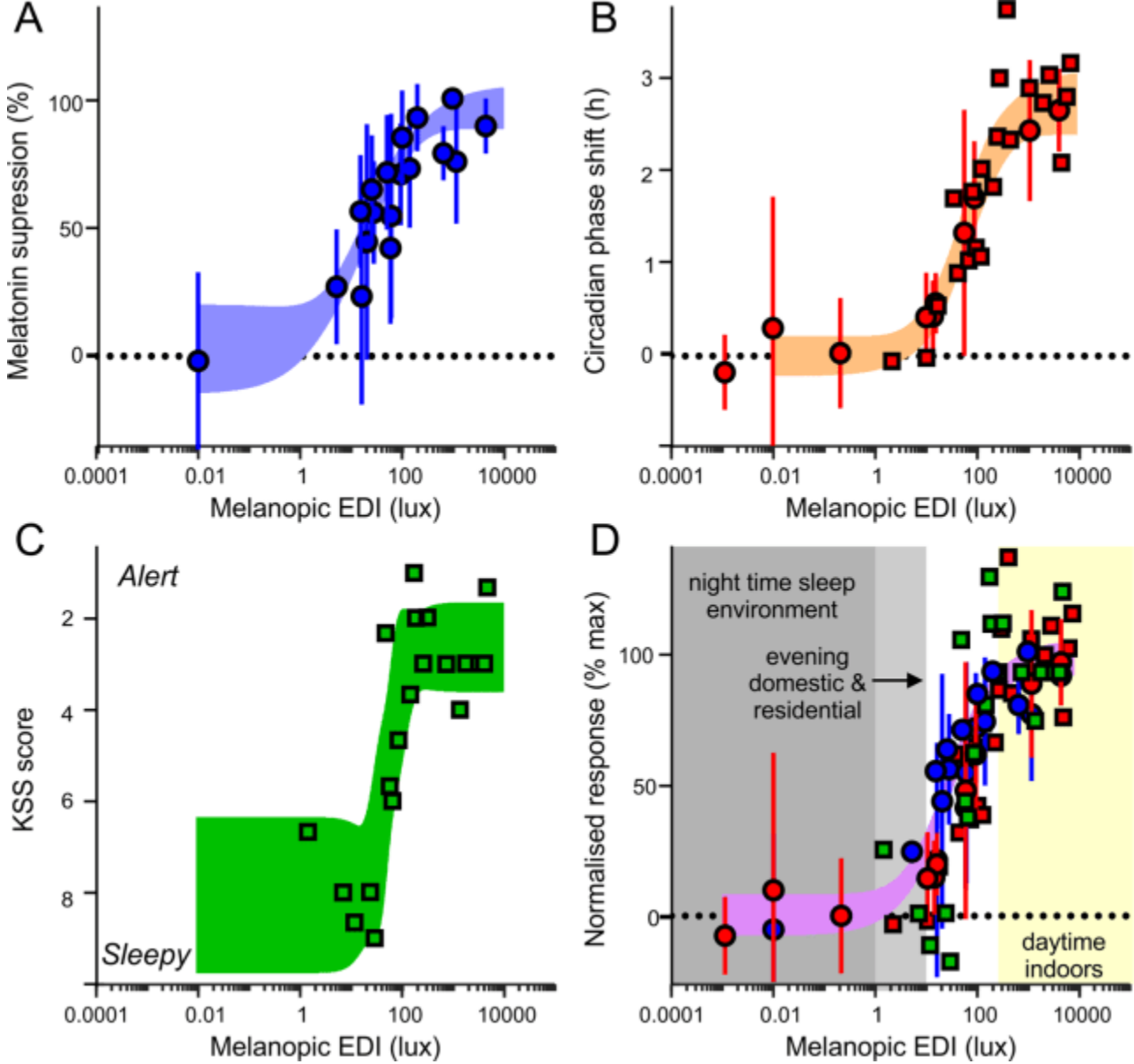

Brown TM, Brainard GC, Cajochen C, Czeisler CA, Hanifin JP, Lockley SW, et al. (2022) Recommendations for daytime, evening, and nighttime indoor light exposure to best support physiology, sleep, and wakefulness in healthy adults. PLoS Biol 20(3): e3001571. https://doi.org/10.1371/journal.pbio.3001571

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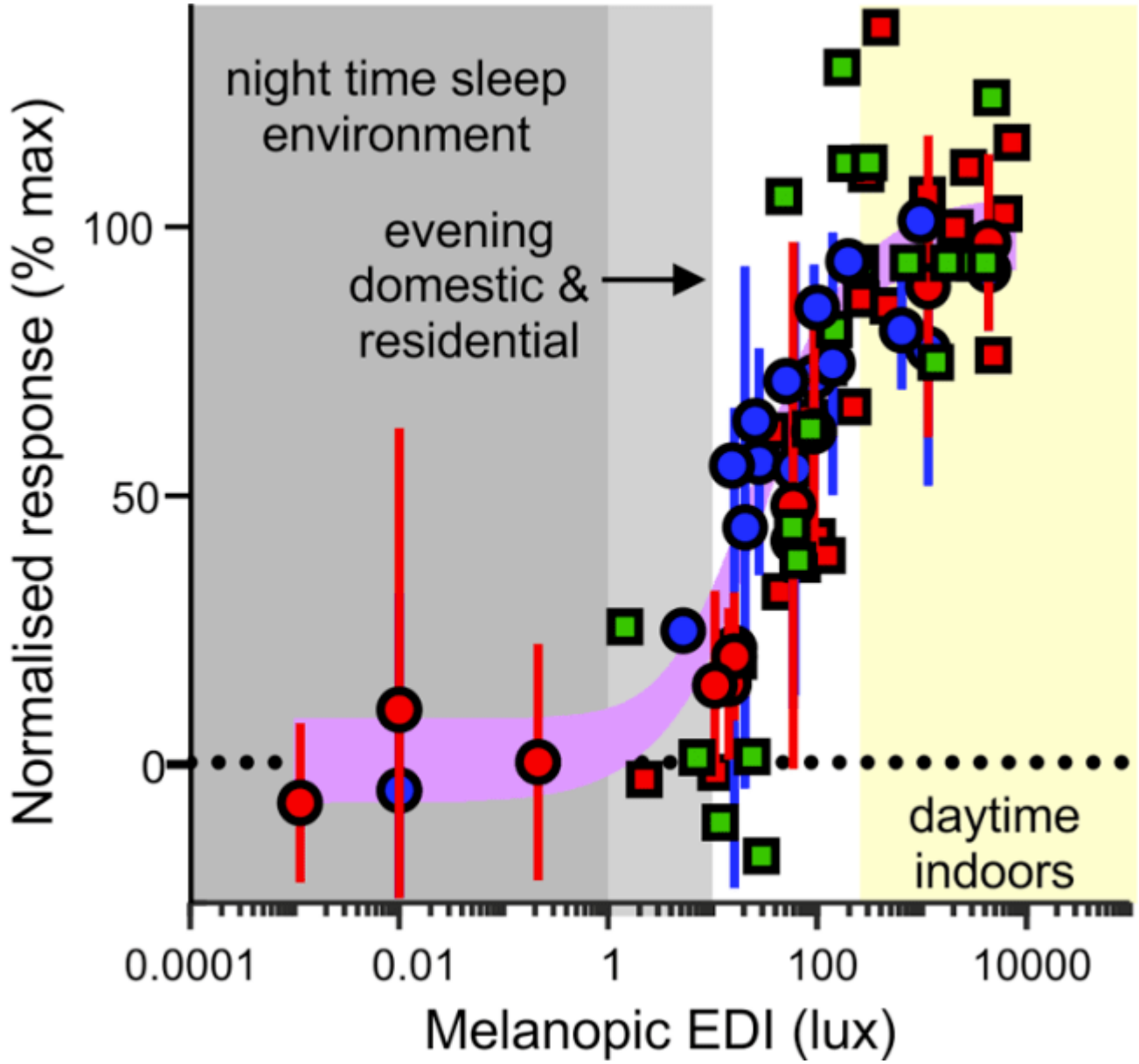
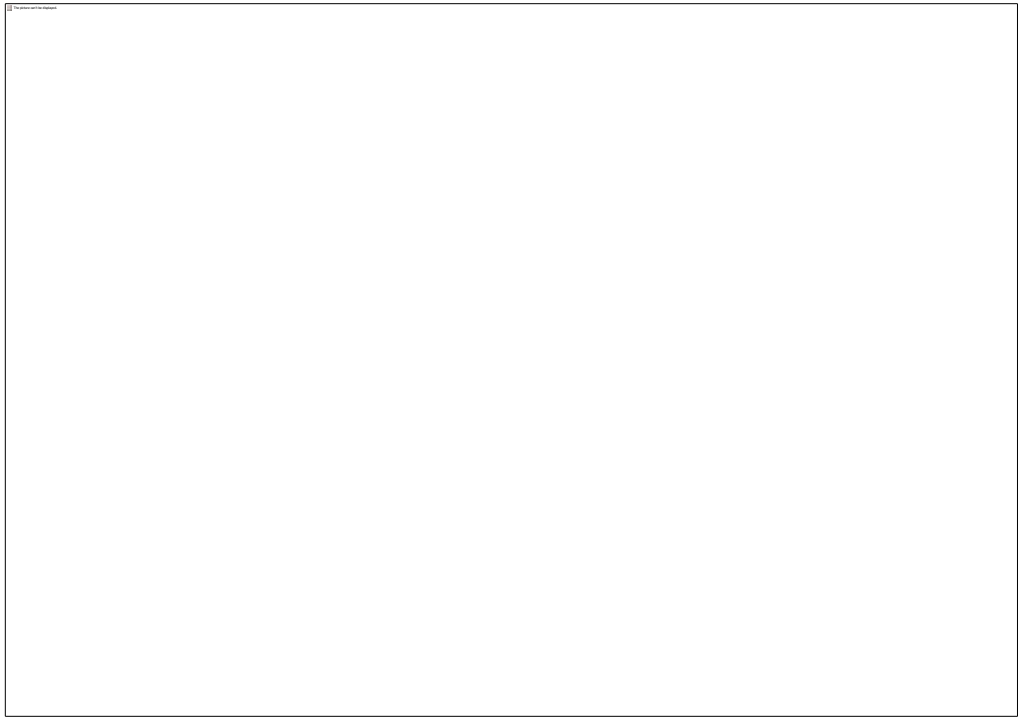
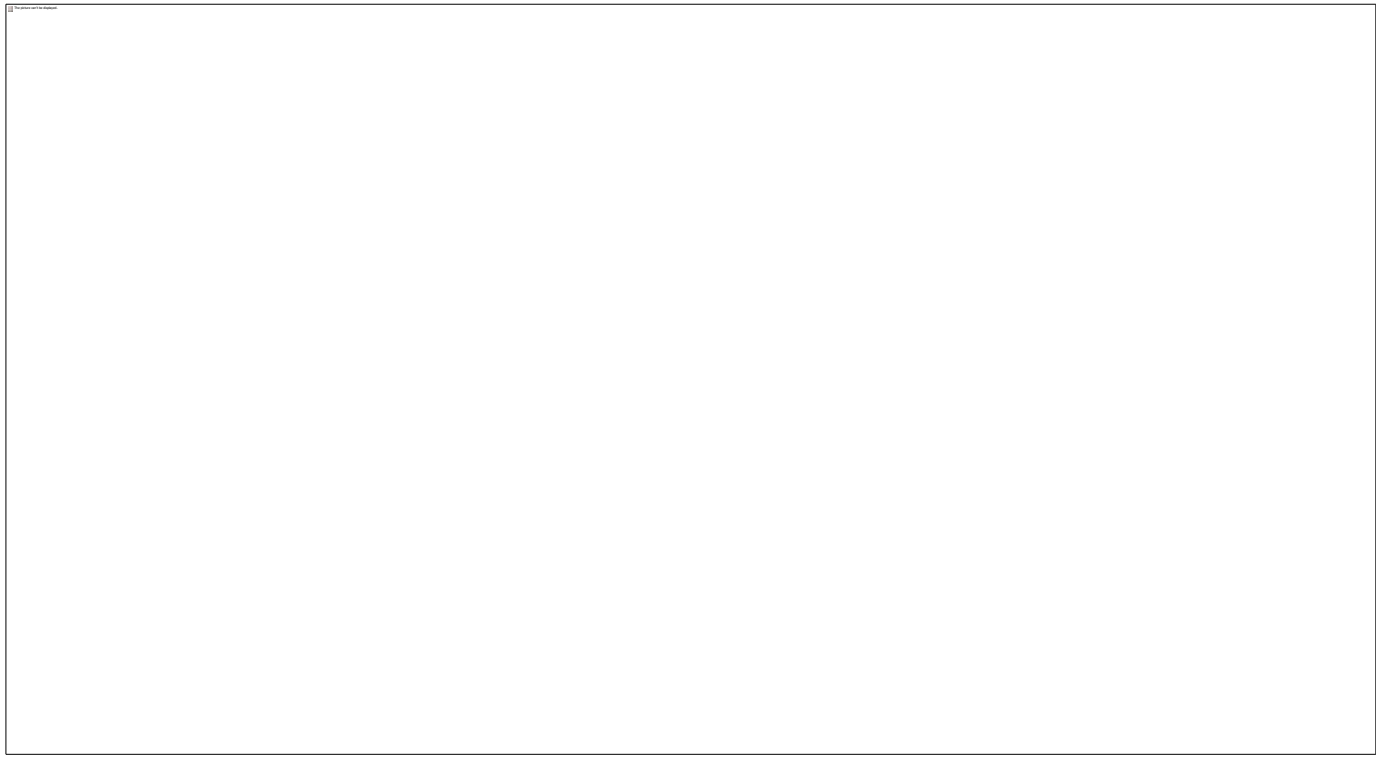
- Daytime - MelEDI >250 lux
- Presleep - MelEDI <10 lux
- Night time - MelEDI <1 lux



Citation: Brown TM, Brainard GC, Cajochen C, Czeisler CA, Hanifin JP, Lockley SW, et al. (2022) Recommendations for daytime, evening, and nighttime indoor light exposure to best support physiology, sleep, and wakefulness in healthy adults. PLoS Biol 20(3): e3001571. https://doi.org/10.1371/journal.pbio.3001571





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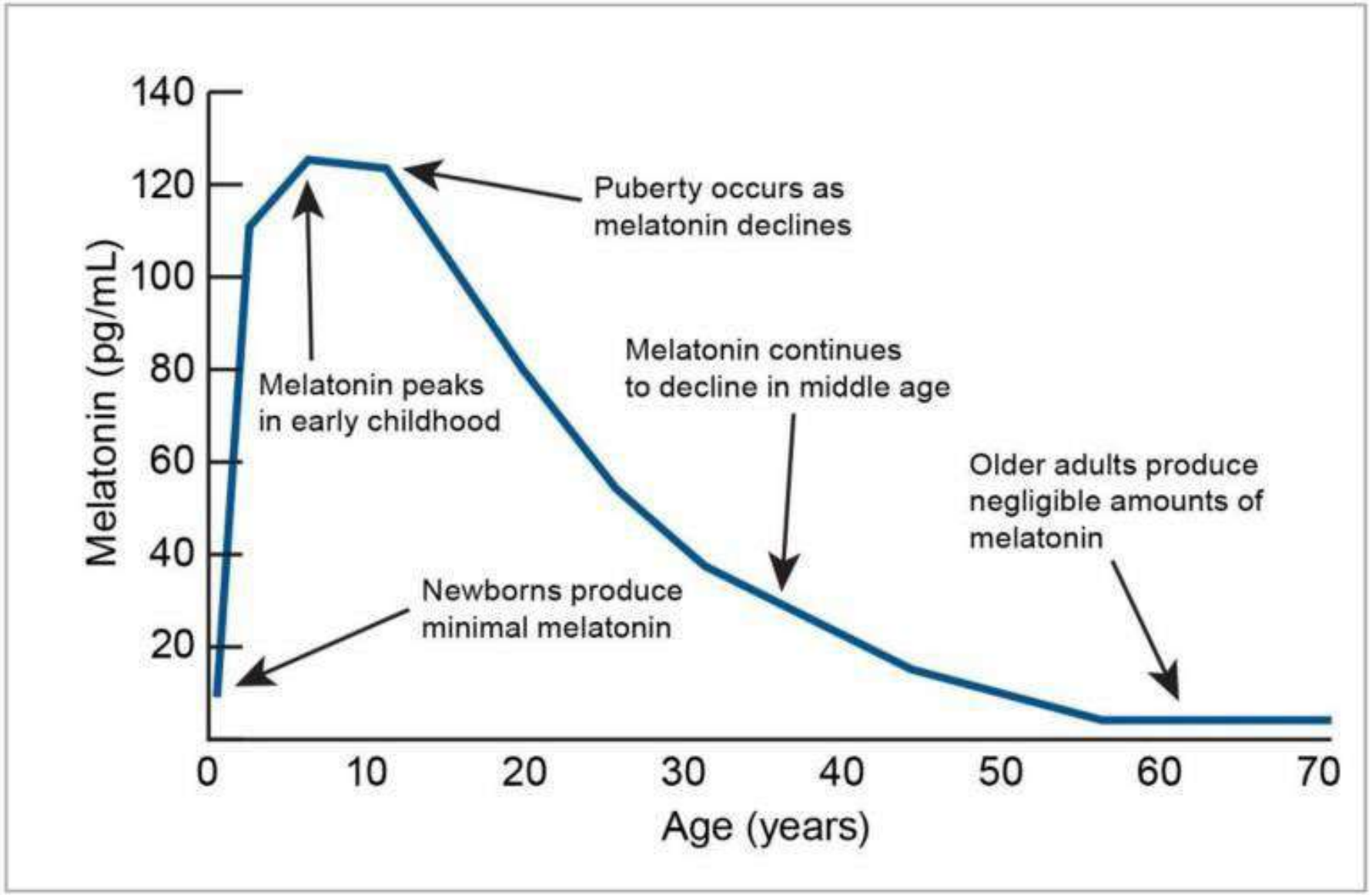
AGE



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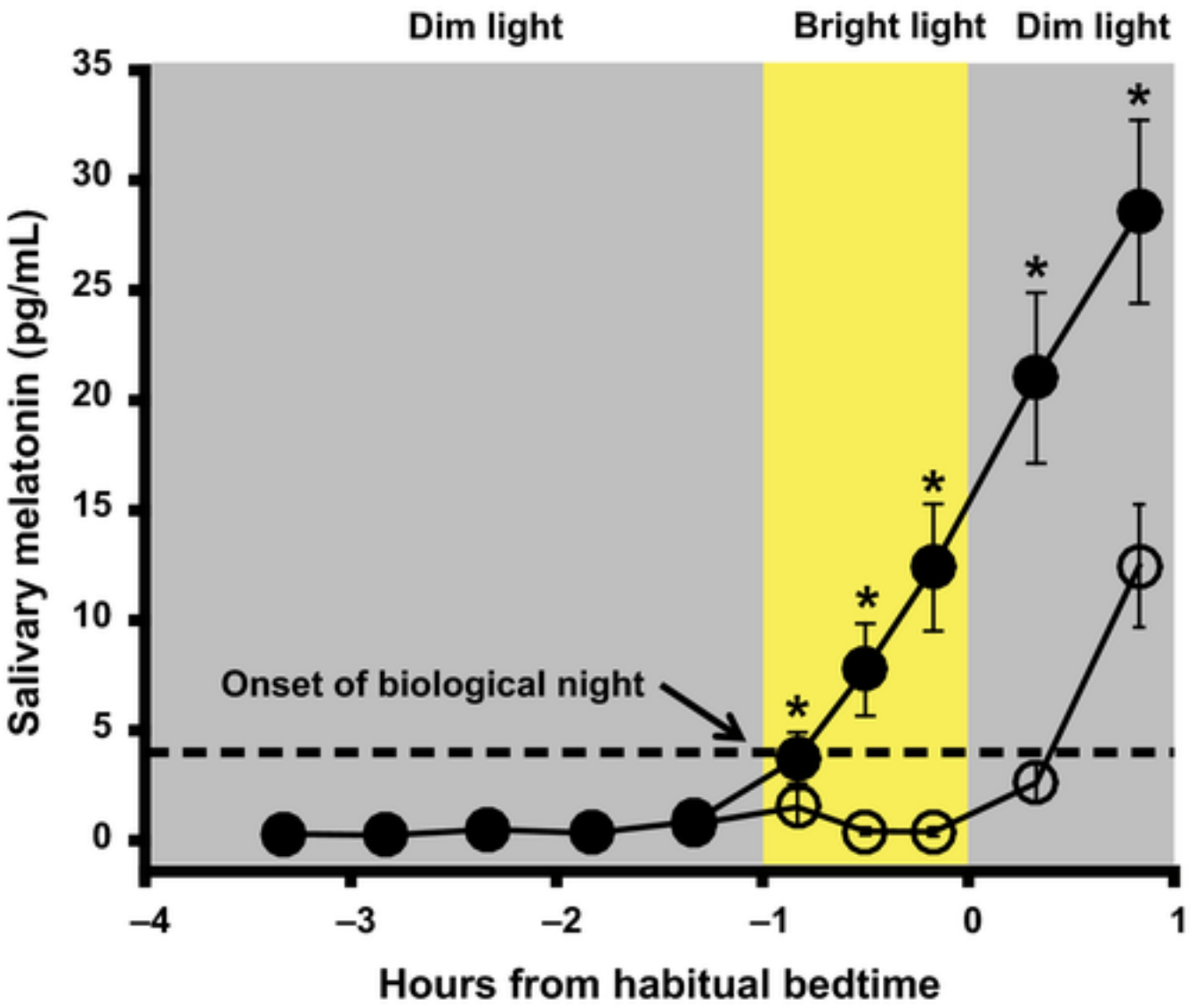

Akacem, L. D., Wright Jr., K. P., & LeBourgeois, M. K. (2018). Sensitivity of the circadian system to evening bright light in preschool-age children. *Physiological Reports*, *6*(5), e13617. https://doi.org/https://doi.org/10.14814/phy2.13617

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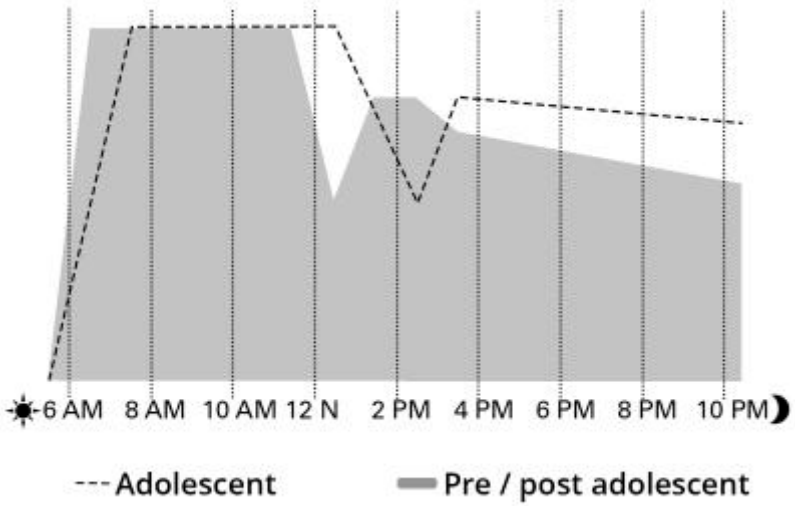
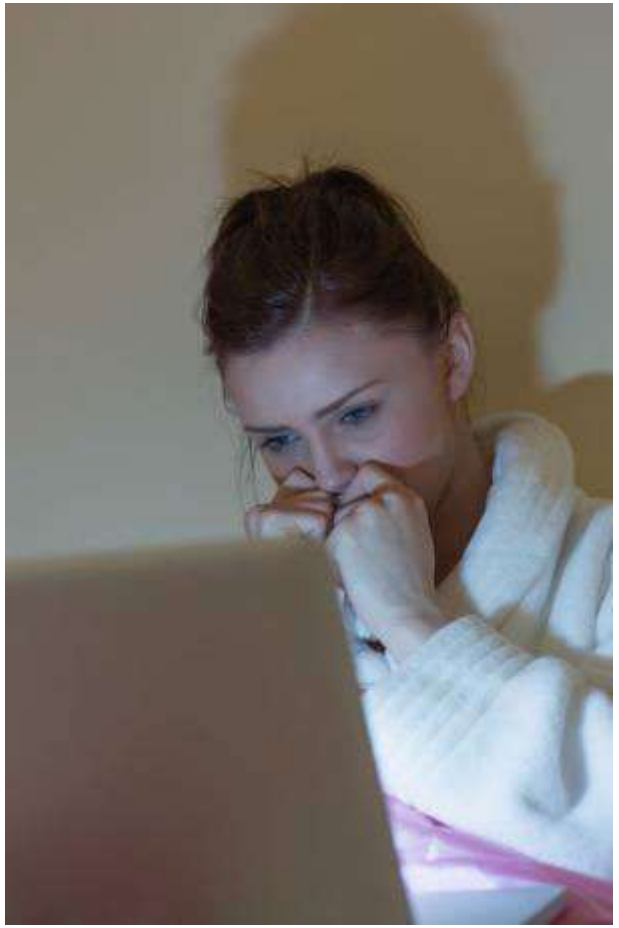
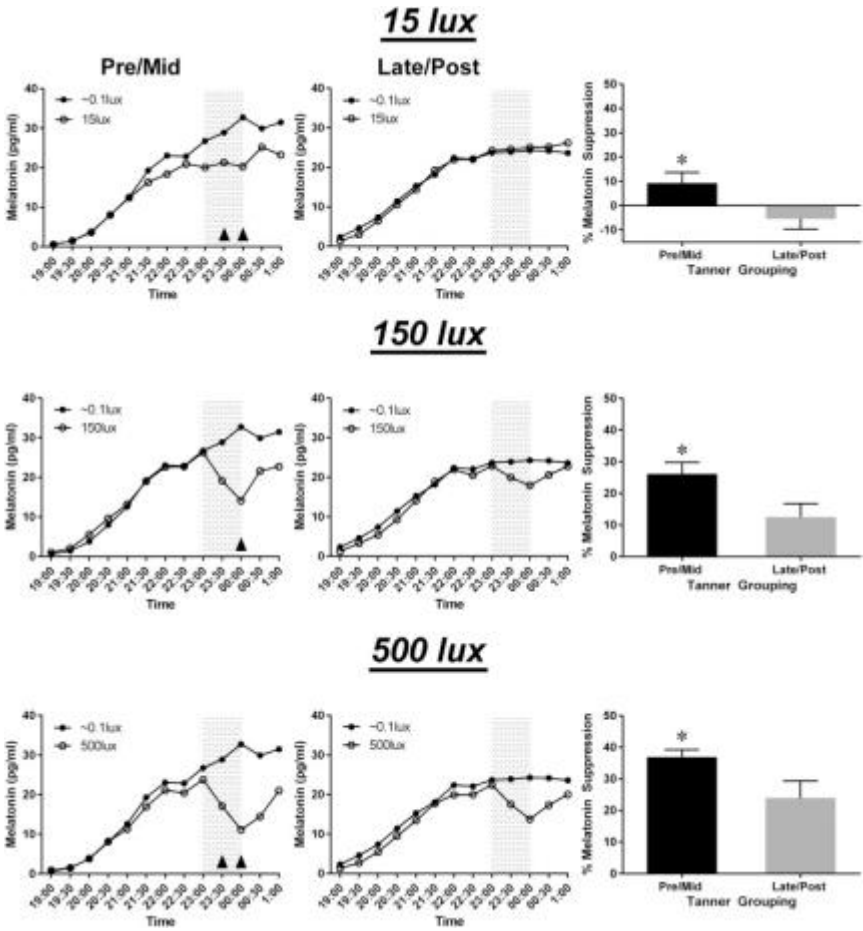
Teens shift two hours later
Extreme evening light sensitivity
Pre- v post adolescents
15 lux: 9.2 v -5.3%
150 lux 26.0 v 12.5
500 lux 36.9 v 21.7%







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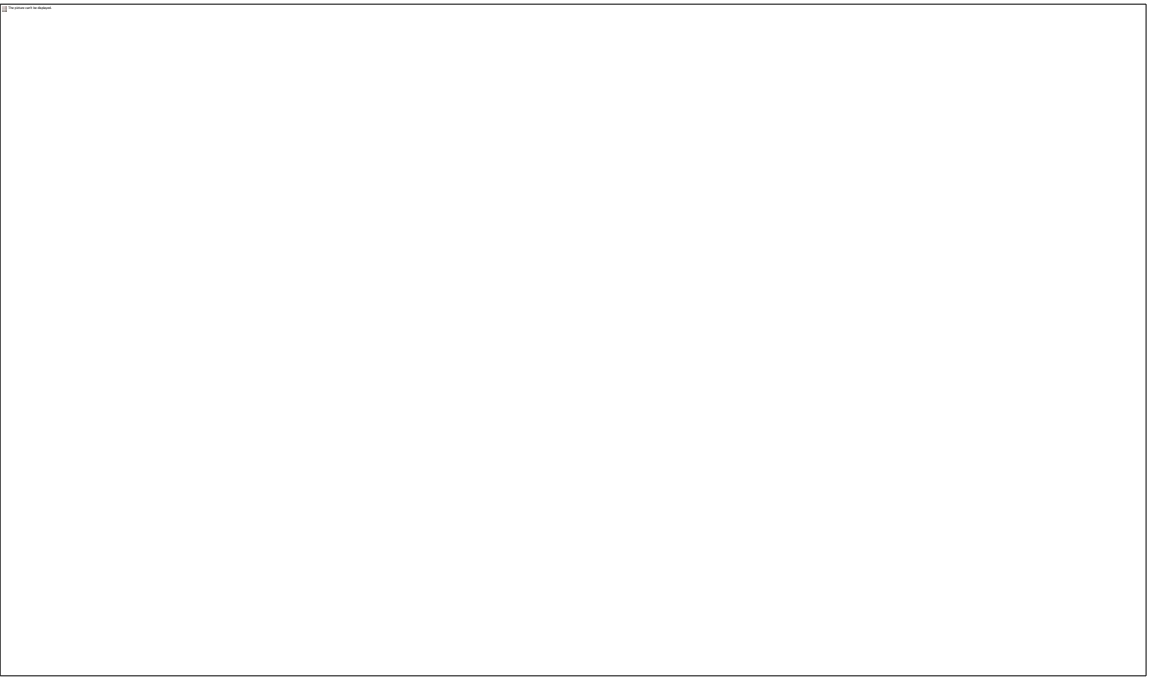

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Learning Outcome 2

KNOW HOW NEW RESEARCH IS CHALLENGING ESTABLISHED MODELS OF NON-VISUAL RESPONSE, WITH PARTICULAR REFERENCE TO THE MELATONIN PATHWAY AND ITS ROLE IN CIRCADIAN ENTRAINMENT AND MOOD REGULATION SO THAT PARTICIPANTS CAN INTERPRET LIGHTING STANDARDS AND REGULATIONS MORE EFFECTIVELY.

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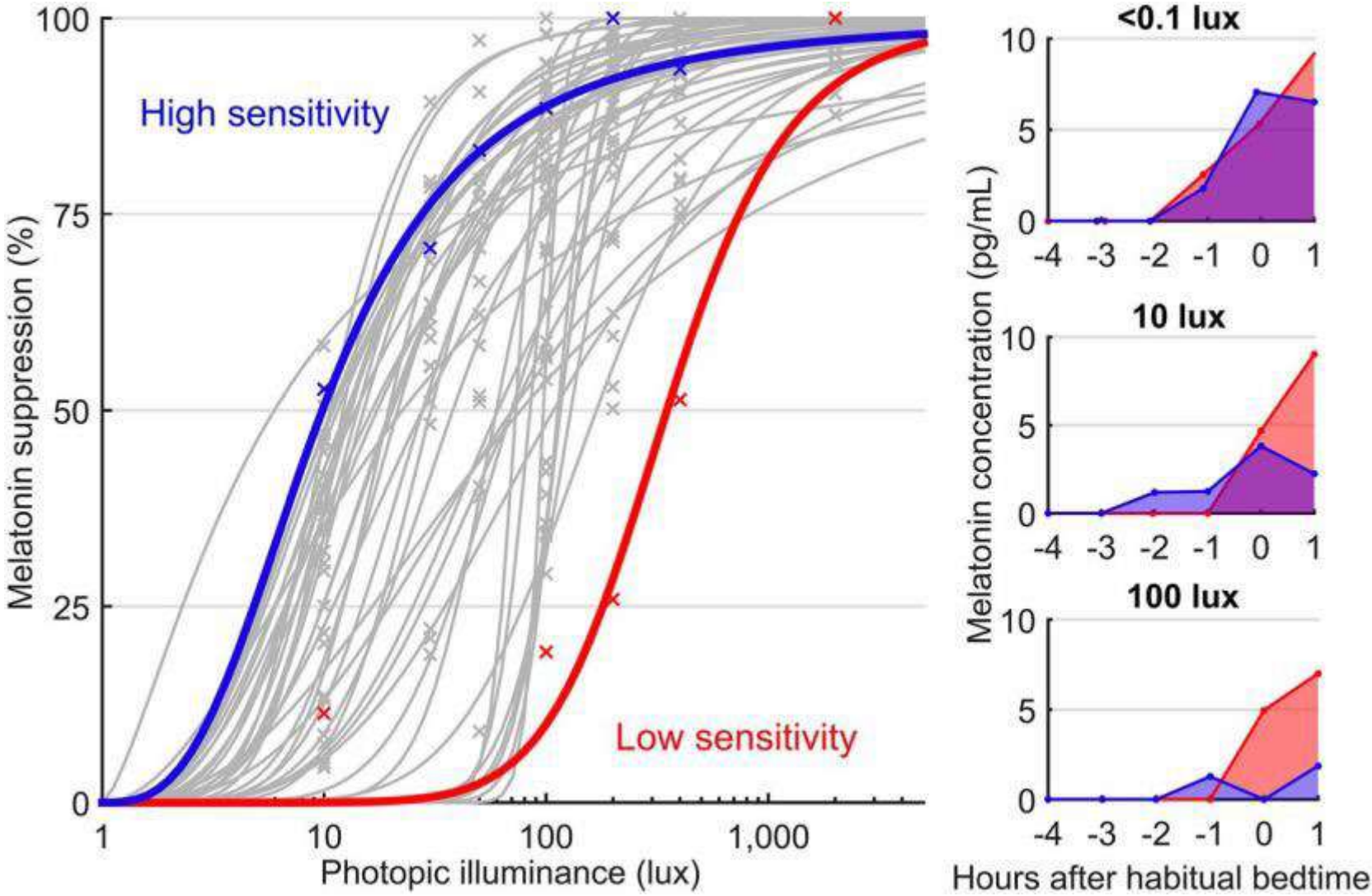
Range of response

X50 difference between people

50% of homes bright enough to disrupt circadian entrainment for 50% of people



Cain, S. W., McGlashan, E. M., Vidafar, P., Mustafovska, J., Curran, S. P. N., Wang, X., Mohamed, A., Kalavally, V., & Phillips, A. J. K. (2020). Evening home lighting adversely impacts the circadian system and sleep. Scientific Reports, 10(1), 19110. https://doi.org/10.1038/s41598-020-75622-4

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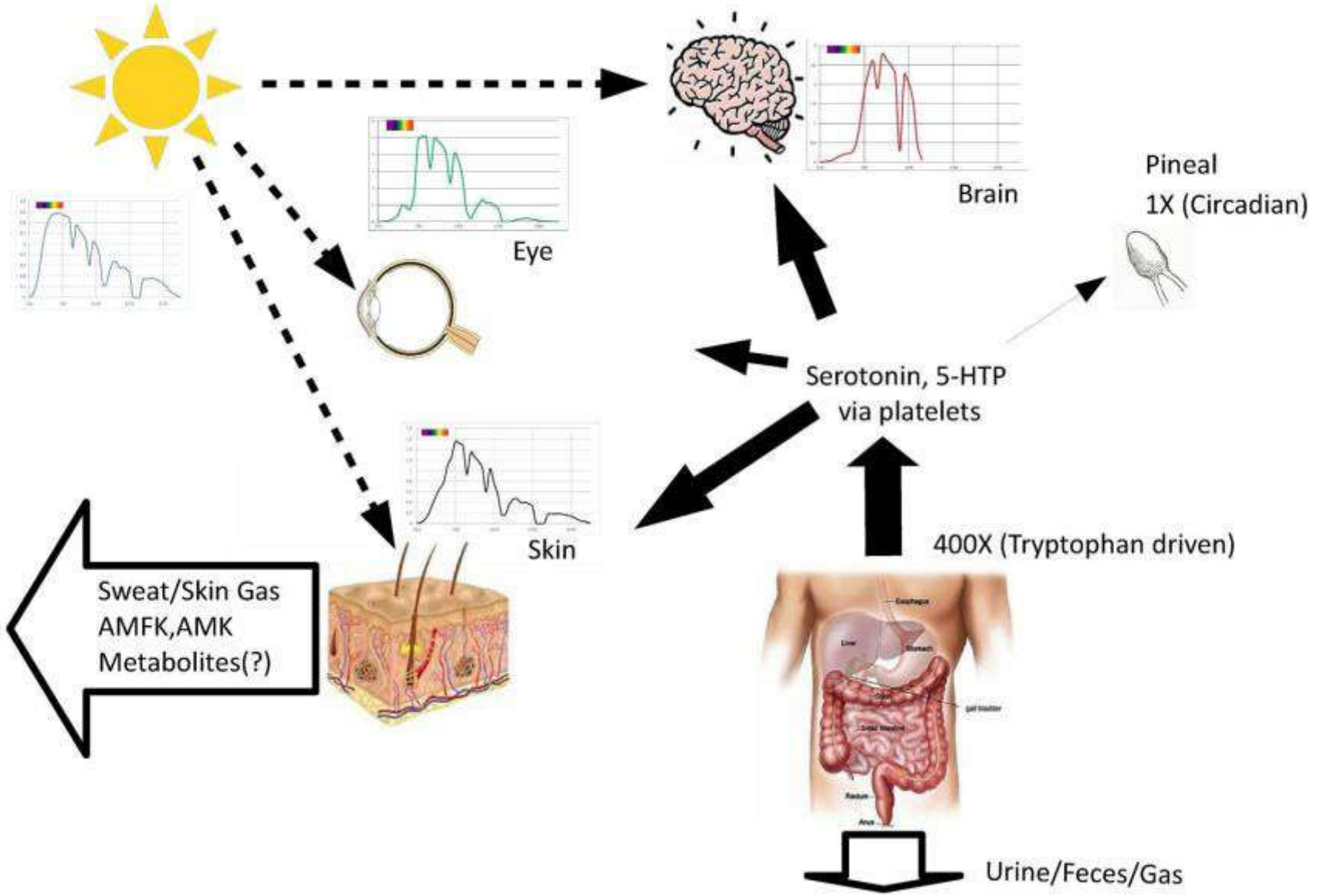

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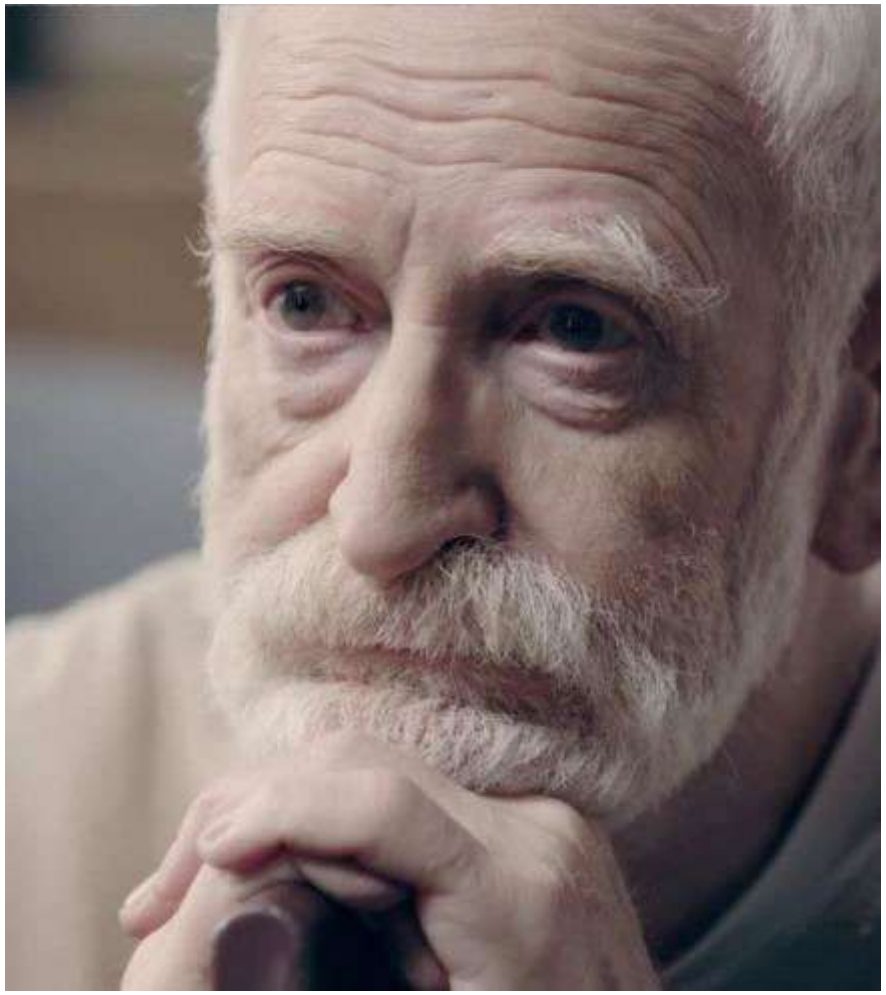

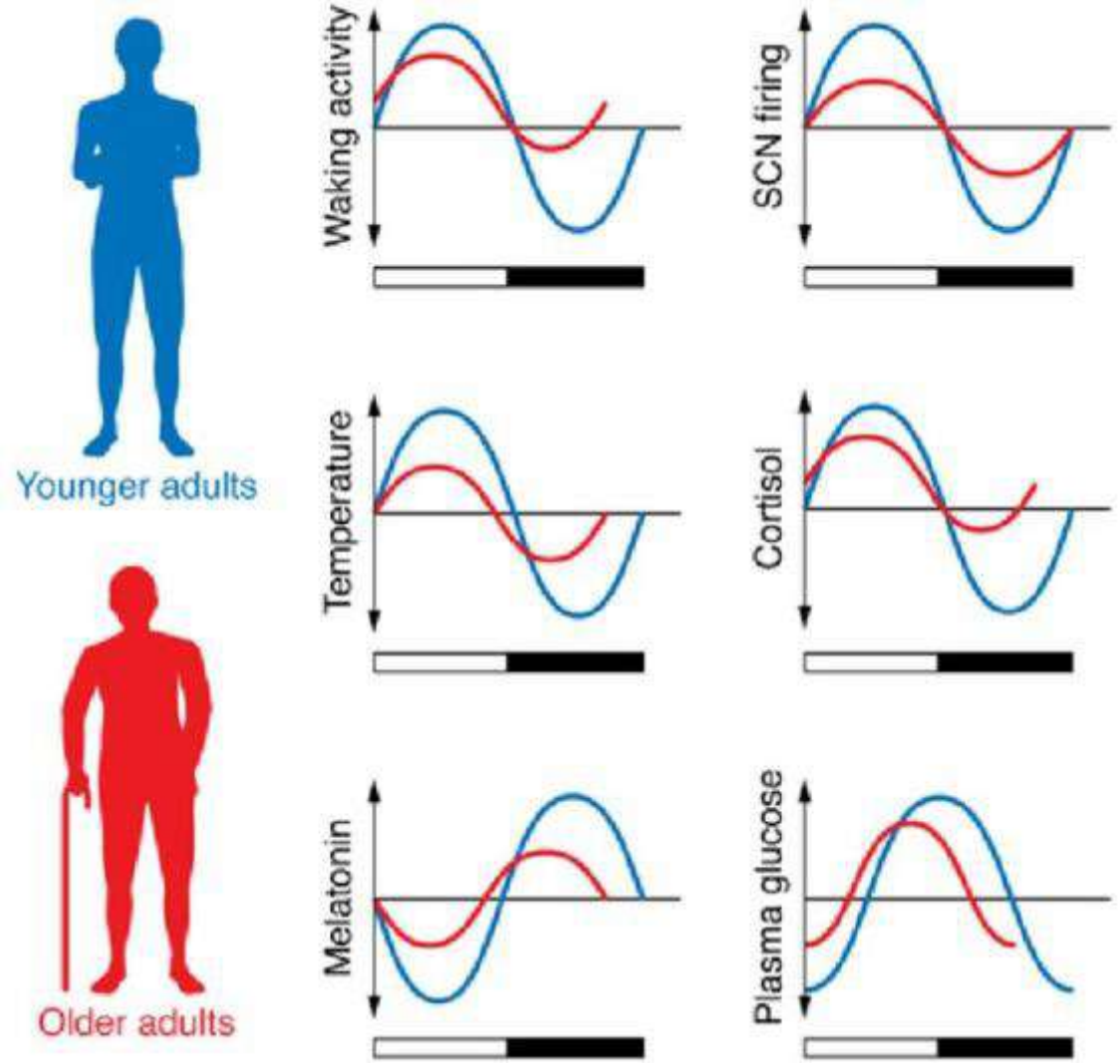

Hood, S., & Amir, S. (2017). The aging clock: Circadian rhythms and later life. *Journal of Clinical Investigation*, *127*, 437-446. https://doi.org/10.1172/JCI90328

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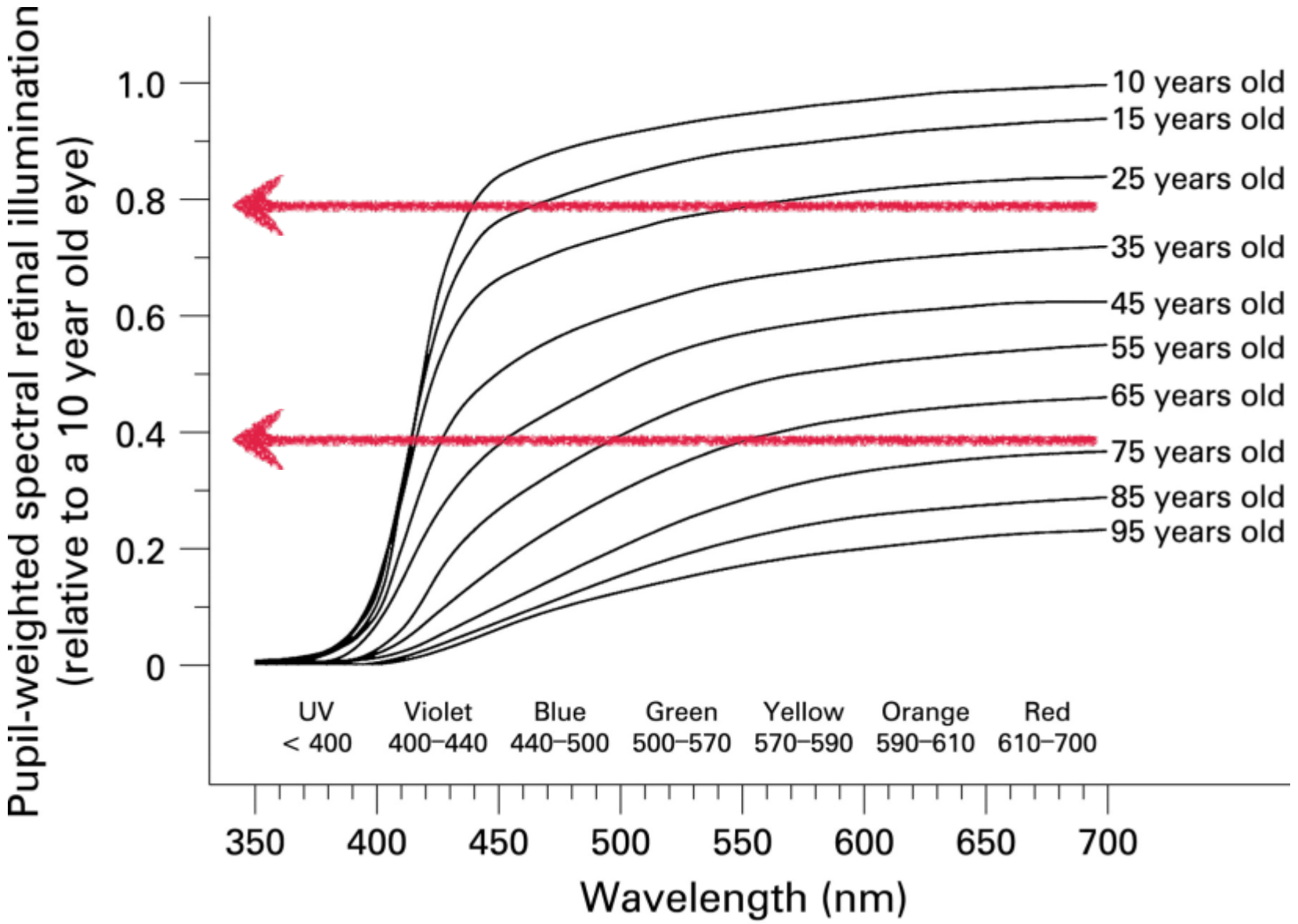
LENS TRANSMISSION



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https://sheilamccallan.files.wordpress.com/2015/02/screen-shot-2015-02-23-at-19-09-09.png

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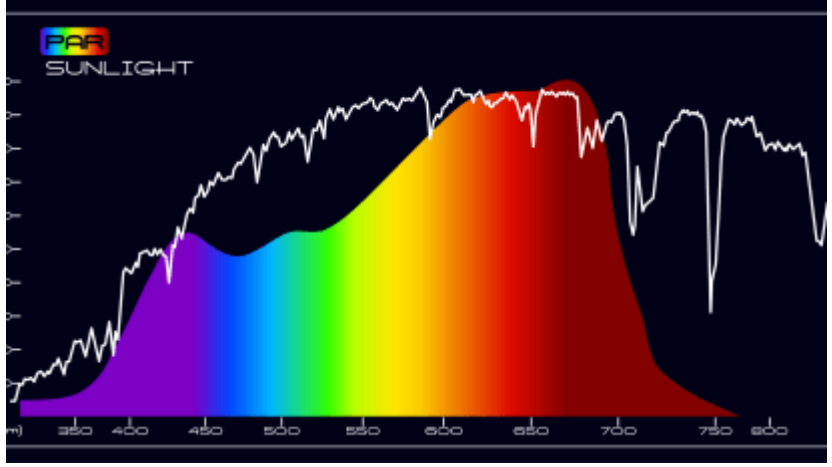
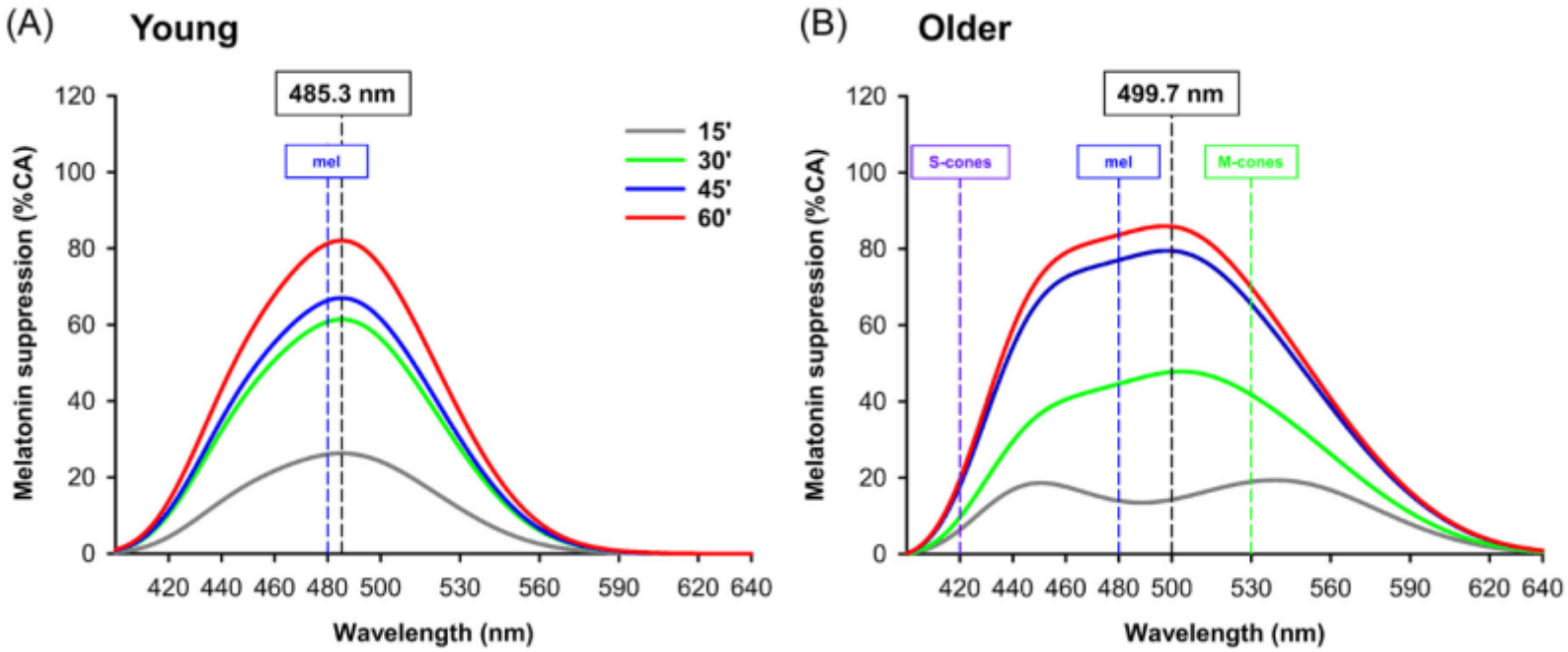
BUT CIRCADIAN RESPONSE IS CONSERVED…

"Healthy ageing is not always associated with reduced light sensitivity on neuroendocrine function…"

"Response to short wavelength light (>500nm) similar in young and old."

= a shift to the 'red'…





Najjar, R., Prayag, A., & Gronfier, C. (2024). Melatonin suppression by light involves different retinal photoreceptors in young and older adults. *Journal of Pineal Research*, *76*. https://doi.org/10.1111/jpi.12930 Chellappa, S. L. (2021). Aging, light sensitivity and circadian health. *Aging (Albany NY)*, *13*(24), 25604-25606. https://doi.org/10.18632/aging.203806
Najjar RP , et al. Aging of non-visual spectral sensitivity to light in humans: compensatory mechanisms? *PLoS One*. 2014;9(1):e85837.

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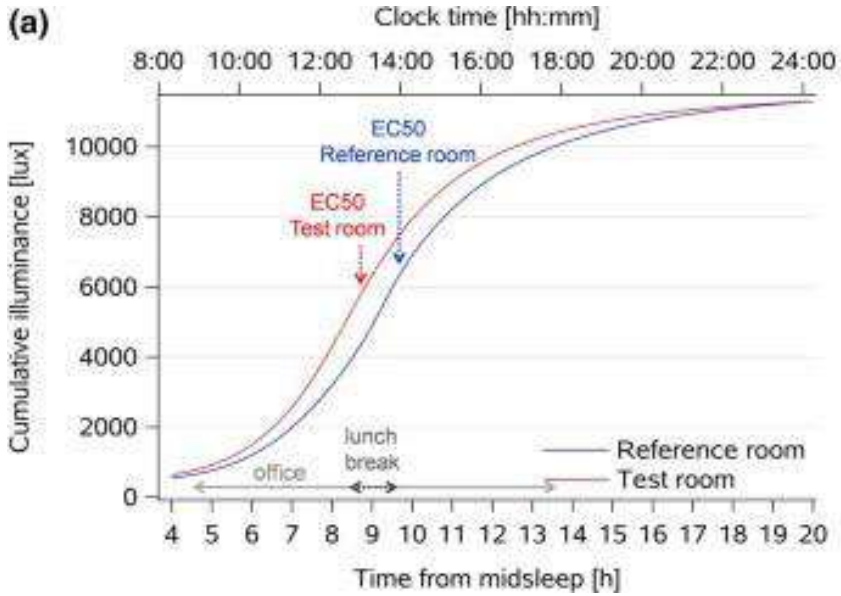
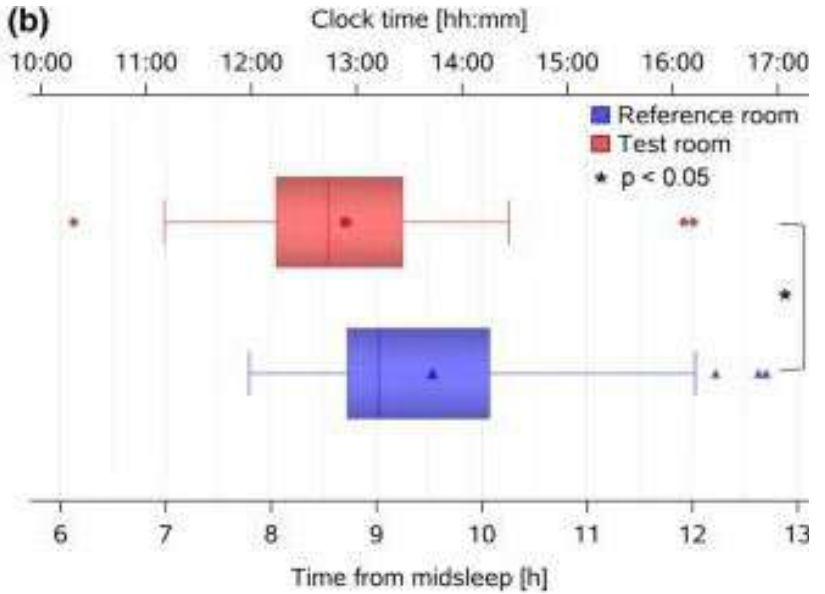
Impact of dynamic lighting

Optimized dynamic workplace lighting (windows and artificial light) ‘promote earlier melatonin onset and peripheral heat loss prior to bedtime.’





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Control room

Dynamic lighting

Significant increase in

- Peak melatonin concentration
- Cognitive performance after night work

Stable

- Physiological and behavioural rhythms
- Mood status

Nie, J., Zhou, T., Chen, Z. et al. The effects of dynamic daylight-like light on the rhythm, cognition, and mood of irregular shift workers in closed environment. Sci Rep 11, 13059 (2021). https://doi.org/10.1038/s41598-021-92438-y

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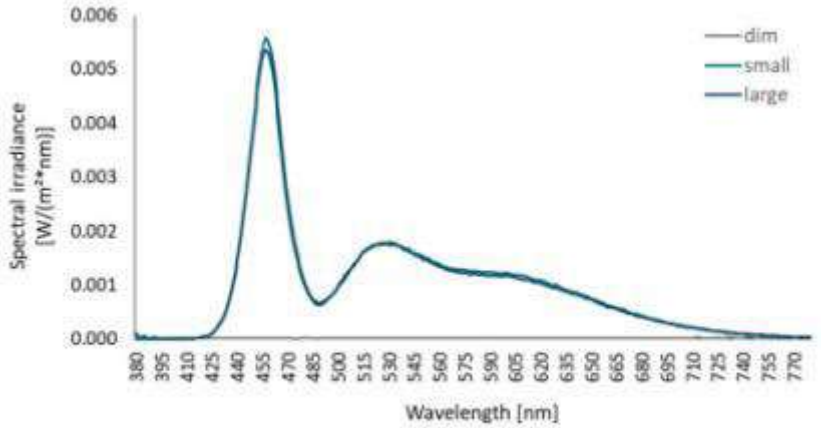
20% of crashes and fatalities involving long haul truck drivers occur between midnight and 6m, peak driver fatigue.

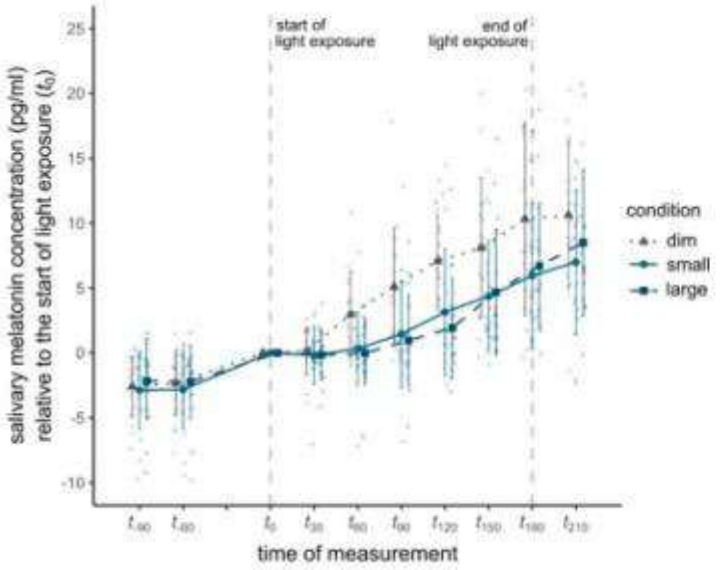
30 minutes of blue-enriched light
Suppressed melatonin
Improved subjective sleepiness.



(a)

(a)

(b)



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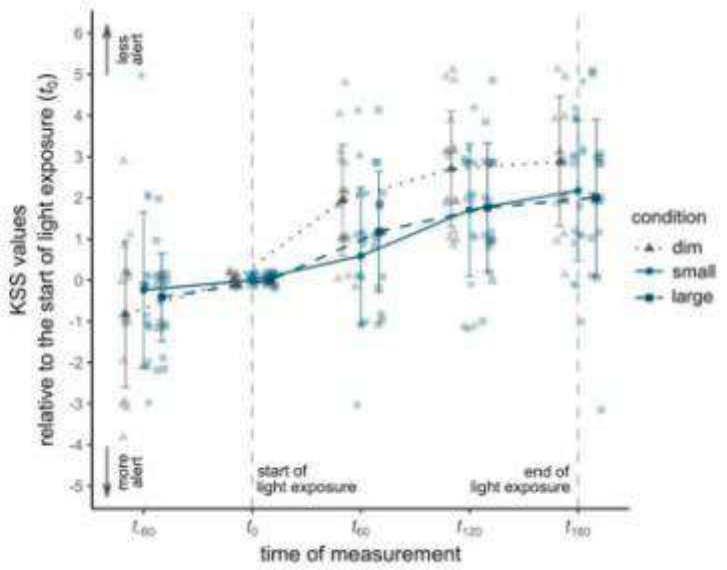

(b)

Weng, M., Schöllhorn, I., Kazhura, M., Cardini, B. B., & Stefani, O. [illegible] Light Exposures with Different Solid Angles on Circadian Melatonin Rhythms, Alertness, and Visual Comfort in an Automotive Setting. *Clocks Sleep*, *4*(4), 607-622. https://doi.org/10.3390/clockssleep4040047

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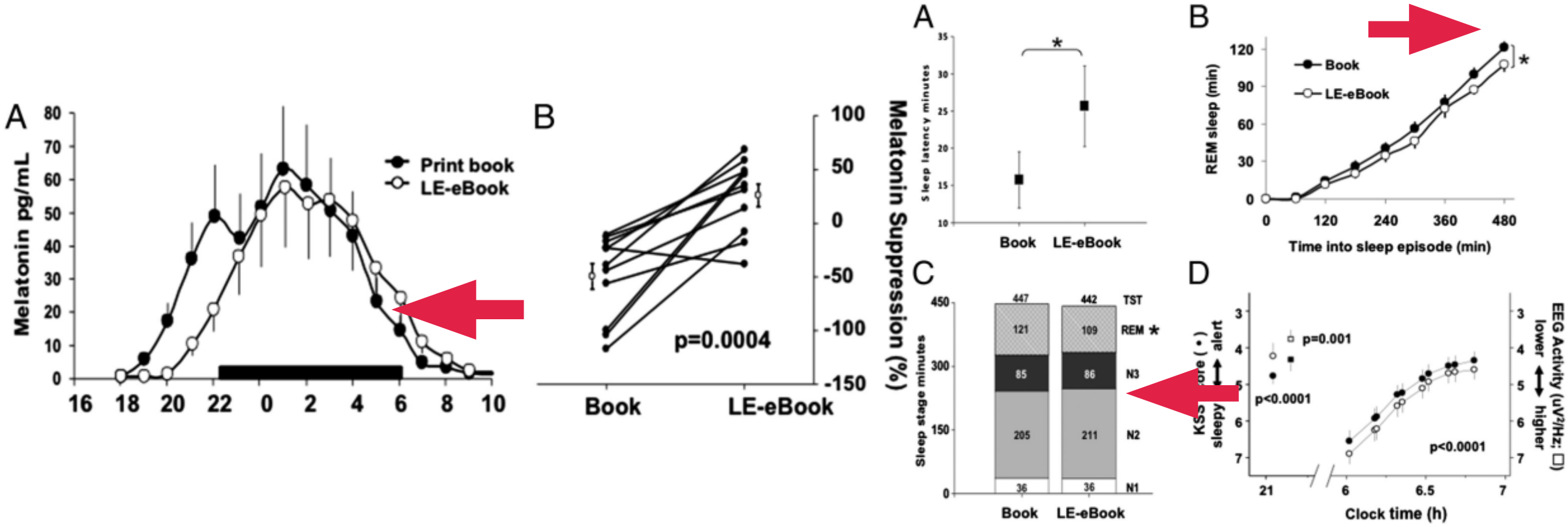

Chang, A.-M., Aeschbach, D., Duffy, J.F., Czeisler, C.A., 2015. Evening use of light-emitting eReaders negatively affects sleep, circadian timing, and next-morning alertness. Proceedings of the National Academy of Sciences 112, 1232–1237..
https://doi.org/10.1073/pnas.1418490112

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Original Article

Two hours of evening reading on a self-luminous tablet vs. reading a physical book does not alter sleep after daytime bright light exposure

Frida H. Rångtell [a], Emelie Ekstrand [a], Linnea Rapp [a], Anna Lagermalm [a], Lisanne Liethof [a], Marcela Olaya Búcaro [a], David Lingfors [b], Jan-Erik Broman [a], Helgi B. Schiöth [a], Christian Benedict [a]

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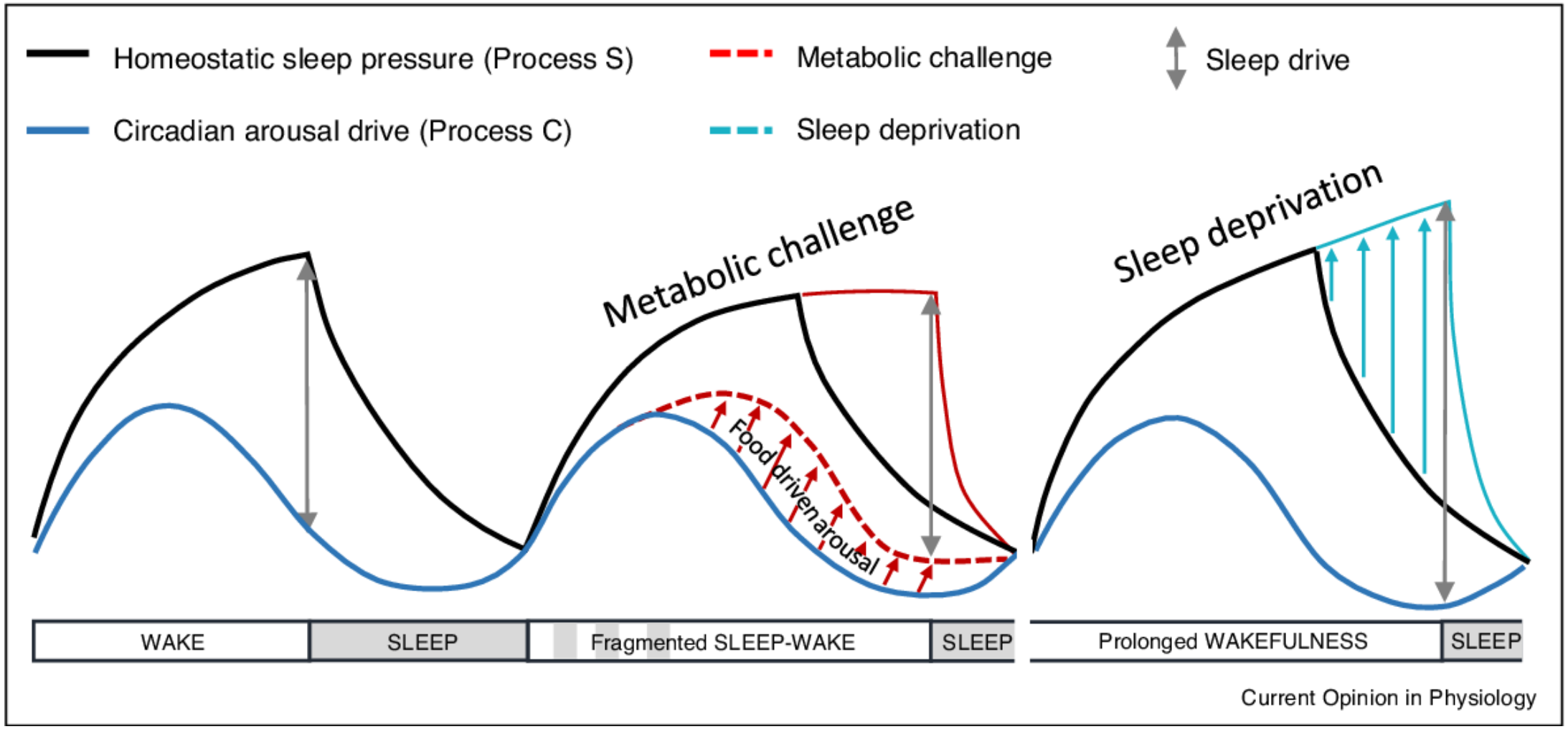
Highlights

- Evening reading on a tablet for two hours did not alter saliva melatonin levels.
- Sleepiness, sleep onset latency, as well as sleep composition remained unaffected.
- Tablet reading did not impact power spectral density during slow-wave sleep.

Rångtell, F. H., Ekstrand, E., Rapp, L., Lagermalm, A., Liethof, L., Búcaro, M. O., Lingfors, D., Broman, J.-E., Schiöth, H. B., & Benedict, C. (2016). Two hours of evening reading on a self-luminous tablet vs. reading a physical book does not alter sleep after daytime bright light exposure. Sleep Medicine, 23, 111-118. https://doi.org/https://doi.org/10.1016/j.sleep.2016.06.016



Northeast, R. C., Vyazovskiy, V. V., & Bechtold, D. A. (2020). Eat, sleep, repeat: the role of the circadian system in balancing sleep–wake control with metabolic need. *Current Opinion in Physiology*, *15*, 183 - 191.

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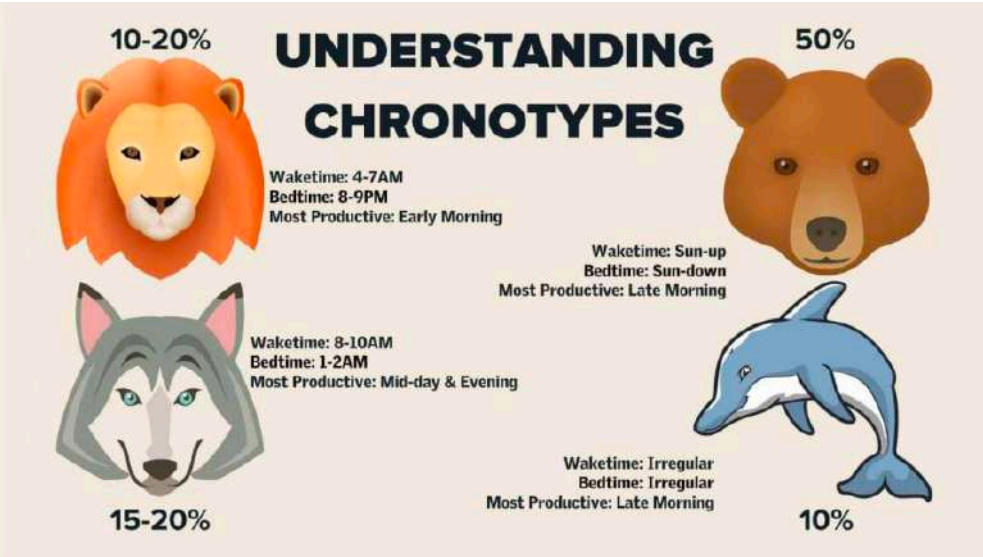

Learning Outcome 3

KNOW THE ROLE OF NON-VISUAL PHOTIC INPUTS, ENVIRONMENTAL, GENETIC AND CULTURAL CUES IN CIRCADIAN ENTRAINMENT AND MOOD REGULATION SO THAT PARTICIPANTS CAN CONTRIBUTE MORE EFFECTIVELY TO SUSTAINABLE INTERDISCIPLINARY DESIGN SOLUTIONS

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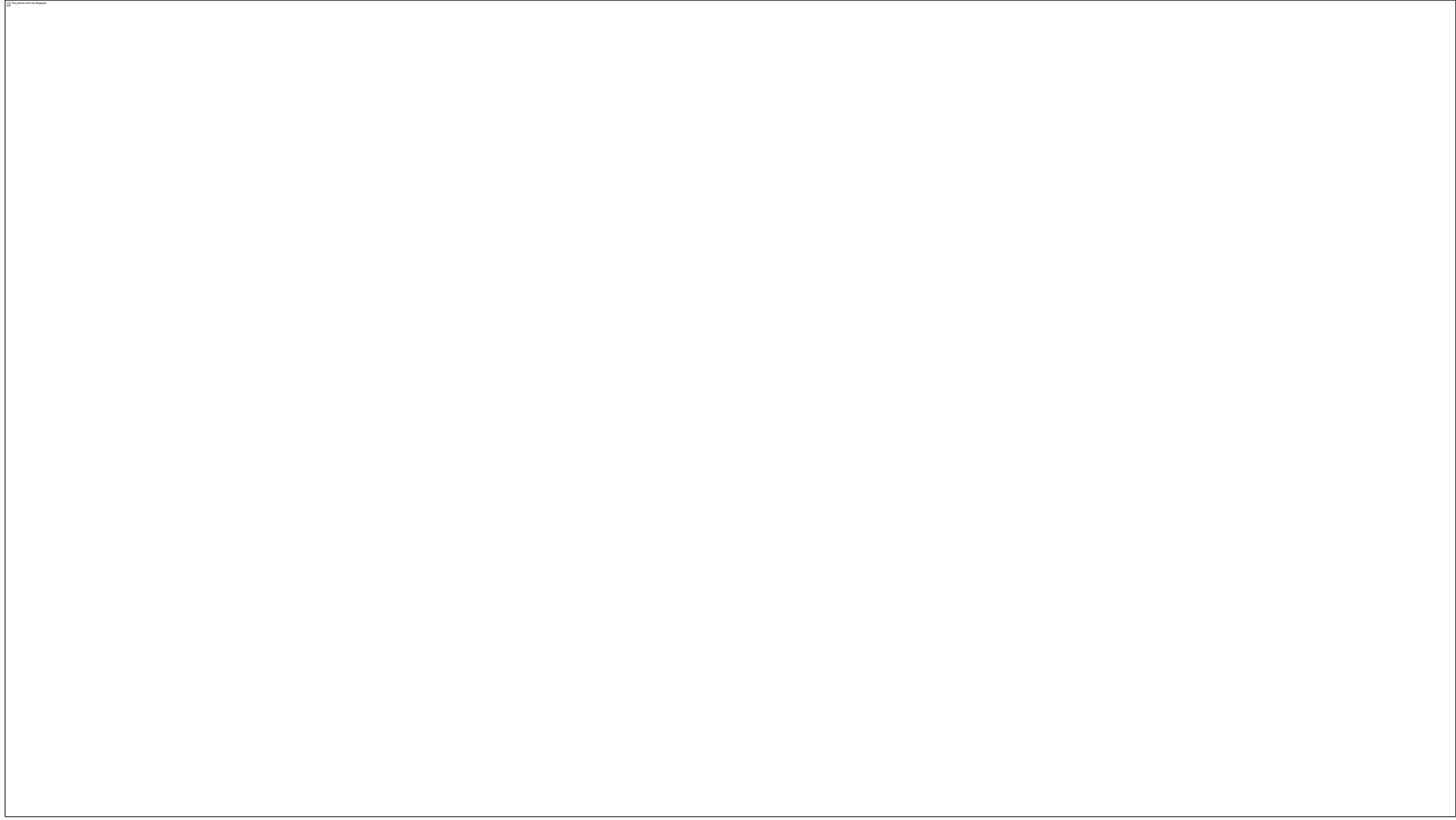
Chronotype and light sensitivity

ncreased risk of physical and
health conditions



Partonen, T. Chronotype and Health Outcomes. Curr Sleep Medicine Rep 1, 205–211 (2015). https://doi.org/10.1007/s40675-015-0022-z

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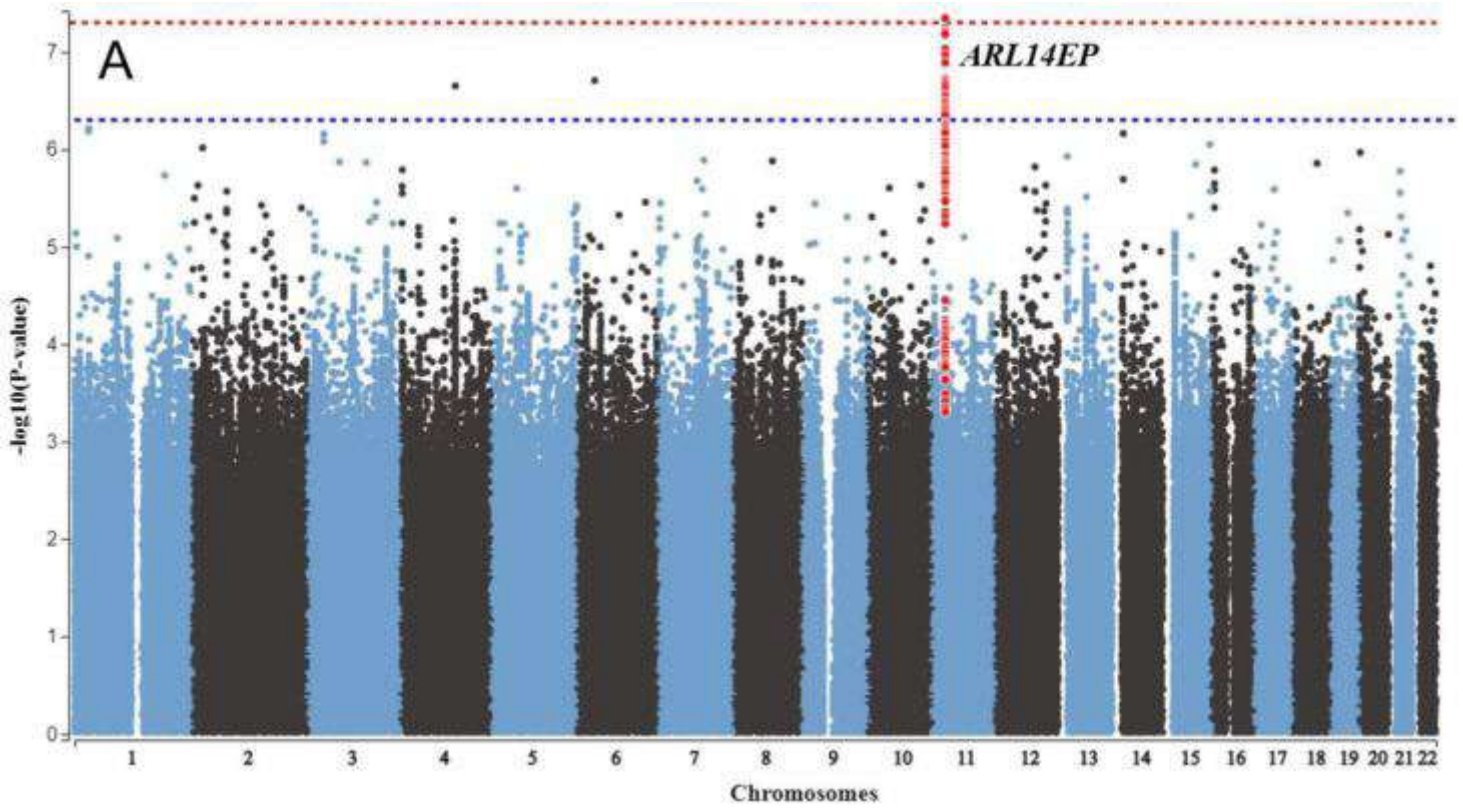

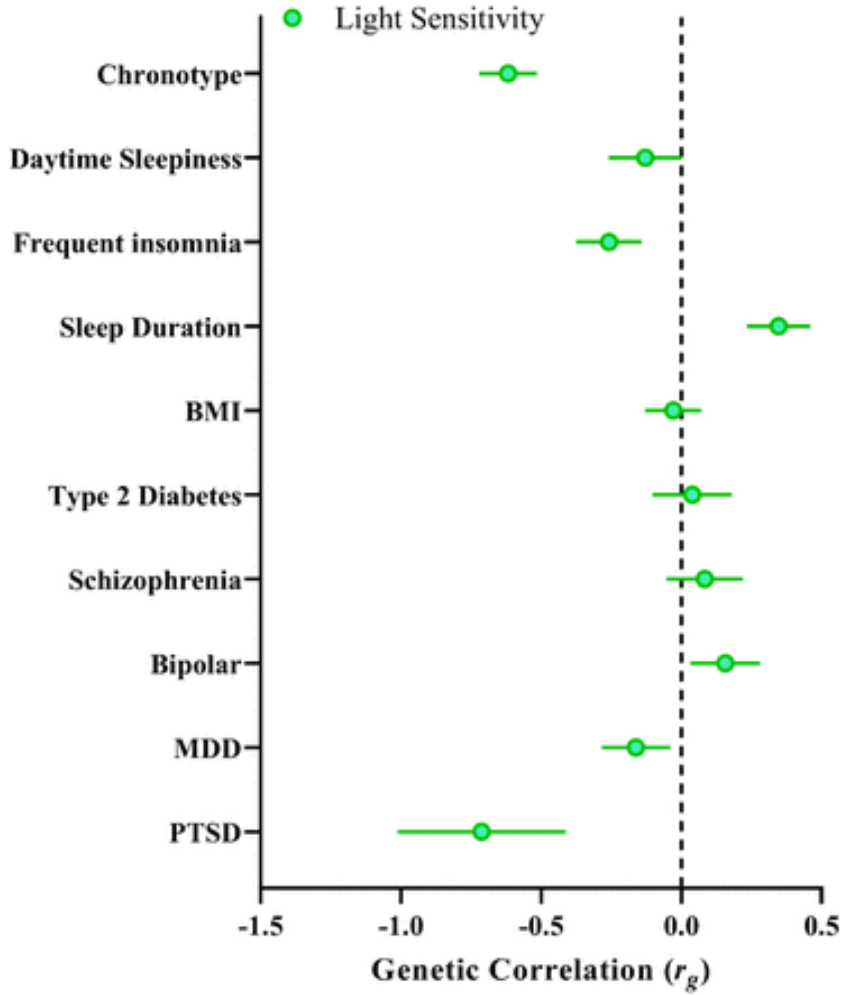

Burns, A. C., Phillips, A. J. K., Rutter, M. K., Saxena, R., Cain, S. W., & Lane, J. M. (2022). Genome-wide gene by environment study of time spent in daylight and chronotype identifies emerging genetic architecture underlying light sensitivity. *Sleep*, *46*(3). https://doi.org/10.1093/sleep/zsac287

Kalmbach, D. A., Schneider, L. D., Cheung, J., Bertrand, S. J., Kariharan, T., Pack, A. I., & Gehrman, P. R. (2017). Genetic Basis of Chronotype in Humans: Insights From Three Landmark GWAS. Sleep, 40(2). https://doi.org/10.1093/sleep/zsw048

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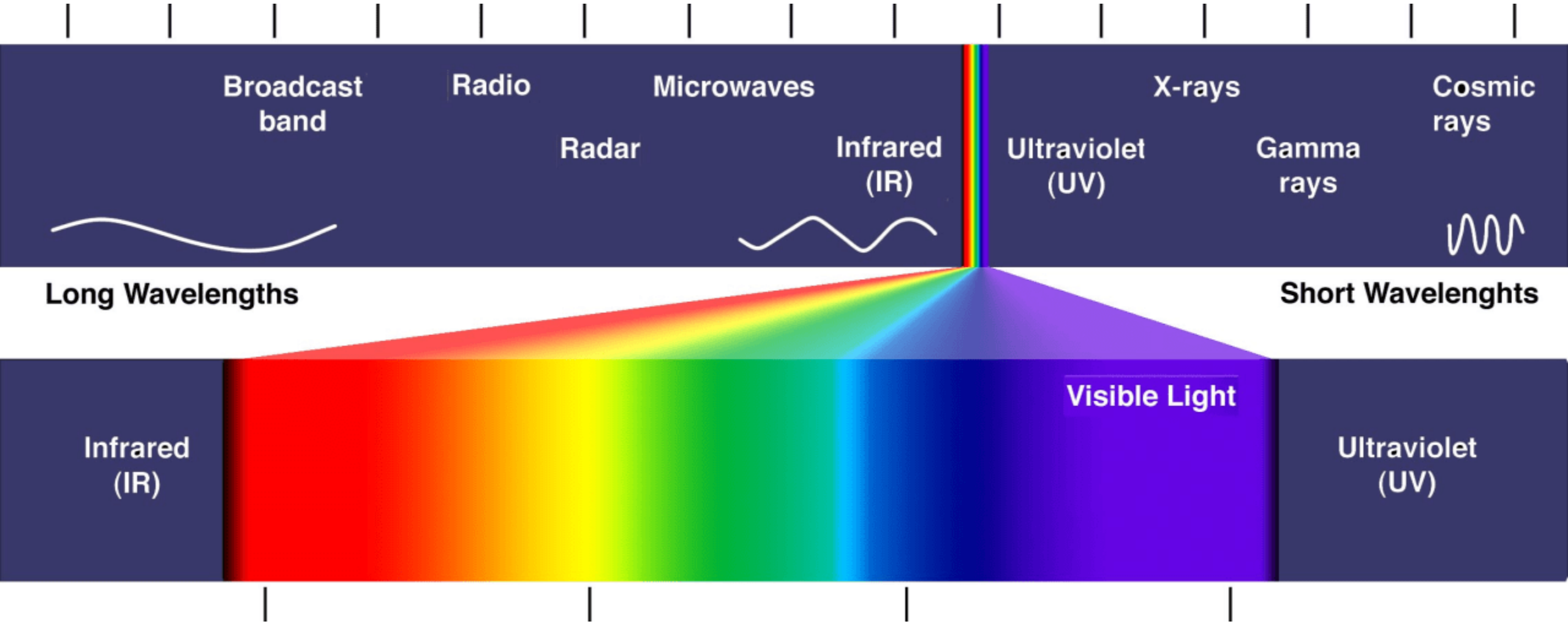

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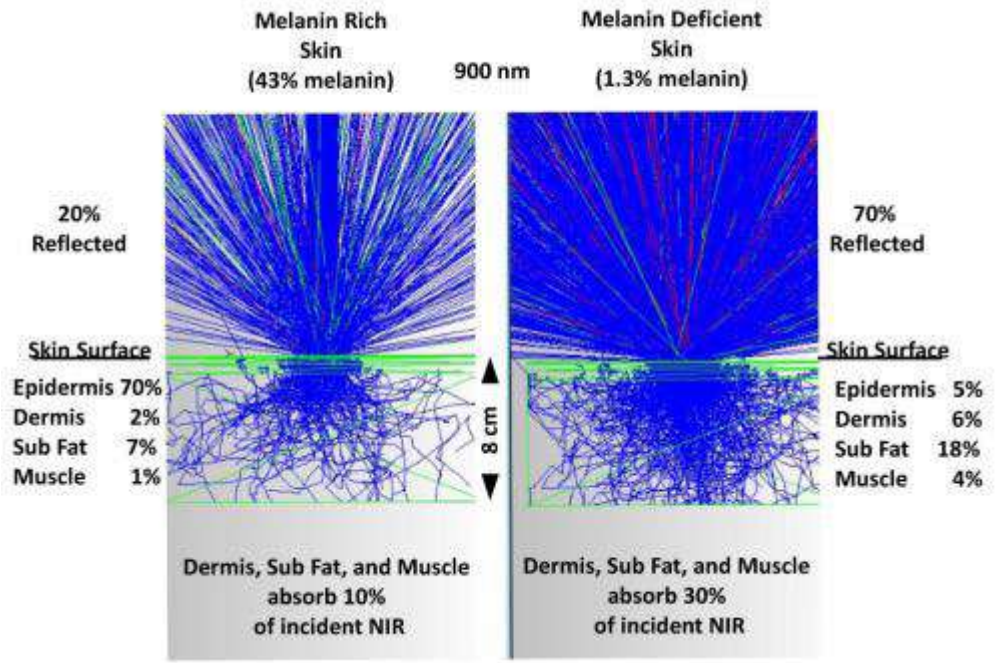
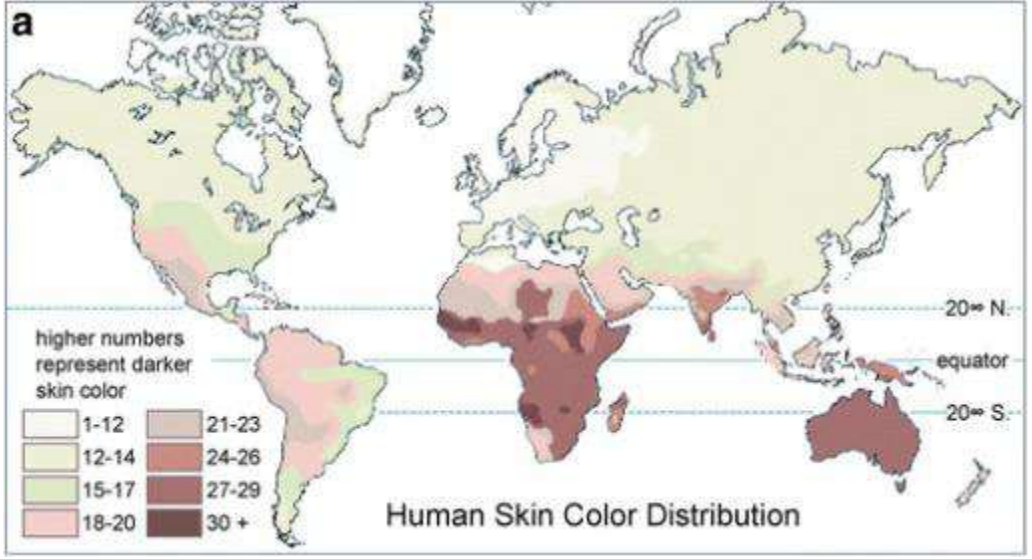
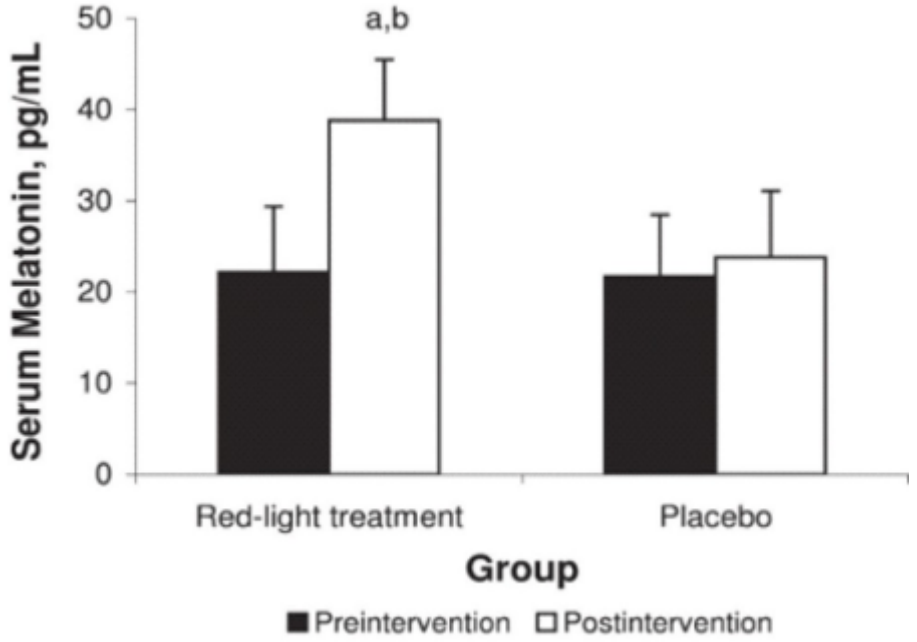
INFRA-RED

670 nm full body (eyes covered)
20 minutes each night for 14 days
Absorption depends on skin colour







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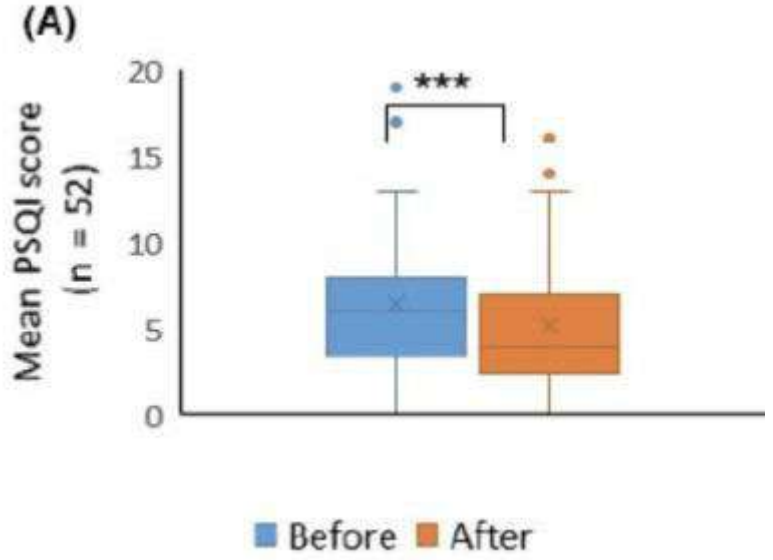
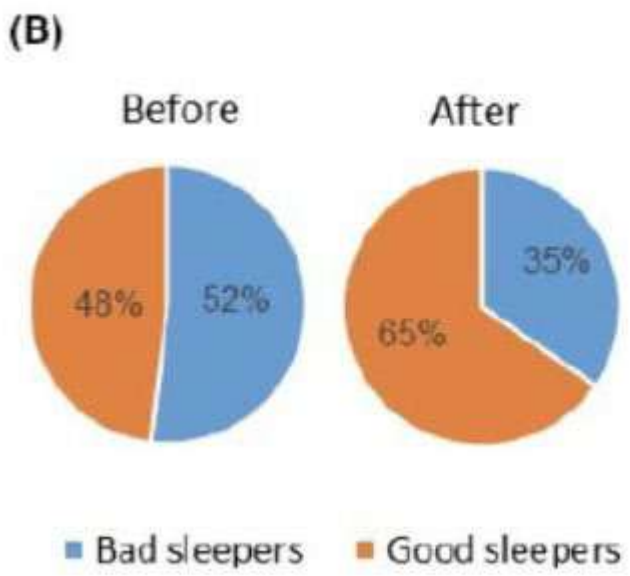
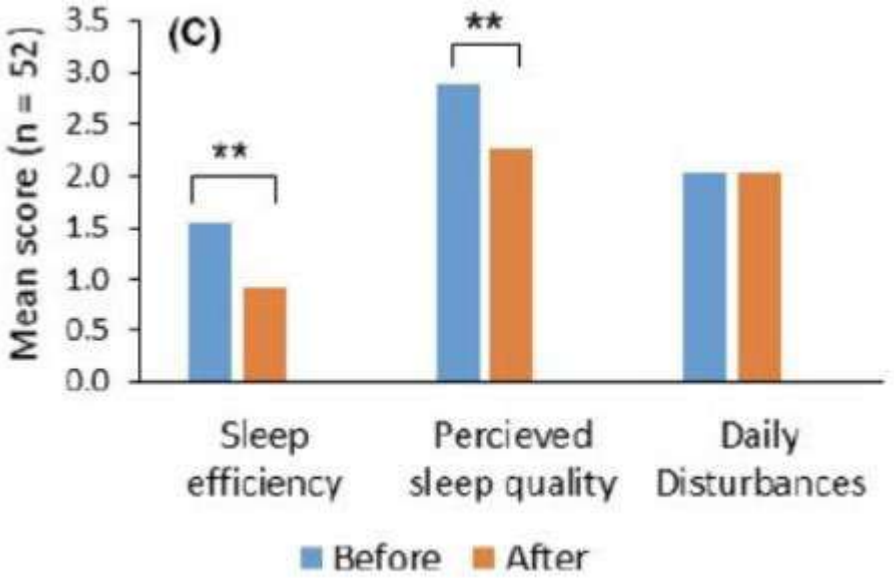
Ultra-violet

4 weeks, narrowband UVB treatment boosted sleep and mood.







Ilan, V., Barzilai, A., Sharon, B., Ohana, O., Pavlotsky, F., & Greenberger, S. (2020). The effect of narrow-band ultraviolet B radiation on sleep, happiness, and appetite: A prospective cohort study. *Photodermatology, Photoimmunology & Photomedicine*, *37*. https://doi.org/10.1111/phpp.12648

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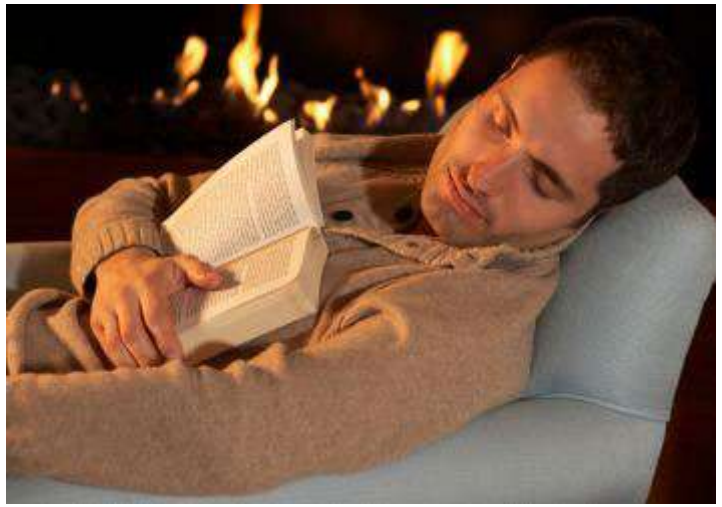
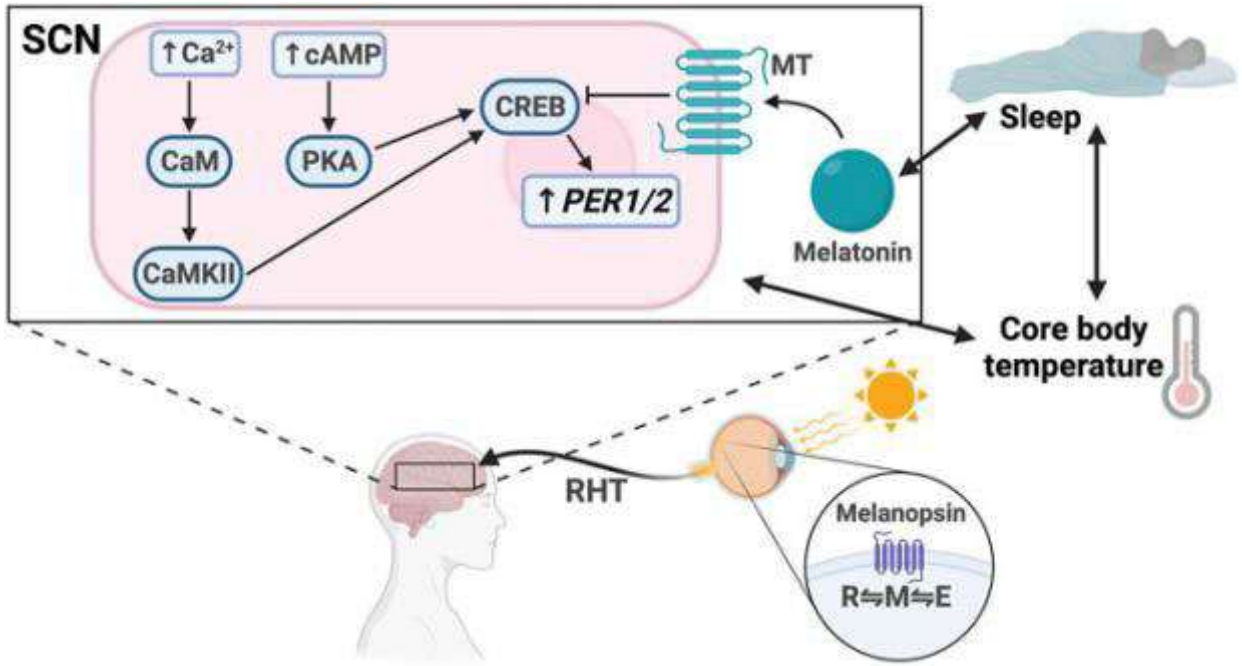
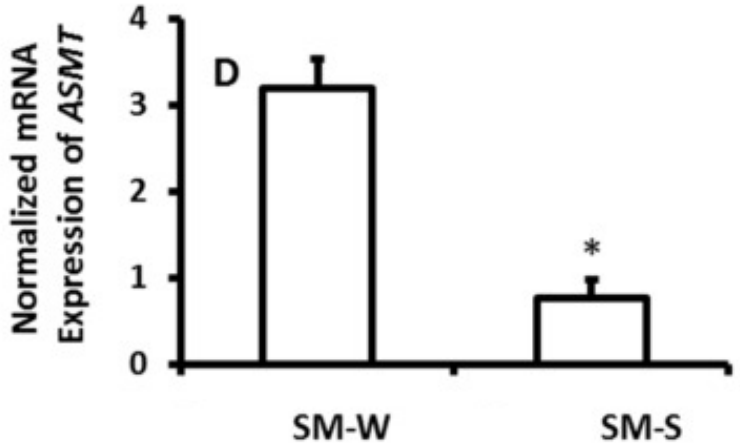
EFFECT OF TEMPERATURE

Higher melatonin expression as core temperature falls







Healy, K. L., Morris, A. R., & Liu, A. C. (2021). Circadian Synchrony: Sleep, Nutrition, and Physical Activity. *Front Netw Physiol*, *1*. https://doi.org/10.3389/fnetp.2021.732243

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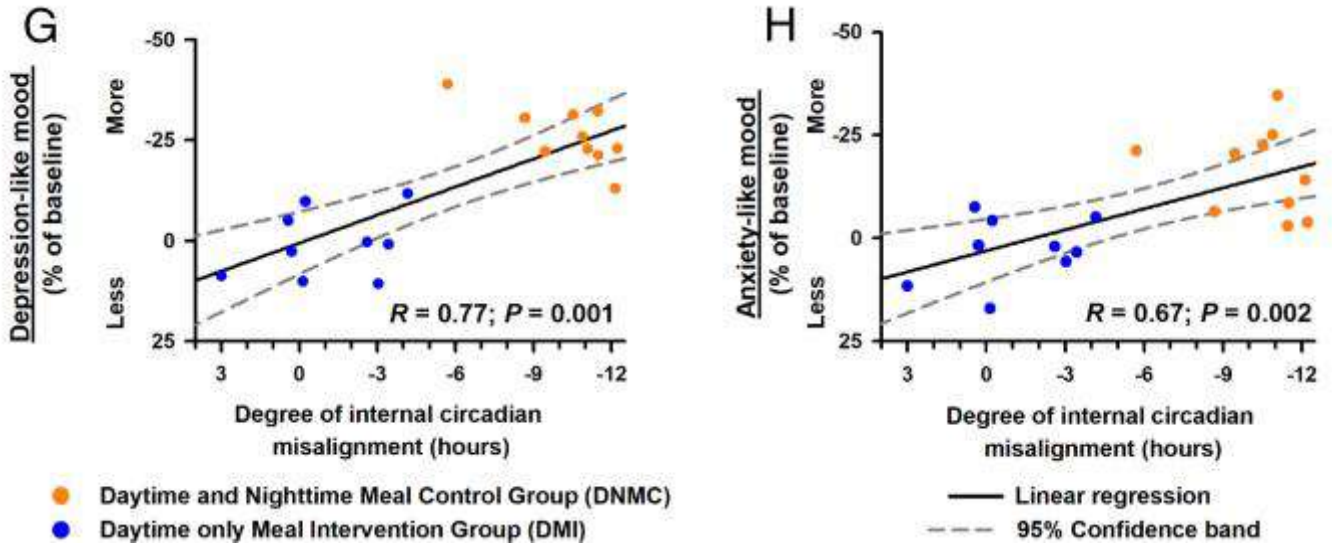
Bidirectional relationship with meal timing, melatonin regulation and mental health



Qian, J., Vujovic, N., Nguyen, H., Rahman, N., Heng, S. W., Amira, S., Scheer, F. A. J. L., & Chellappa, S. L. (2022). Daytime eating prevents mood vulnerability in night work. *Proceedings of the National Academy of Sciences*, *119*(38), e2206348119. https://doi.org/doi:10.1073/pnas.2206348119

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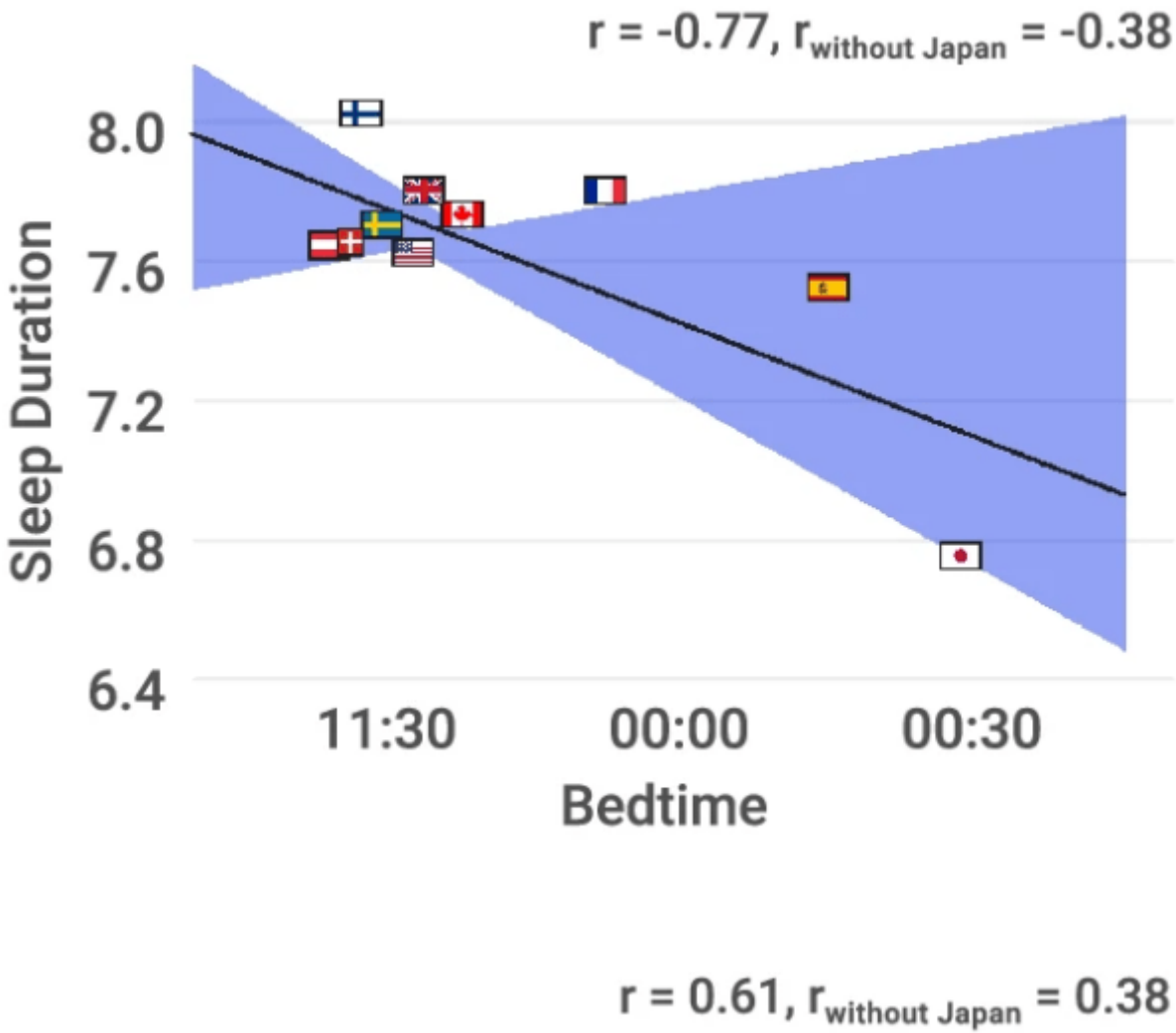
Role of culture

’55% of the variation in sleep quality, and 63% in sleep quantity, are explained by societal factors’



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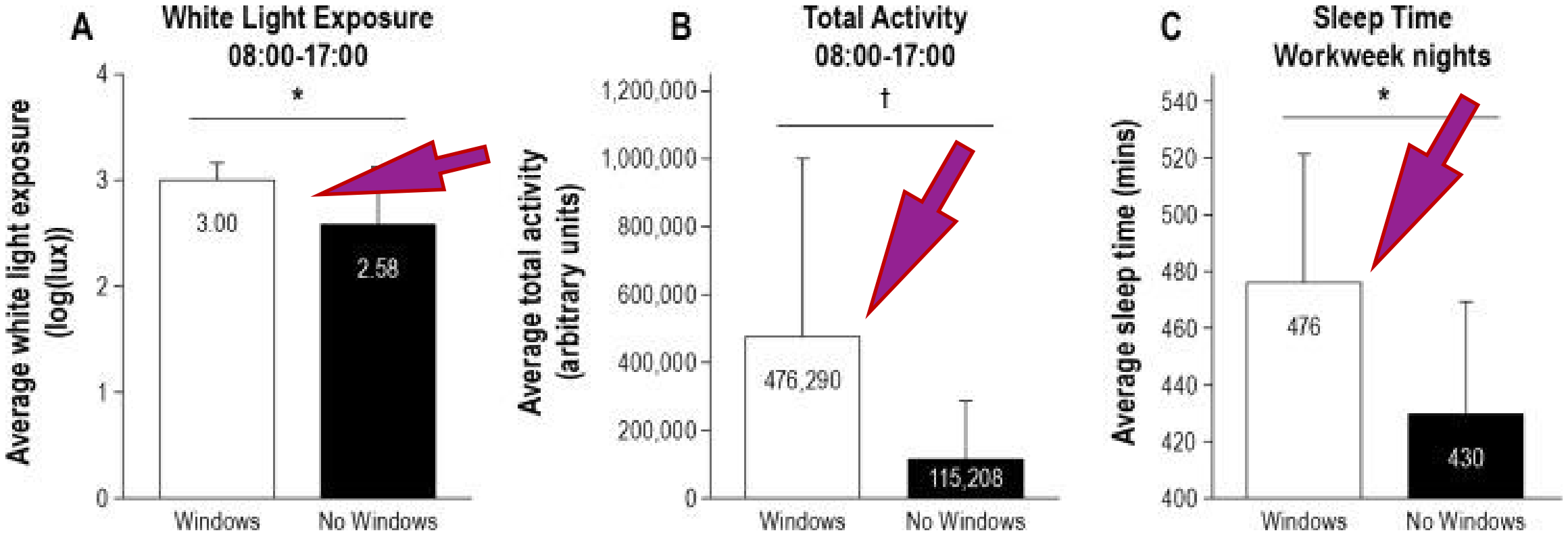
Learning Outcome 4

KNOW HOW THESE PRINCIPLES OFFER A FRAMEWORK FOR 'INTEGRATIVE' LIGHTING DESIGN IN THREE KEY SECTORS: HEALTHCARE, EDUCATION AND SOCIAL HOUSING SO THAT PARTICIPANTS CAN UNDERSTAND THE IMPLICATIONS OF THIS UNDERSTANDING FOR THEIR OWN PRACTICE.

Windows v. No windows…



Boubekri, M., Cheung, I. N., Reid, K. J., Wang, C. H., & Zee, P. C. (2014). Impact of windows and daylight exposure on overall health and sleep quality of office workers: a case-control pilot study. J Clin Sleep Med, 10(6), 603-611. https://doi.org/10.5664/jcsm.3780

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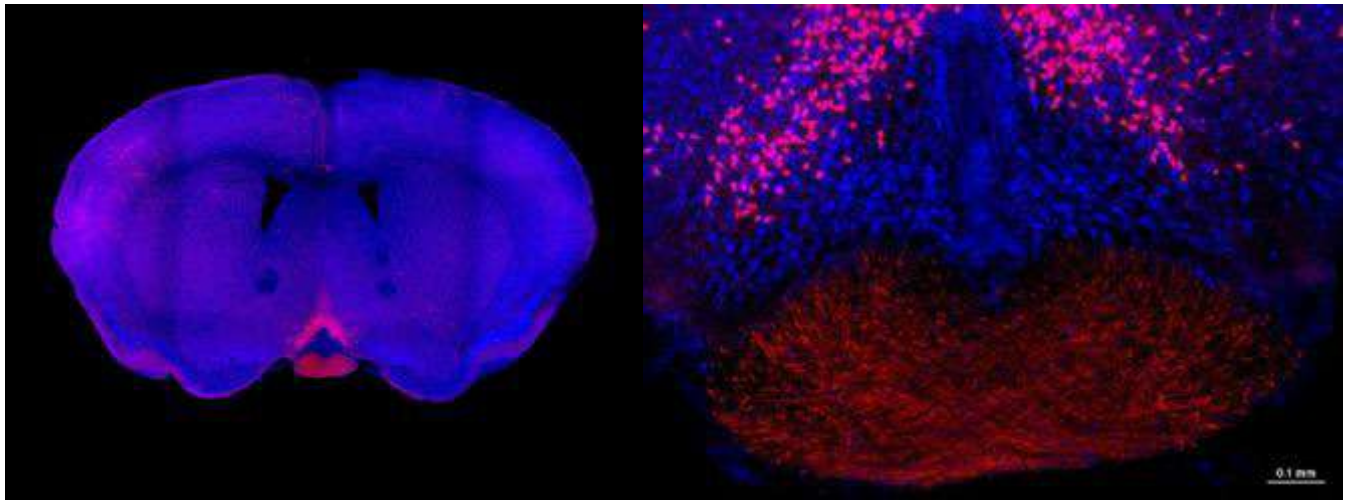
Neonatal units

“ …improved oxygen saturation and heart rate stability, and establishment of a daily melatonin rhythm”



Santos J, Pearce SE, Stroustrup A. Impact of hospital-based environmental exposures on neurodevelopmental outcomes of preterm infants. Curr Opin Pediatr. 2015 Apr;27(2):254-60. doi: 10.1097/MOP.0000000000000190. PMID: 25635585; PMCID: PMC4410011.

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Residential Care: Falls reduced by 43%



Maple Ridge CARE CENTER

BRIGHAM AND WOMEN'S HOSPITAL | HARVARD MEDICAL SCHOOL

Impact of Upgraded Lighting on Falls in Care Home ResidentsGrant, Leilah K. et al.Journal of the American Medical Directors Association, July 15, 2022 DOI:https://doi.org/10.1016/j.jamda.2022.06.013

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GGzE

TILBURG UNIVERSITY

Residential Care…

Nighttime wandering - 11 to 5 times

Daytime naps - 16 to 7 times

Time out of bed- 180 to 104 min

Night time sleep - 408 to 495 min

Ellen van Lieshout-van Dal, Liselore Snaphaan, Inge Bongers, Biodynamic lighting effects on the sleep pattern of people with dementia,, Volume 150, 2019, Pages 245-253, ISSN 0360-1323, https://doi.org/10.1016/j.buildenv.2019.01.010. (https://www.sciencedirect.com/science/article/pii/S0360132319300101)

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“They’re just not so agitated now… it’s easier to communicate”

Staff member, WCS Care

“Before the circadian lighting, we had a lot of night time agitation among the residents. But since the installation, it’s progressively become calmer.”

Schledermann, Kathrine & Hansen, Torben & Bjørner, Thomas. (2022). Perceived visual comfort and usefulness of a circadian lighting system implemented at a nursing home. Multimedia Tools and Applications. 1-17. 10.1007/s11042-022-13364-3.

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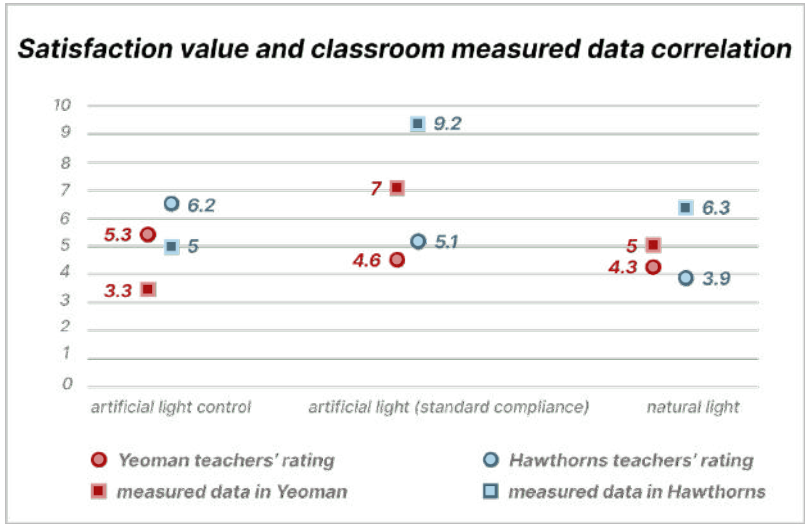
SEND Conference

8 February 2023 | Science Gallery London



Haverstock

NOVIUN ARCHITECTS

The Hawthorns

celebrating diverse abilities

Yeoman Park ACADEMY

UCL

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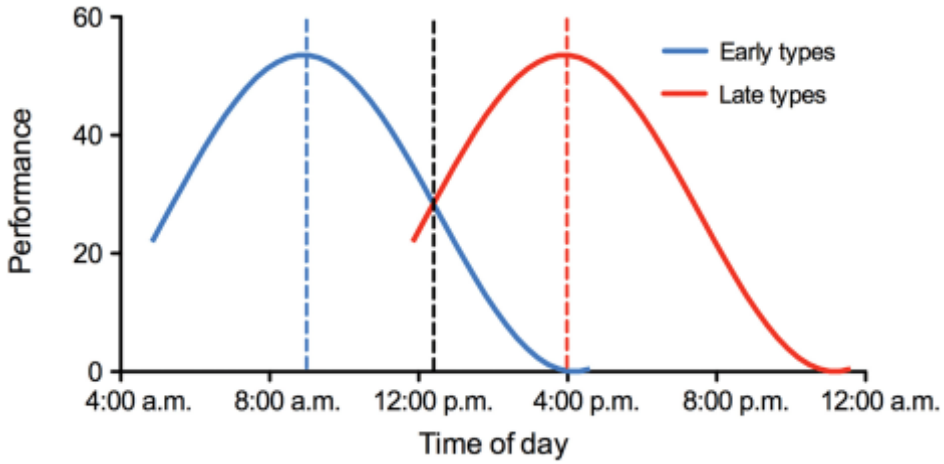

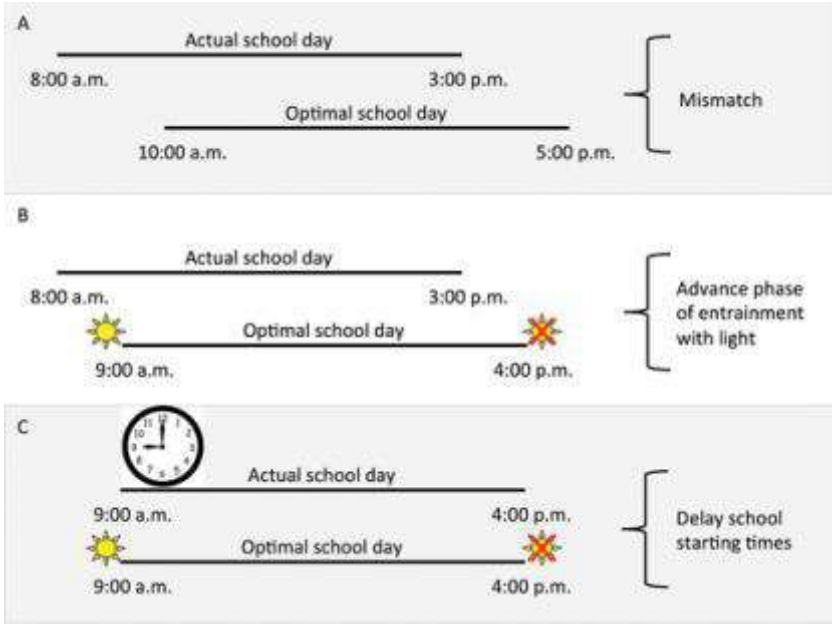

Zerbini, G., & Merrow, M. (2017). Time to learn: How chronotype impacts education. *PsyCh Journal*, *6*(4), 263-276. https://doi.org/https://doi.org/10.1002/pchj.178
Gasperetti CE, Dolsen EA, Harvey AG. The influence of intensity and timing of daily light exposure on subjective and objective sleep in adolescents with an evening circadian preference. Sleep Med. 2021 Mar;79:166-174. doi: 10.1016/j.sleep.2020.11.014. Epub 2020 Nov 16. PMID: 33262011; PMCID: PMC7925365.

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There were significant correlations between colour temperature of light and DLMO …

although no significant correlations were found between illuminance level and DLMO…

high color temperature light at home might be a cause of the delay of circadian phase in adults and children

Westwood, E., Smith, S., Mann, D., Pattinson, C., Allan, A., & Staton, S. (2023). The effects of light in children: A systematic review. *Journal of Environmental Psychology*, *89*, 102062. https://doi.org/https://doi.org/10.1016/j.jenvp.2023.102062
Higuchi, S., Lee, S.-i., Kozaki, T., Harada, T., & Tanaka, I. (2016). Late circadian phase in adults and children is correlated with use of high color temperature light at home at night. *Chronobiology international*, *33*(4), 448-452. https://doi.org/10.3109/07420528.2016.1152978

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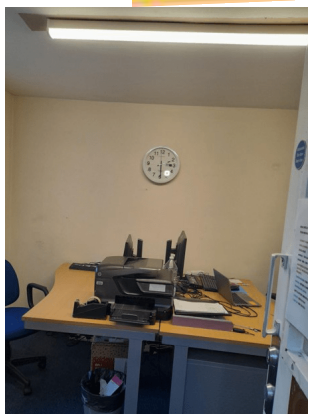
Housing Association

SPEIRS MAJOR

Royal College of Art
DESIGN AGE INSTITUTE

CLARION HOUSING



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… measured content of -83% to +478% of the labeled melatonin dose.

…variability in content within the same product of up to 465%.[45]

…pharmacologically active contaminant, serotonin, in eight of the supplements.

Tuft, C., Matar, E., Menczel Schrire, Z., Grunstein, R. R., Yee, B. J., & Hoyos, C. M. (2023). Current Insights into the Risks of Using Melatonin as a Treatment for Sleep Disorders in Older Adults. *Clin Interv Aging*, *18*, 49-59. https://doi.org/10.2147/cia.S361519

…due diligence should be exercised during prescribing with regard to related comorbidities, such as in those with liver disease and at risk of labile blood pressure or falls.

Reference

Summary

1. Origins of melatonin and history of discovery
2. New evidence challenging simplistic paradigm
3. New evidence for complex interaction of nature and nurture
4. Implications for the future of our profession

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Thank you!
Questions?
Do get in touch - shelley@ageoflightinnovations.com