How does light affect human health? From biology to application

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TUMCREATE | Principal Investigator
Max Planck Institute for Biological Cybernetics | Research Group Leader

16 May 2025

International Day of Light

TRANSLATIONAL SENSORY & CIRCADIAN NEUROSCIENCE UNIT

Acknowledgements

Funding and support

Our international team works on understanding how light impacts human physiology and behaviour

MAX PLANCK INSTITUTE FOR BIOLOGICAL CYBERNETICS

TUMCREATE

Technical University of Munich

Maydel Fernandez-Alonso (Postdoc)
Marie Luise Schreiter (Postdoc)
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Carolina Guidolin (PhD student)
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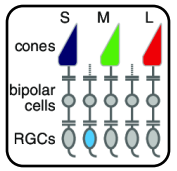
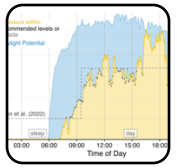


Mechanisms underlying non-visual photoreception



Real-world light exposure and effects

Behavioural and technological interventions

Ecosystem development

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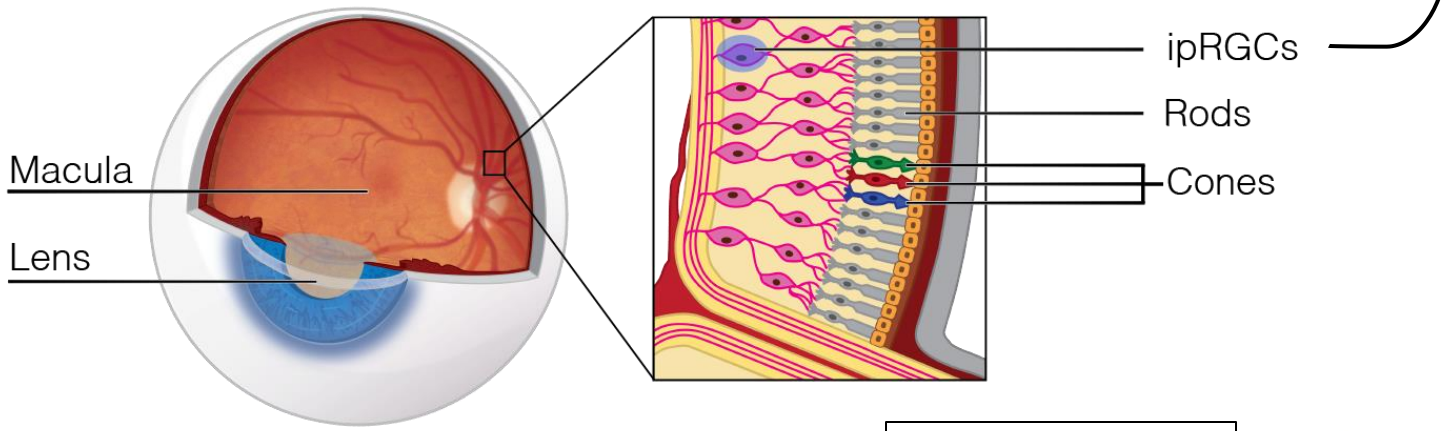
https://tscnlab.org/

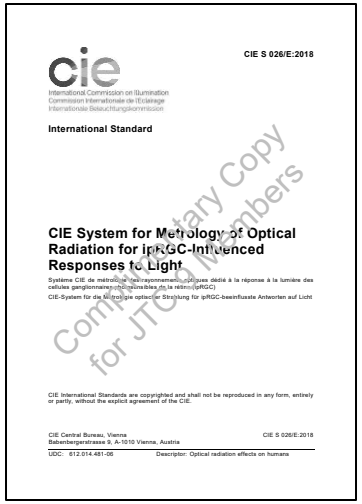
Over the last 20+ years, our understanding of the human retina has changed significantly

intrinsically photosensitive retinal ganglion cells expressing *melanopsin*



Provencio et al. (1998, 2000)

Berson, Hattar, Foster, Dacey, Lucas, … (2000–)


cie
International Commission on Illumination
Commission Internationale de l'Eclairage
Internationale Beleuchtungskommission

CIE S 026/E:2018

International Standard

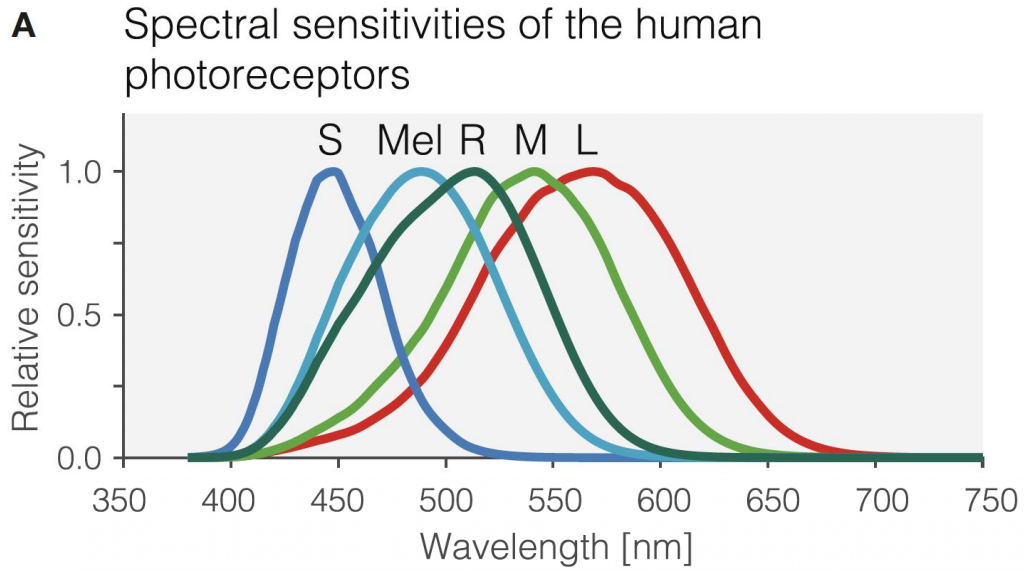
CIE System for Metrology of Optical Radiation for ipRGC-Influenced Responses to Light

Système CIE de métrologie des rayonnements optiques dédié à la réponse à la lumière des cellules ganglionnaires photosensibles de la rétine (ipRGC)

CIE-System für die Messtechnik optischer Strahlung für ipRGC-beeinflusste Antworten auf Licht

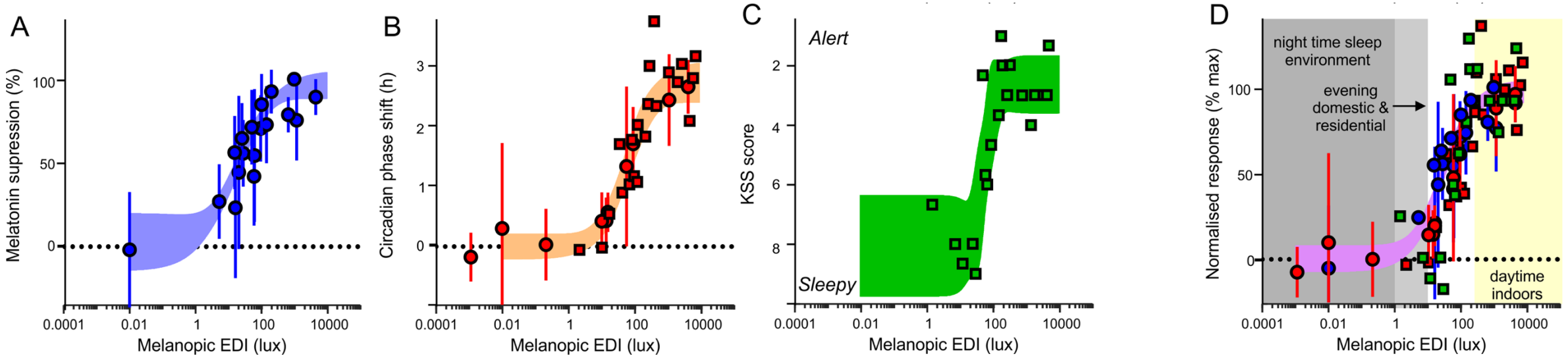
CIE Central Bureau, Vienna
Babenbergerstrasse 9, A-1010 Vienna, Austria
CIE S 026/E:2018
UDC: 612.014.481-06
Descriptor: Optical radiation effects on humans

CIE S 026/E:2018



The melanopsin-containing ipRGCs mediate the impact of light on human physiology and behaviour

Neuroendocrine | **Circadian** | **Neurocognitive**



Brown et al. (2022)

A lot of studies

Laboratory studies → Field studies → Epidemiological studies → Real world

No evidence (yet)

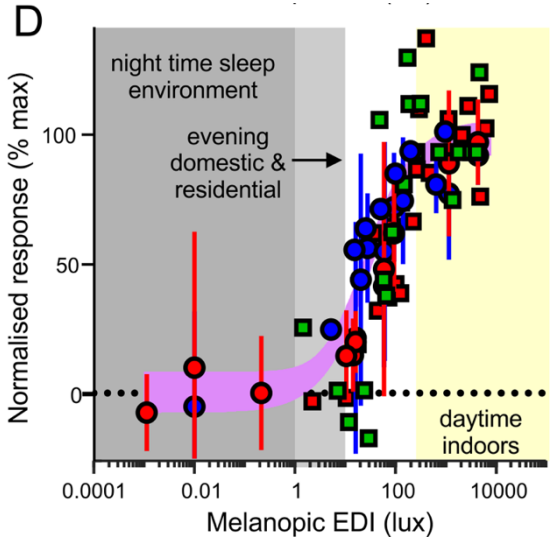
In 2022, the first consensus recommendations for light exposure were published

PLOS BIOLOGY

CONSENSUS VIEW

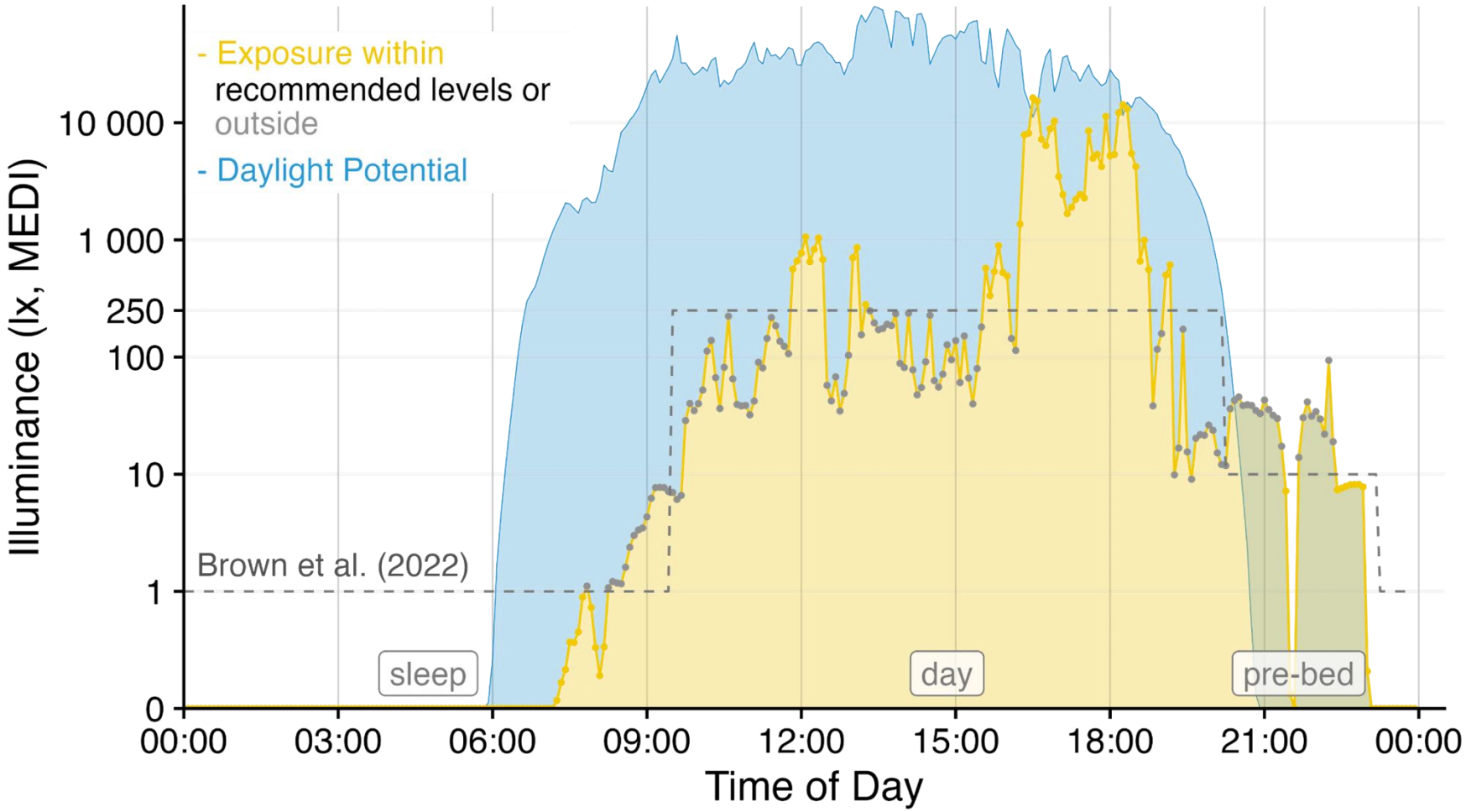
Recommendations for daytime, evening, and nighttime indoor light exposure to best support physiology, sleep, and wakefulness in healthy adults

Timothy M. Brown[1]*, George C. Brainard[2], Christian Cajochen[3], Charles A. Czeisler[4,5], John P. Hanifin[2], Steven W. Lockley[4,5,6], Robert J. Lucas[1], Mirjam Münch[3,7], John B. O'Hagan[8], Stuart N. Peirson[9], Luke L. A. Price[8], Till Roenneberg[10], Luc J. M. Schlangen[11,12], Debra J. Skene[13], Manuel Spitschan[14,15,16], Céline Vetter[17], Phyllis C. Zee[18,19], Kenneth P. Wright, Jr[20]*



Daytime >250 lx melanopic EDI
Pre-sleep <10 lx melanopic EDI
Sleep <1 lx melanopic EDI

The impact of light depends on the time of day

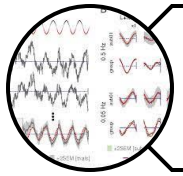


Disruptive effects of light in the evening and at night

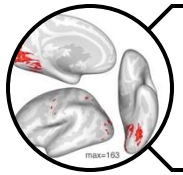
Positive effects of light during the day

Interaction between daytime and nighttime light exposure

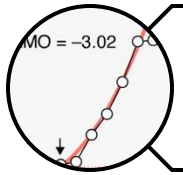
Over the past years, we've advanced our understanding of how light impacts human physiology using carefully controlled studies



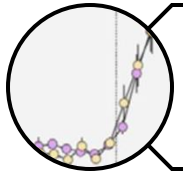
S cones drive the pupil response paradoxically (activation of S cones dilates the pupil) [Spitschan et al., 2014]



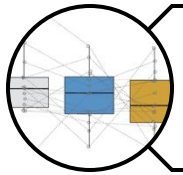
Melanopsin signals reach human visual cortex [Spitschan et al., 2017]



Cones are not needed for normal circadian phenotype [Spitschan et al., 2021]

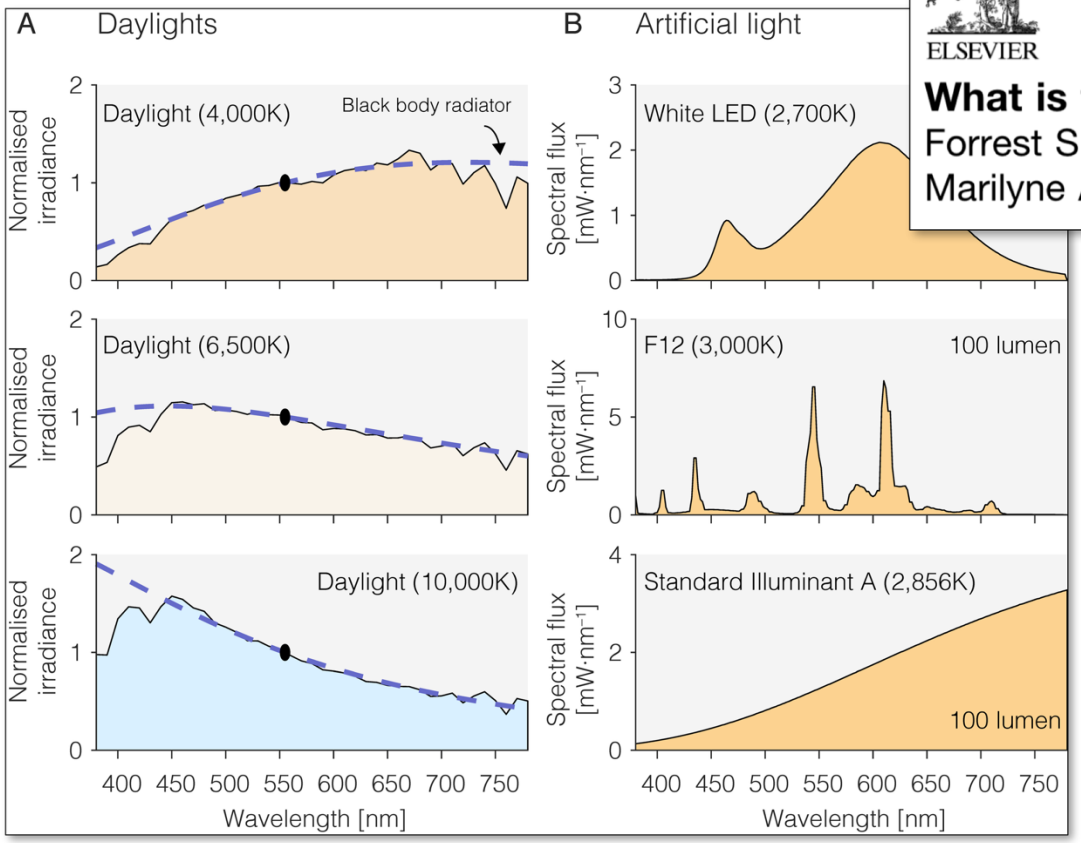


S cones do not demonstrably influence melatonin suppression [Spitschan et al., 2019]



S-[L+M] activation does not demonstrably influence circadian phase shifting [Blume et al., 2023]

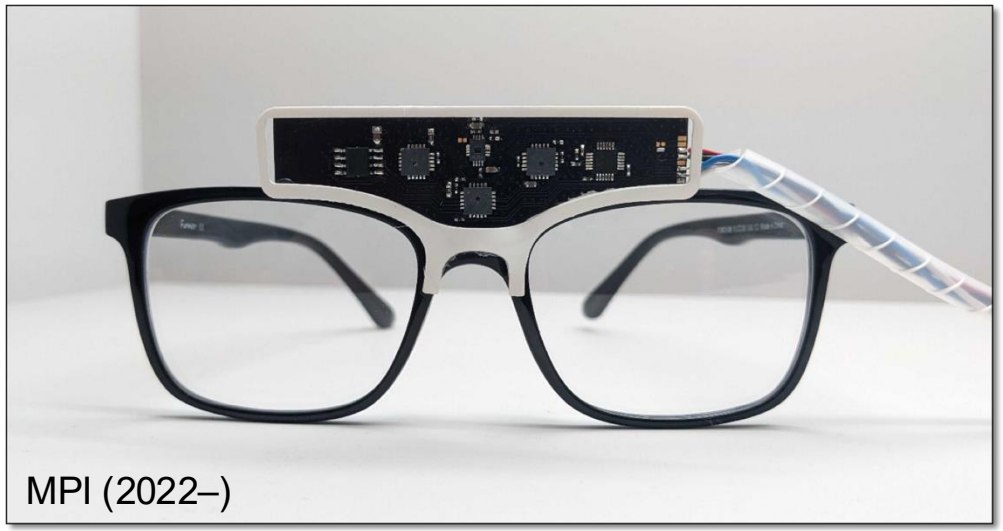
Moving from the lab into the field requires good measurements of light exposure



Available online at www.sciencedirect.com
ScienceDirect
Current Opinion in Behavioral Sciences

What is the 'spectral diet' of humans?

Forrest S Webler[1,#], Manuel Spitschan[2,3,4,#], Russell G Foster[5], Marilyne Andersen[1] and Stuart N Peirson[5]



Wearable light loggers can close this gap

MeLi Dos
Metrology for wearable light loggers and optical radiation dosimeters
EURAMET

EURAMET-funded MeLiDos project on wearable light logging

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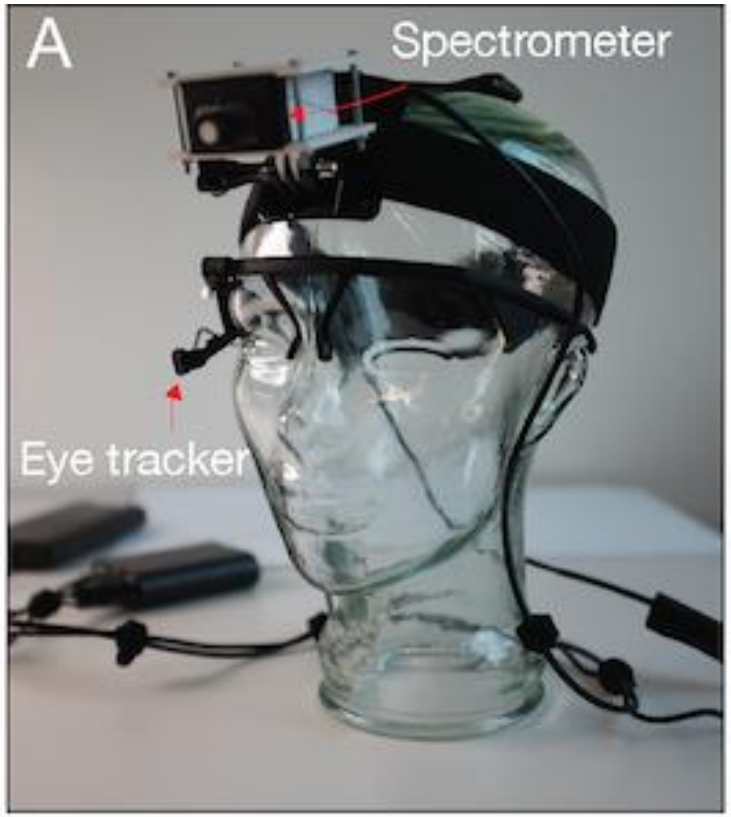
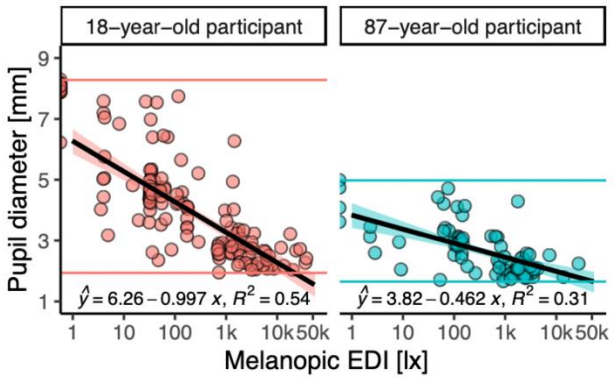
Data measurement campaign with cohorts in Spain, Sweden, Netherlands, Germany, Turkey, Ghana and Costa Rica

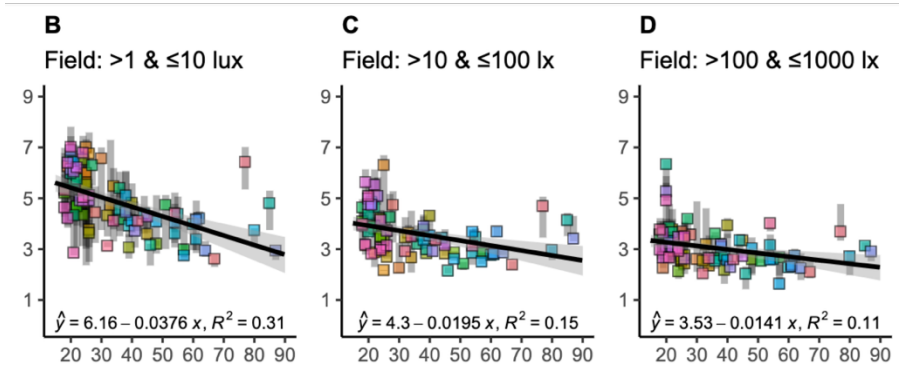
Field measurements of stimulus and response are feasible



Parametric measurements of physiological responses to lighting conditions only go ‘so far’ in predicting real-world responses to light

Conjoint measurements of pupil size and spectrum for ‘real-world’ research

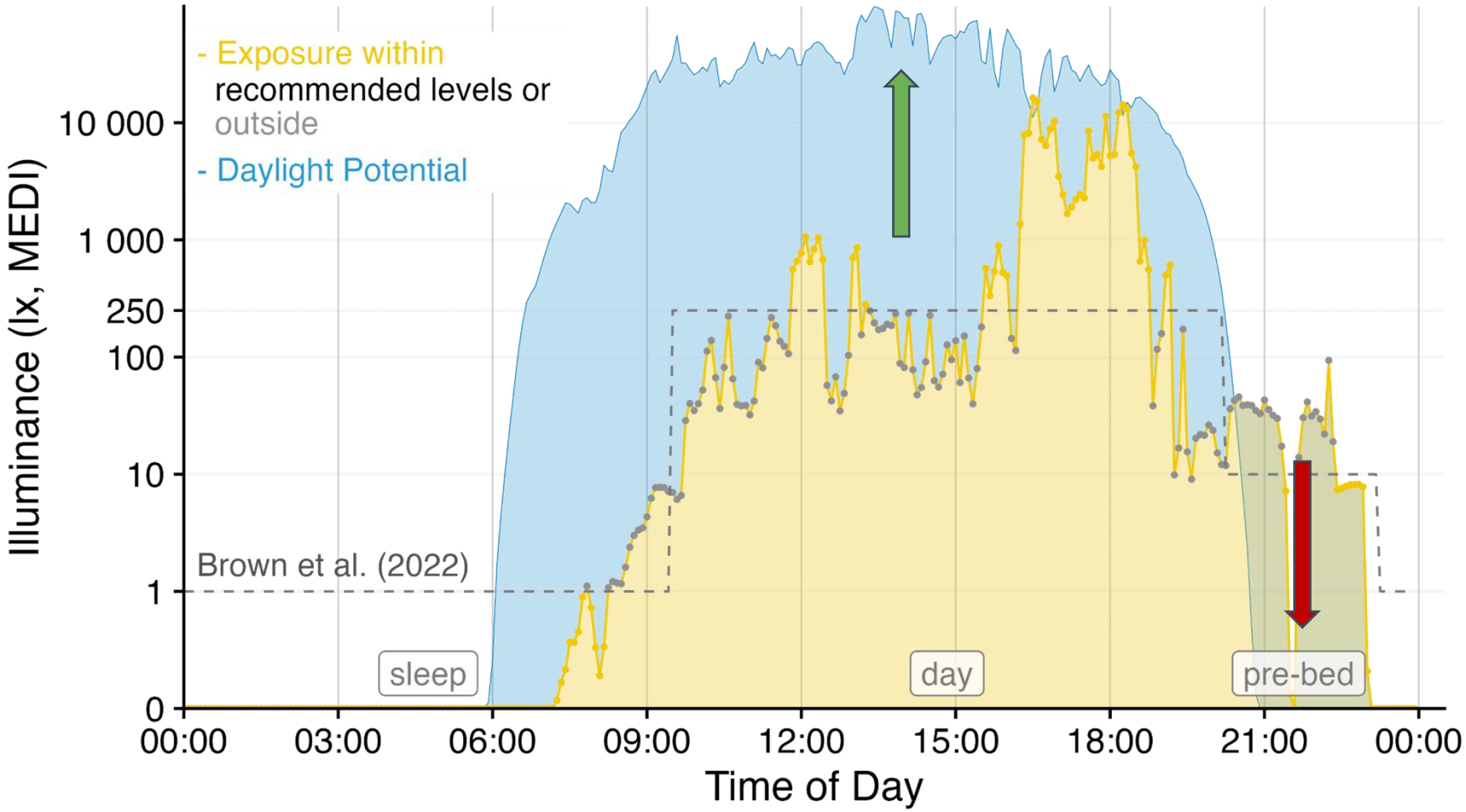




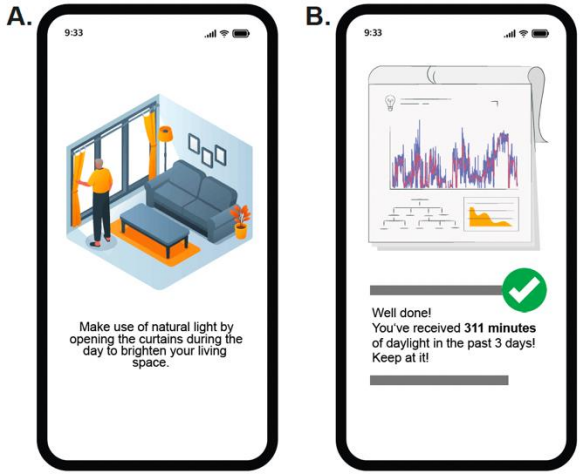
Effect of age on pupil size

Lazar et al. (2024)

We’re developing interventions relying on behaviour, rather than technology

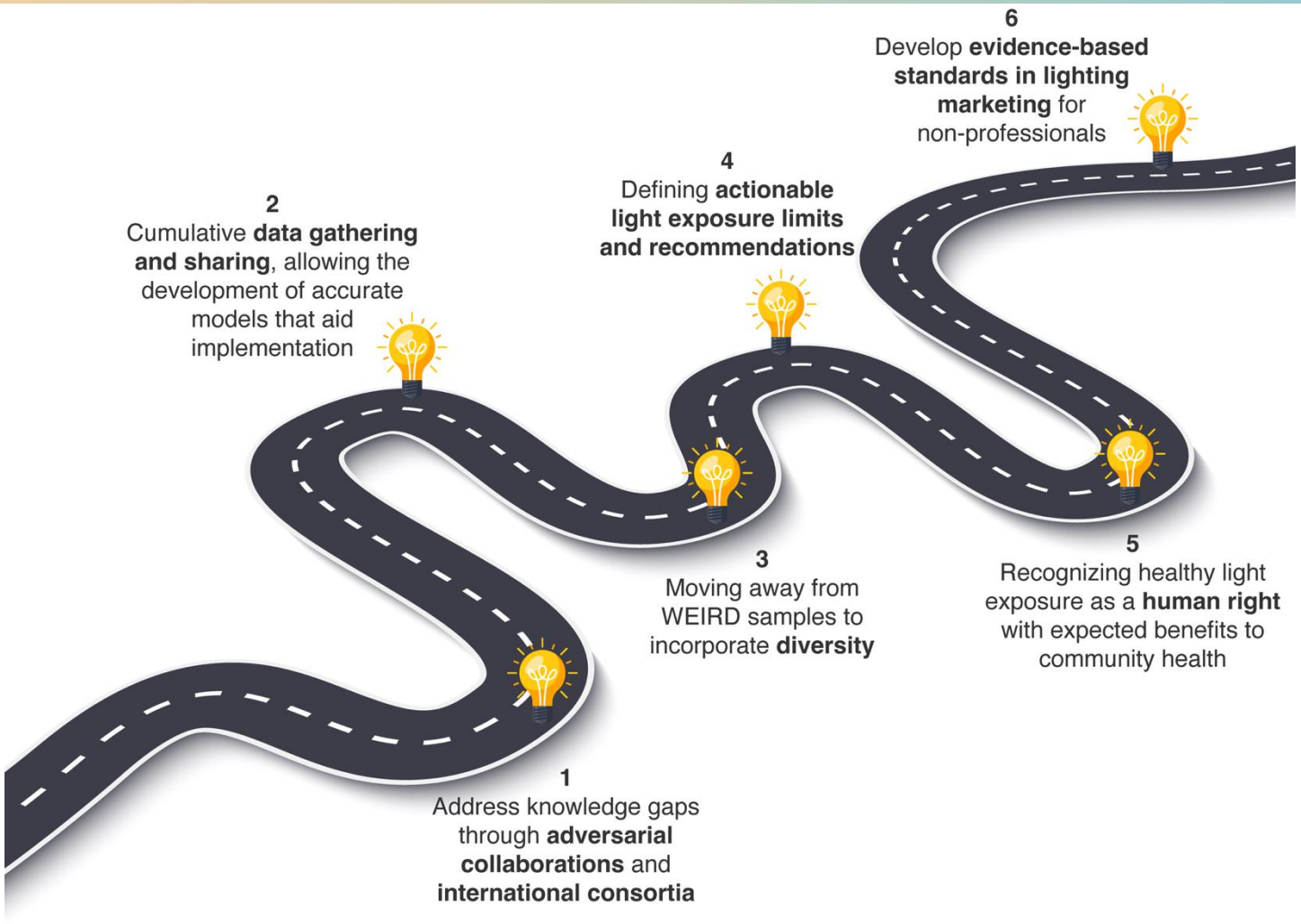


Light span



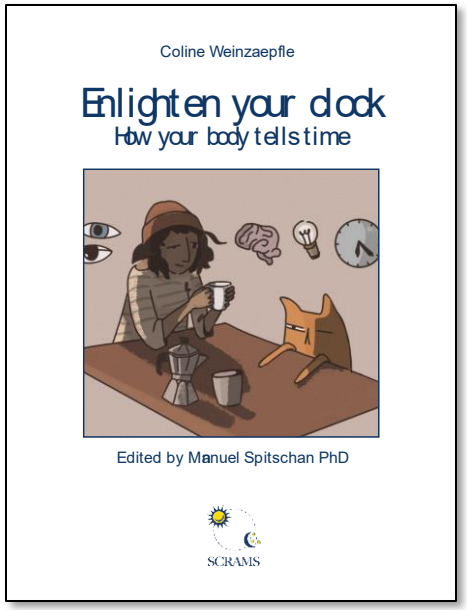
Intervention for the use of light for healthy ageing (2023–)

Several areas of research are high priority to translate our knowledge into practice



Spitschan & Joyce (2023)
Spitschan (2024)

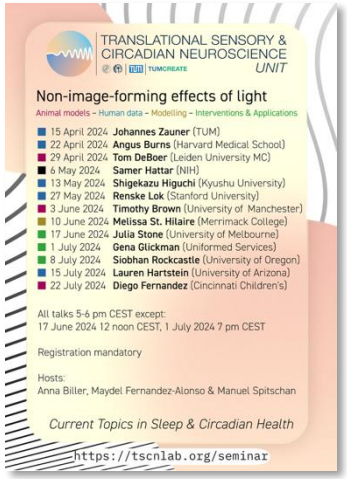
Science communication is a key priority



https://enlightenyourclock.org/

আলোকিত হোক দেহঘড়ি (Bangla)
Descobrindo seu relogio biológico (Brazilian Portuguese)
Il·lumina el teu rellotge (Catalan)
了解你的生物钟 (Chinese)
Kast lys på dit indre ur (Danish)
Verlicht je klok (Dutch)
De la lumière sur votre horloge biologique (French)
Un reloxo con moitas luces (Galician)
Unsere innere Uhr (German)
Διαφώτισε το ρολόι σου (Greek)
अपनी सर्केडियन घड़ी को प्रबुद्ध /सचेत करें (Hindi)
おしゃべりなネコに学ぶ (Japanese)
Apšviesk savo laikrodį (Lithuanian)
Opplys klokken din (Norwegian)
ساعت بدن خودت رو کوک کن! (Persian)
Ilumina o teu relógio (Portuguese)
Просвети свои часы (Russian)
Hágase la luz… en tu reloj interno (Spanish)
Kroppens egen klocka (Swedish)
Ritmine Işık Tut! (Turkish)
روشنی کی گھڑی (Urdu)

Podcast “Light O’Clock” (2024–)
Hosted by Carolina Guidolin
https://tscnlab.org/podcast



Weekly scientific talk series (2022–)
https://tscnlab.org/seminar

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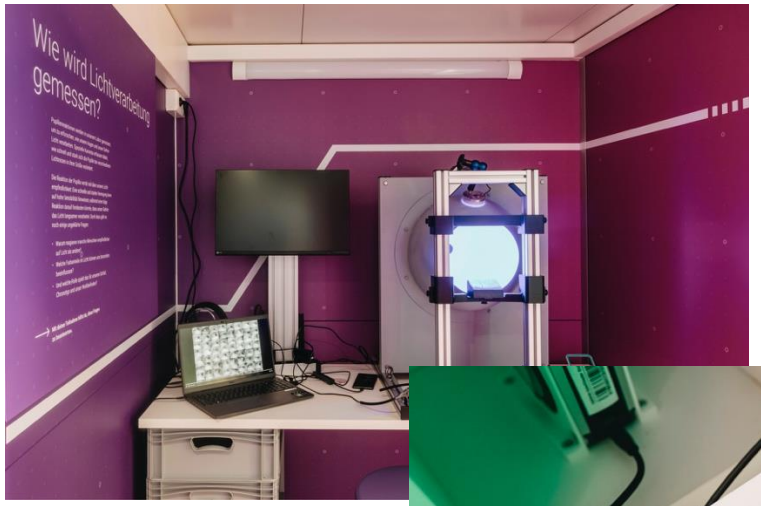
Taking science on the road



nachtmensch-oder-fruehaufsteher.de

The Ladenburg White paper proposed a concerted effort to develop evidence-based messages on light and health

Call for a coordinated international communications effort on the effects of ocular light exposure on health and well-being

White paper from the Ladenburg Roundtable

DOI: 10.17605/osf.io/rxa35 · Date: 7 May 2024

On 14-16 April 2024, 21 international experts on light and health met in Ladenburg, Germany, to share their expertise on the effects of light detected through the eyes on health and wellbeing and to discuss strategies to move from physiology to policy.

We, *the undersigned*, agree on the need for common messaging on this important public health topic and propose that this message could be carried to the world best by using a coordinated international communications effort. We call upon the CIE, Daylight Academy, Good Light Group, SLTBR, and others to join forces in this endeavor.

The steps that are needed:

1. Develop a consensus, evidence-based message on the topic of light and health, including relevant background literature;
2. Ensure that the message is aligned with other public health advice and design principles;
3. Express the message in simple language that makes it accessible to non-experts;
4. Identify the target groups, i.e., the segments of the population that could most benefit from this message;
5. Determine the format and dissemination channels that would be optimal to reach the target groups;
6. Develop materials in a format suitable for local language translations;
7. Formulate indicators to evaluate the outcomes of the communications campaign (e.g., the reach of the message and direct changes in stakeholder activities) and/or the longer-term impacts of this initiative.

Dr **Laura Kervezee**, NL
Dr **Christine Blume**, CH
Prof **George C. Brainard**, USA
Dr **Kai Broszio**, DE
Prof **Timothy Brown**, UK
Jan **Denneman**, NL
Dr **Maydel Fernandez-Alonso**, DE
Dr **Daniel S. Joyce**, AUS
Dr **Renske Lok**, USA
Prof **Robert Lucas**, UK
Dr **Elise M. McGlashan**, AUS
Dr **Raymond P. Najjar**, SG
Dr **Luke Price**, UK
Dr **Sylvia Rabstein**, DE
Dr **David H. Sliney**, USA
Dr **Oliver Stefani**, CH
Dr **Jennifer A. Veitch**, CA
Dr **Daniela Weiskopf**, DE
Dr **Johannes Zauner**, DE
Prof **Manuel Spitschan**, DE

Daimler and Benz Foundation

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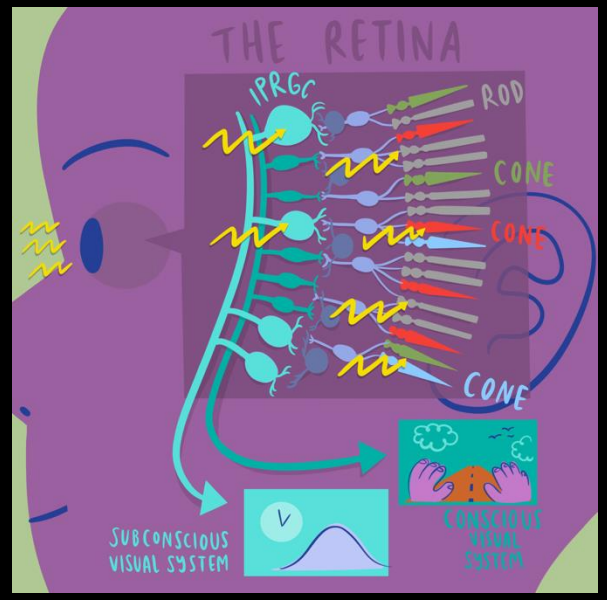
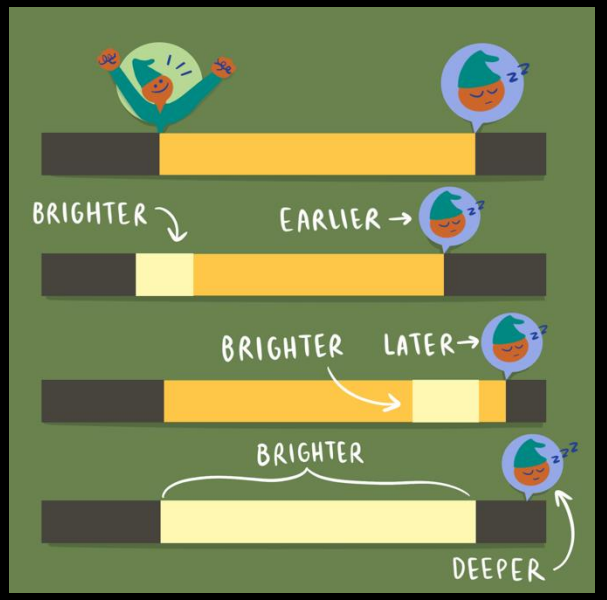
Light for Public Health

- New international initiative on the effects of light on human health
- Focused around 26 consensus statements covering differing areas of science and practice of light
- Targeted to public health multipliers

lightforpublichealth.org

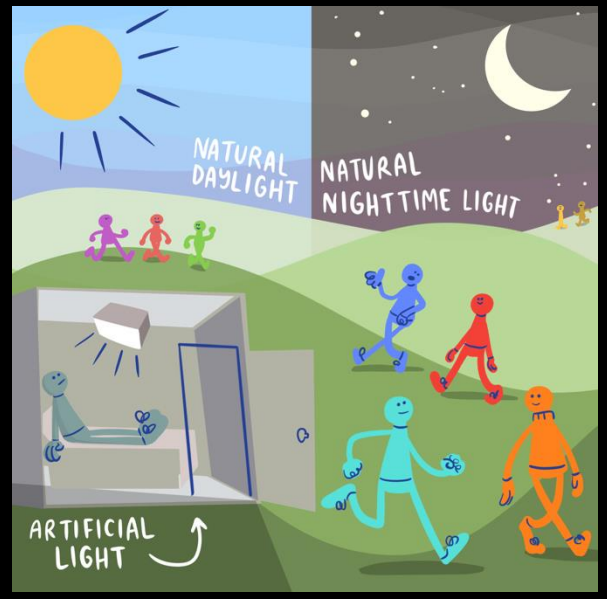
How the eye talks to the brain: Light detection beyond vision

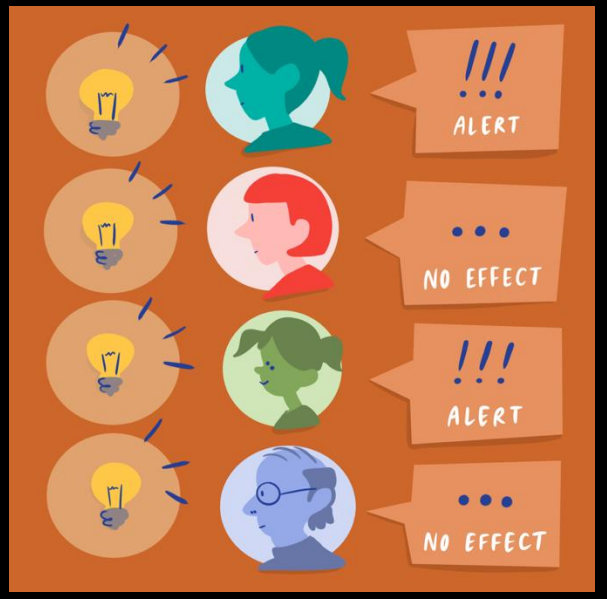




Exposure to light at different times of day alters the timing of sleep and wakefulness

The types of light we see throughout the day: Daylight vs. electric light

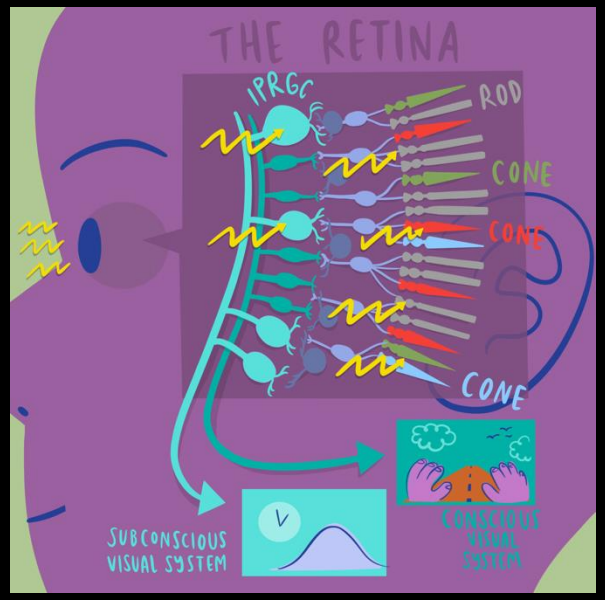


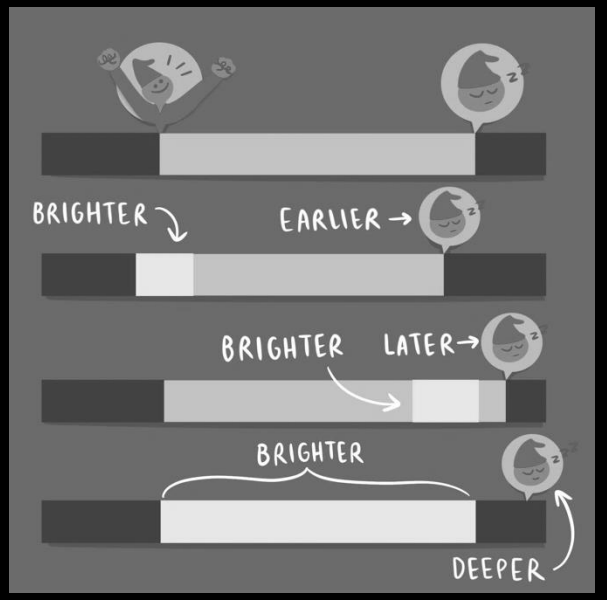


Same light, different effects: How age, gender, and other factors influence the effects of light

Illustrations by Olivia Walch

How the eye talks to the brain: Light detection beyond vision





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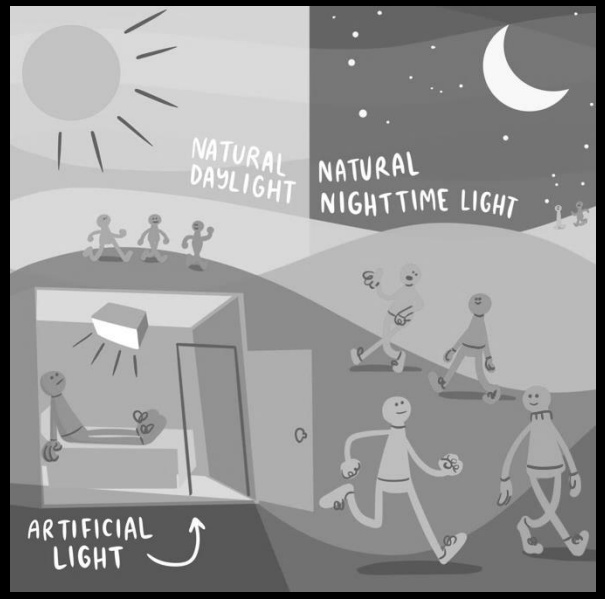
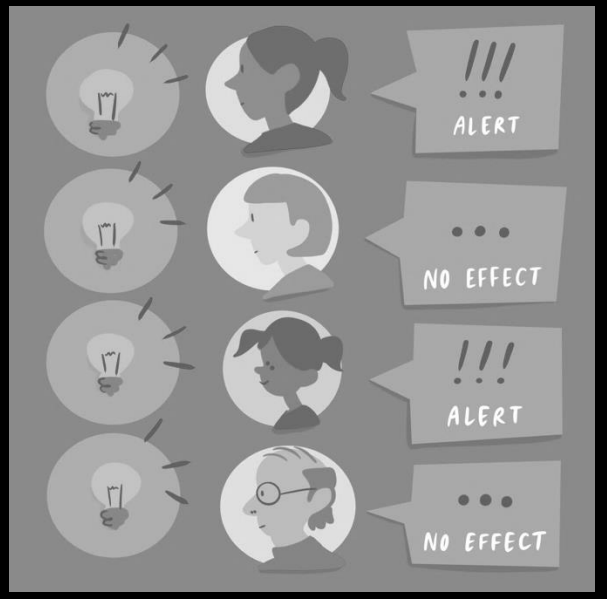
The types of light we see throughout the day: Daylight vs. electric light



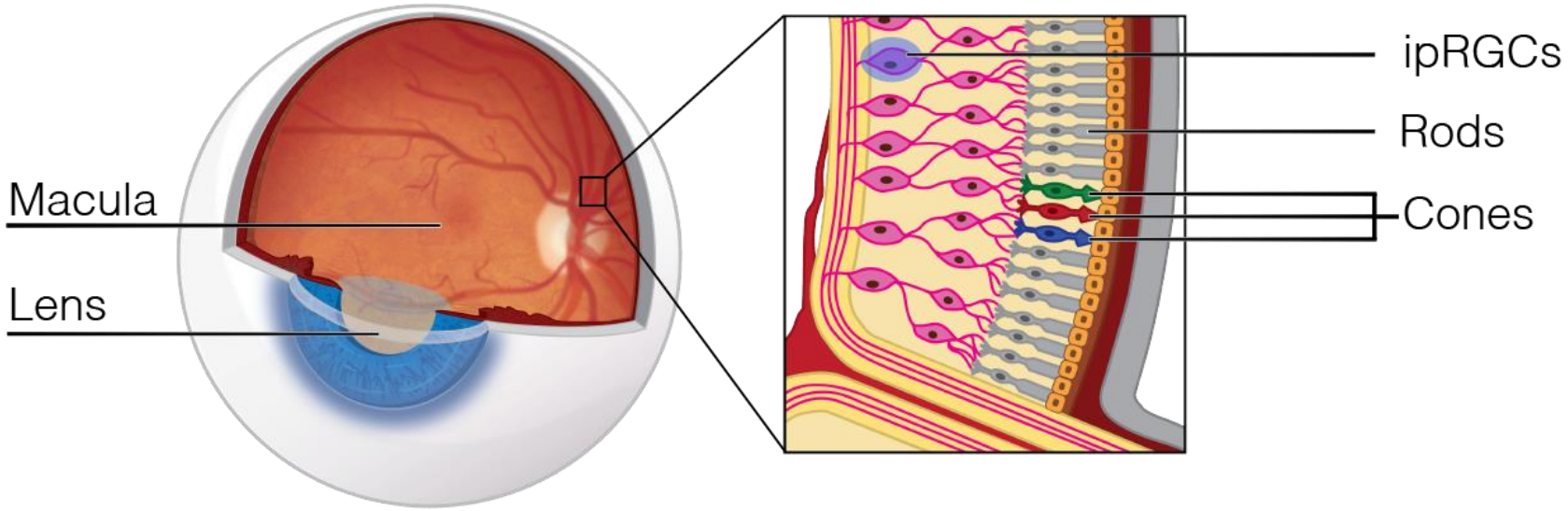


Same light, different effects: How age, gender, and other factors influence the effects of light

How the eye talks to the brain: Light detection beyond vision

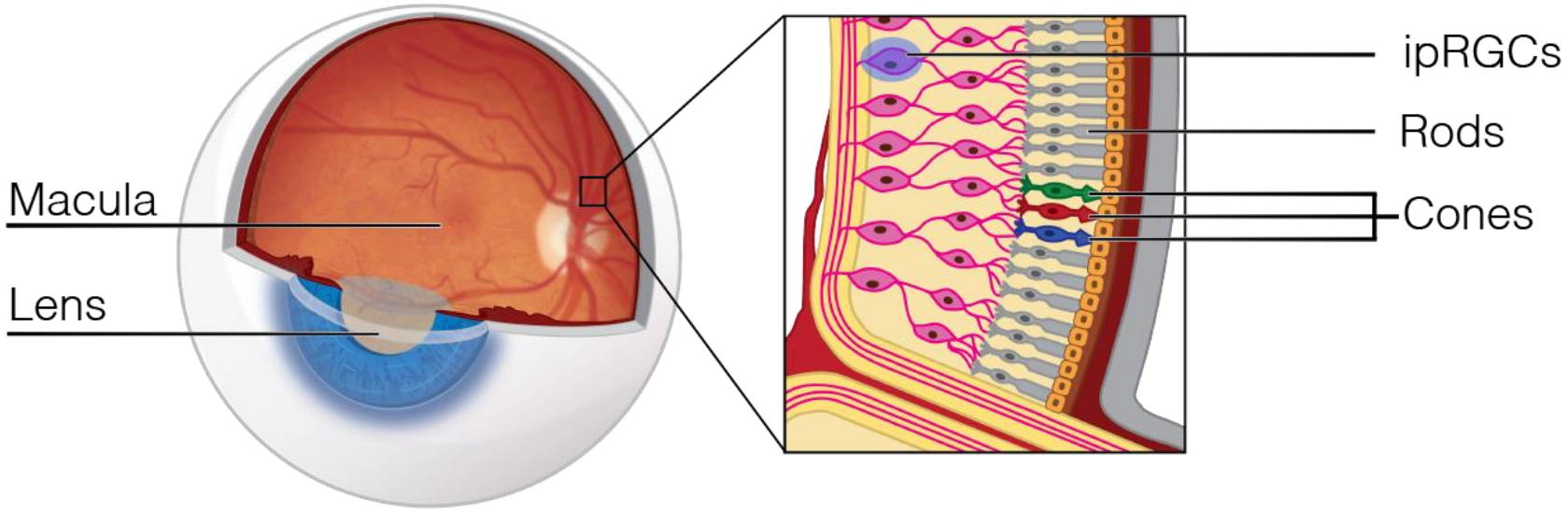
The human eye contains the retina, which has several photosensitive cells that differ in their responses to different wavelengths.

These cells are called **cones**, **rods**, and **intrinsically photosensitive retinal ganglion cells (ipRGCs)**.



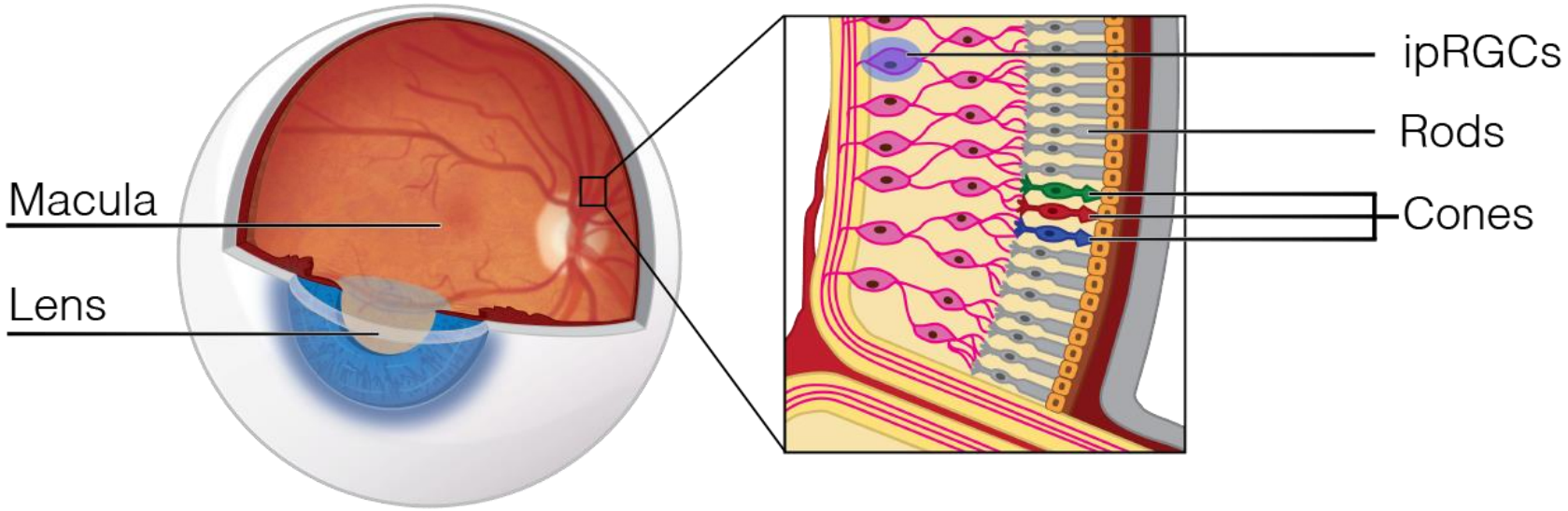
How the eye talks to the brain: Light detection beyond vision

The cones allow us to see **colour**, **motion** and **spatial detail** in bright lighting conditions.



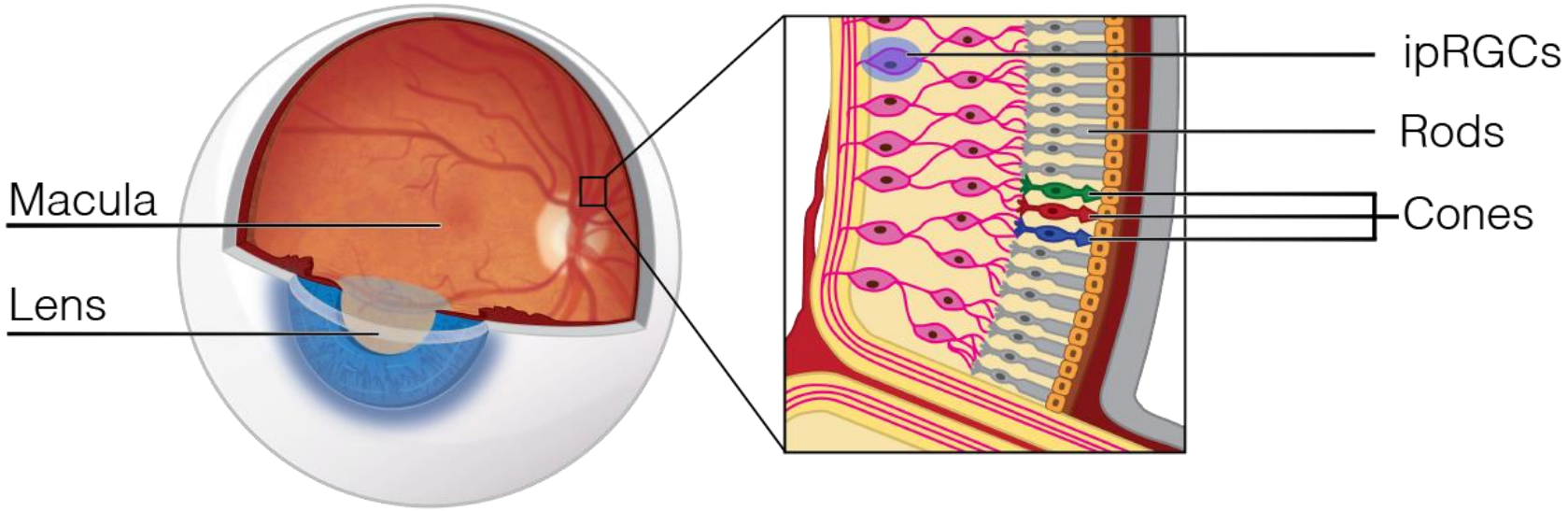
How the eye talks to the brain: Light detection beyond vision

The rods allow us to see **rudimentary spatial detail** under dim light.



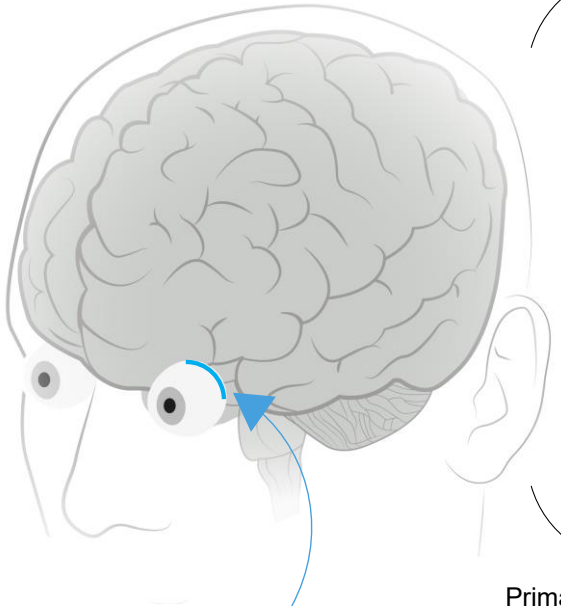
How the eye talks to the brain: Light detection beyond vision

The **intrinsically photosensitive retinal ganglion cells (ipRGCs)** convert light into signals that influence many physiological functions.



Biller, Balakrishnan & Spitschan (2024)

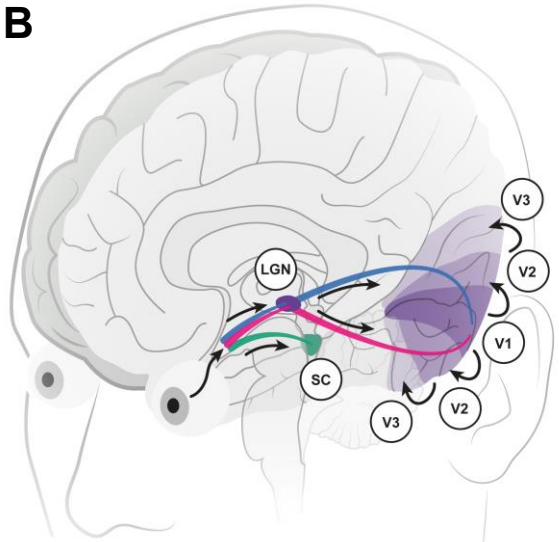
A



Retina containing
– Rods
– Cones
– ipRGCs with melanopsin

Primarily **rod**- and **cone**-mediated

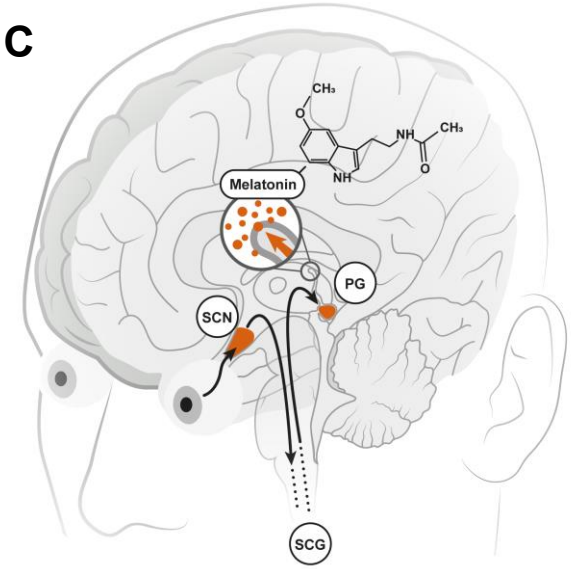
B



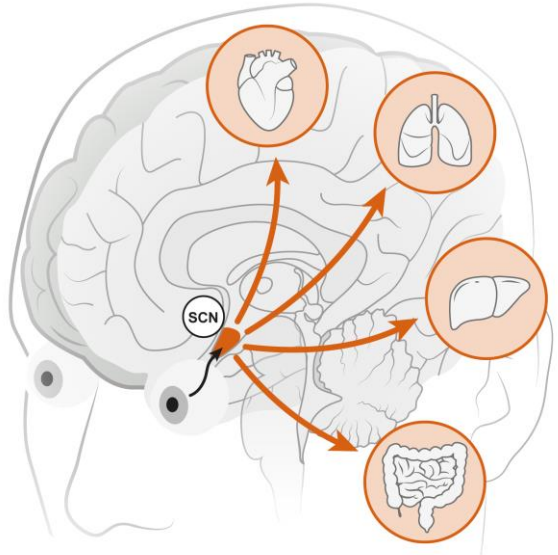
Canonical visual pathways

Primarily **melanopsin/ ipRGC**-mediated

C



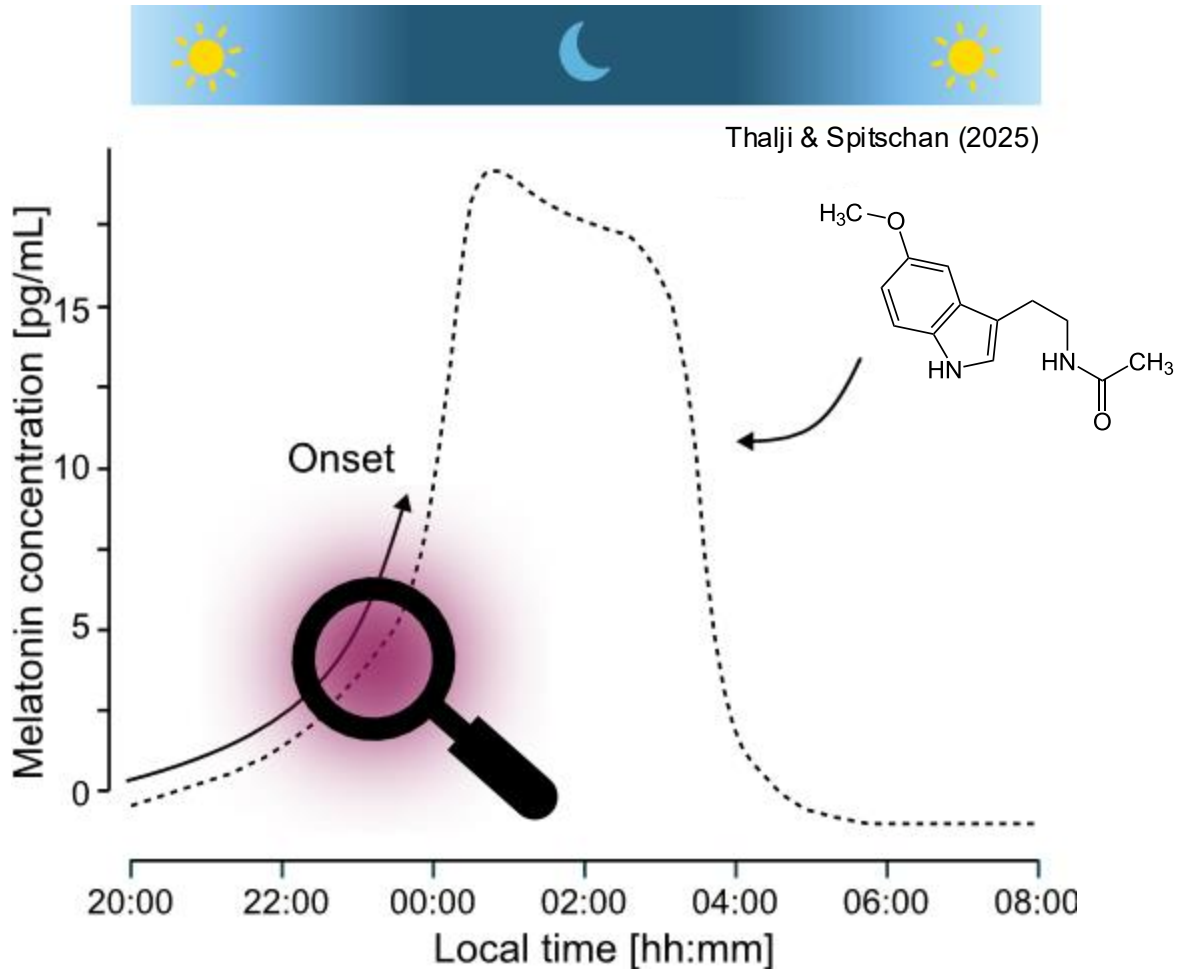
Retinohypothalamic non-image-forming (NIF) pathway



Peripheral clocks affected by central circadian pacemaker

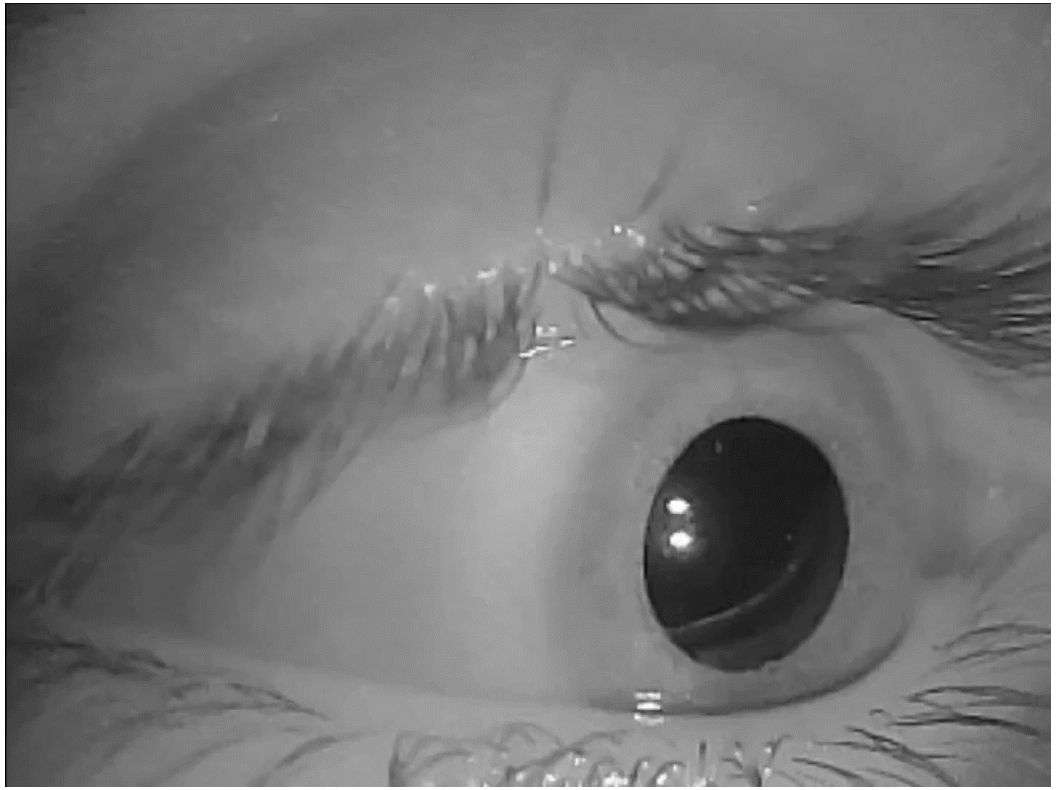
How the eye talks to the brain: Light detection beyond vision

Through the ipRGCs, light causes the **suppression of melatonin** in the evening and at night.



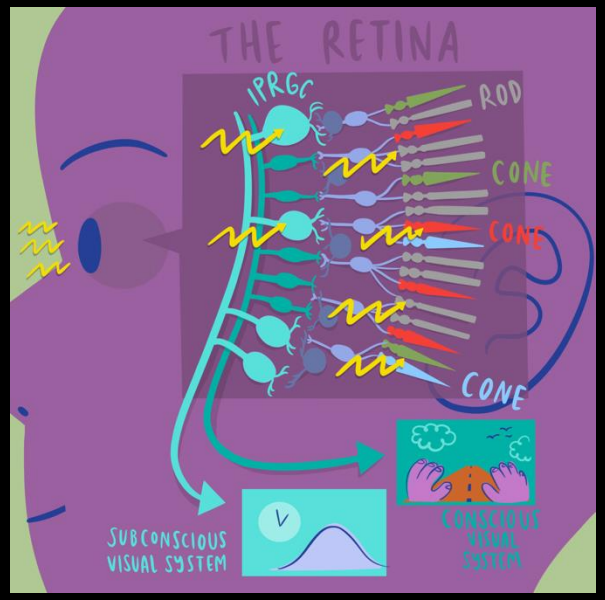
How the eye talks to the brain: Light detection beyond vision

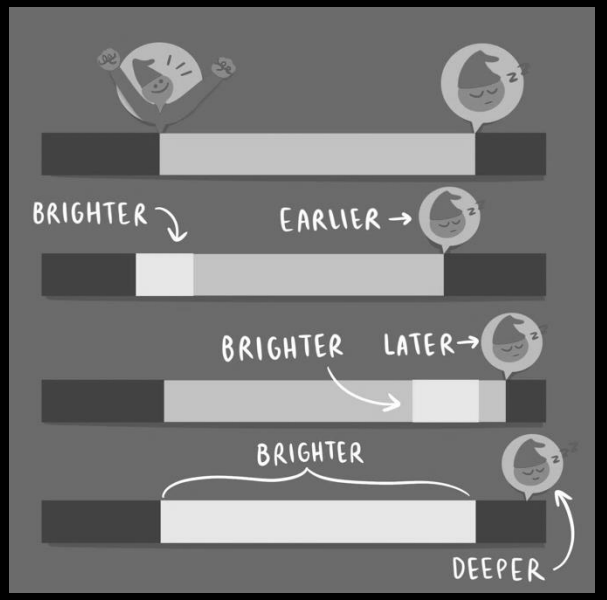
What determines these physiological responses to light is primarily determined by **how much light reaches the retina** and stimulates the ipRGCs at a certain time.



Lazar et al. (2024)

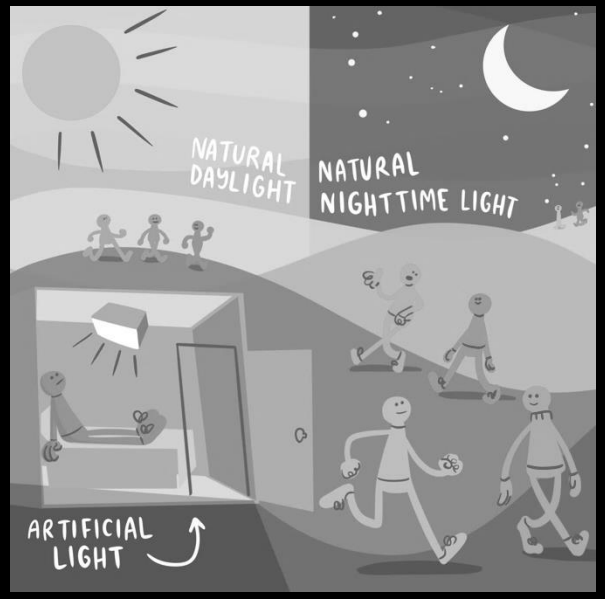
How the eye talks to the brain: Light detection beyond vision

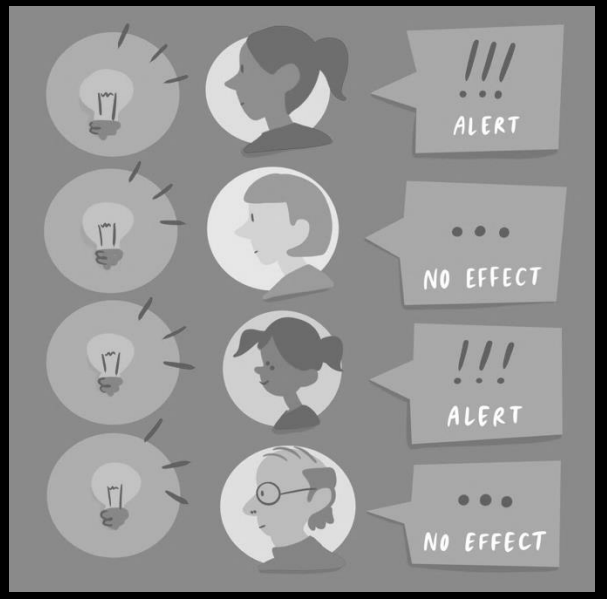




Exposure to light at different times of day alters the timing of sleep and wakefulness

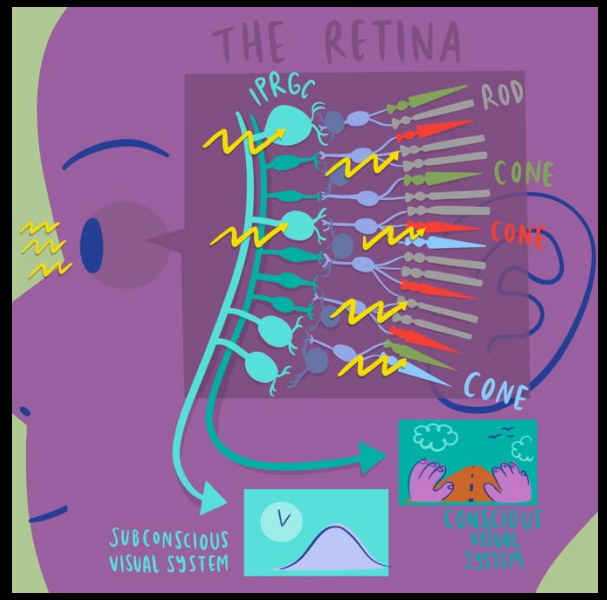
The types of light we see throughout the day: Daylight vs. electric light

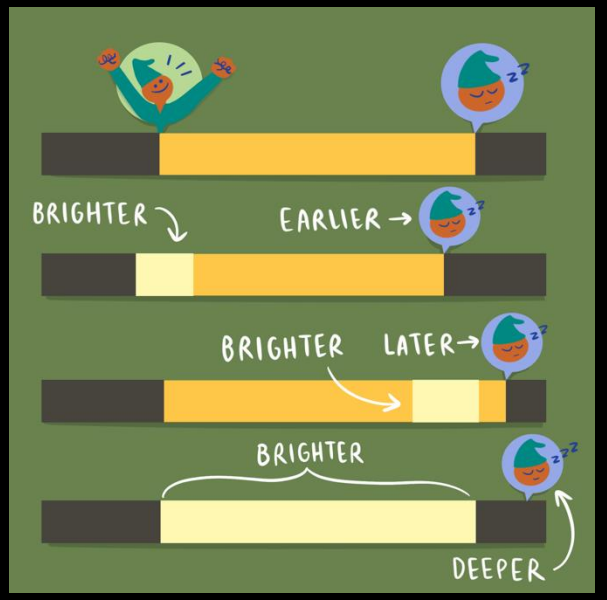




Same light, different effects: How age, gender, and other factors influence the effects of light

How the eye talks to the brain: Light detection beyond vision





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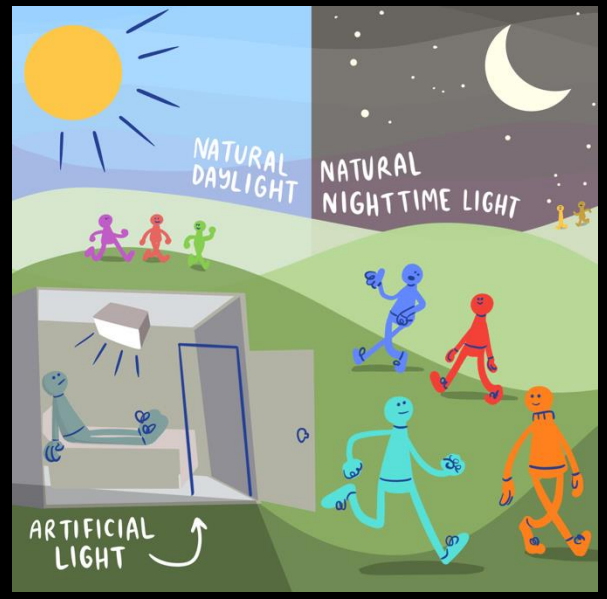

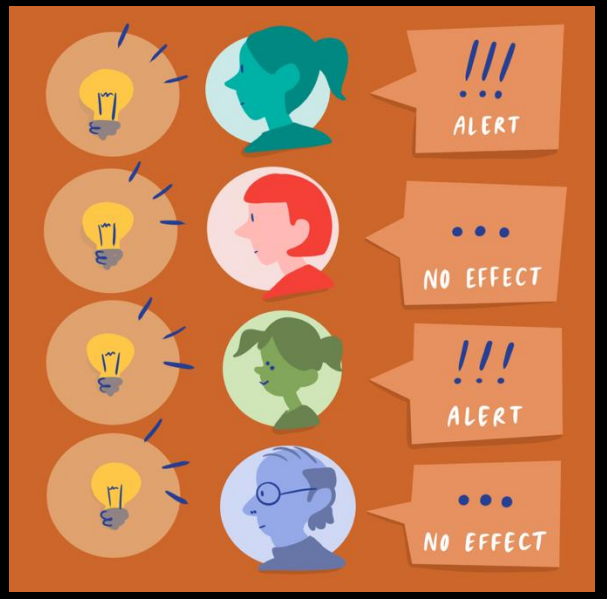

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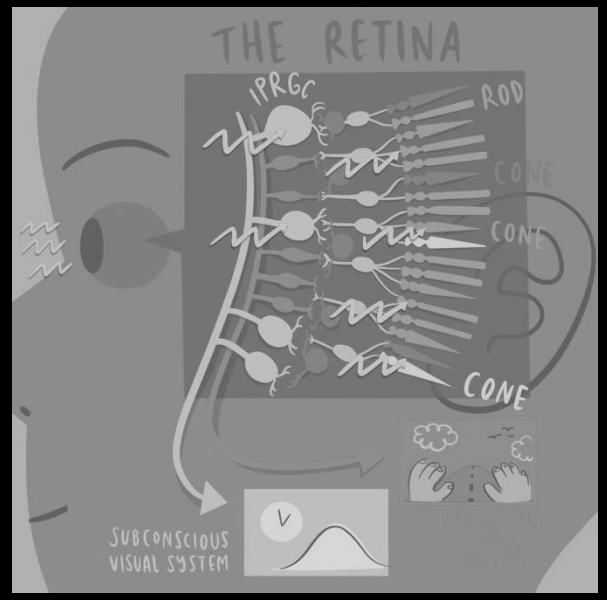

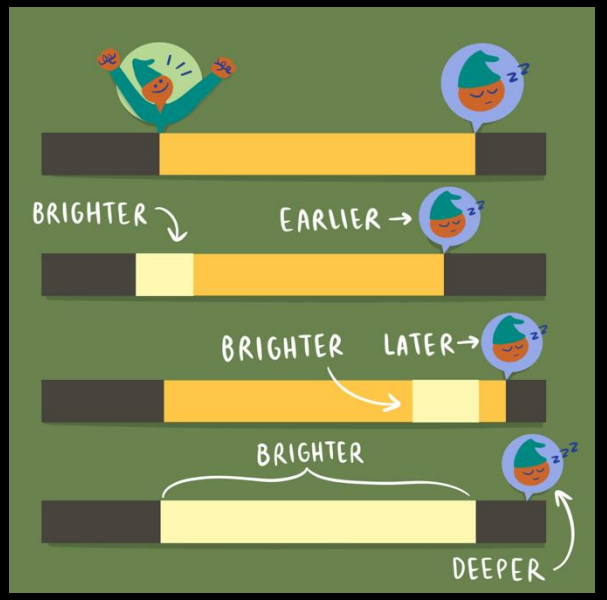

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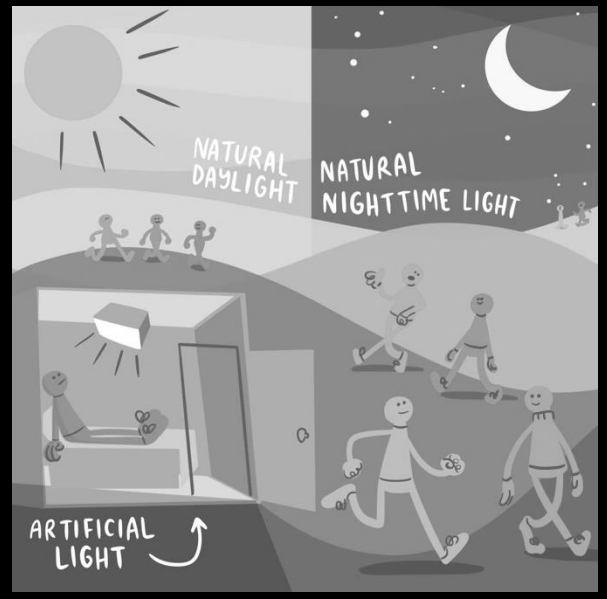
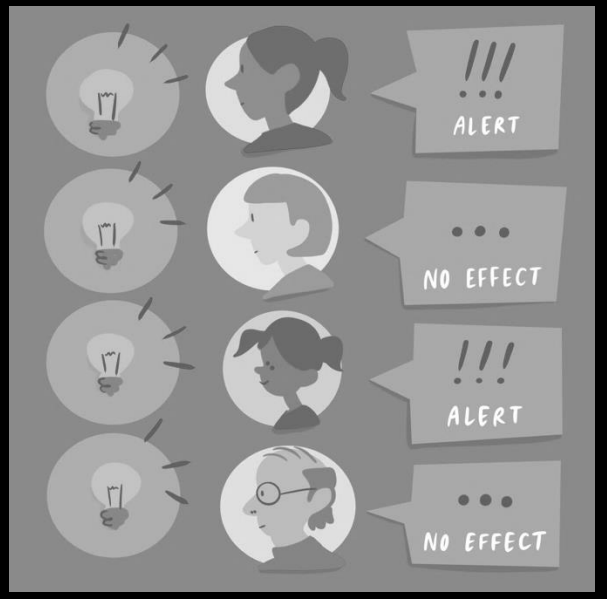
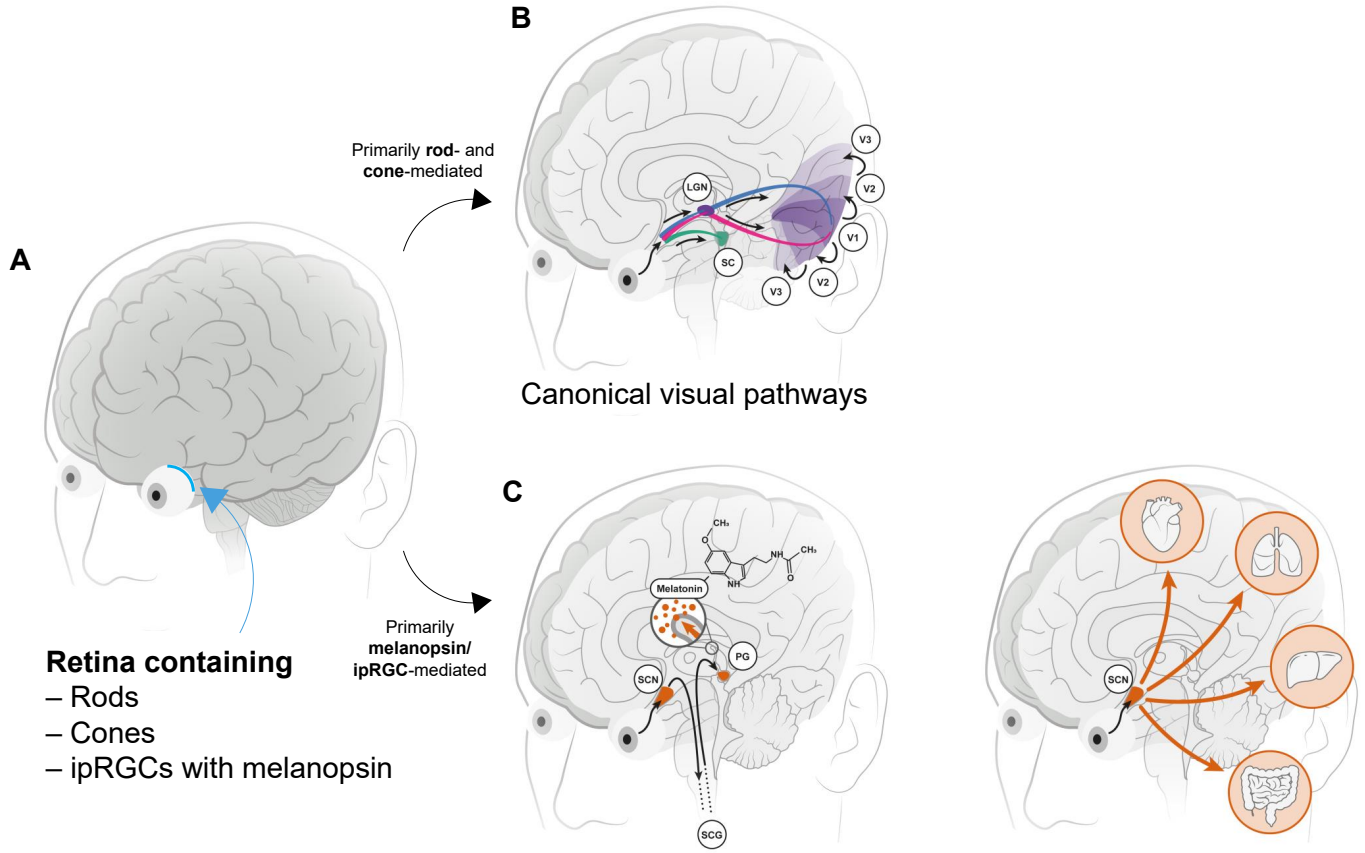




Same light, different effects: How age, gender, and other factors influence the effects of light

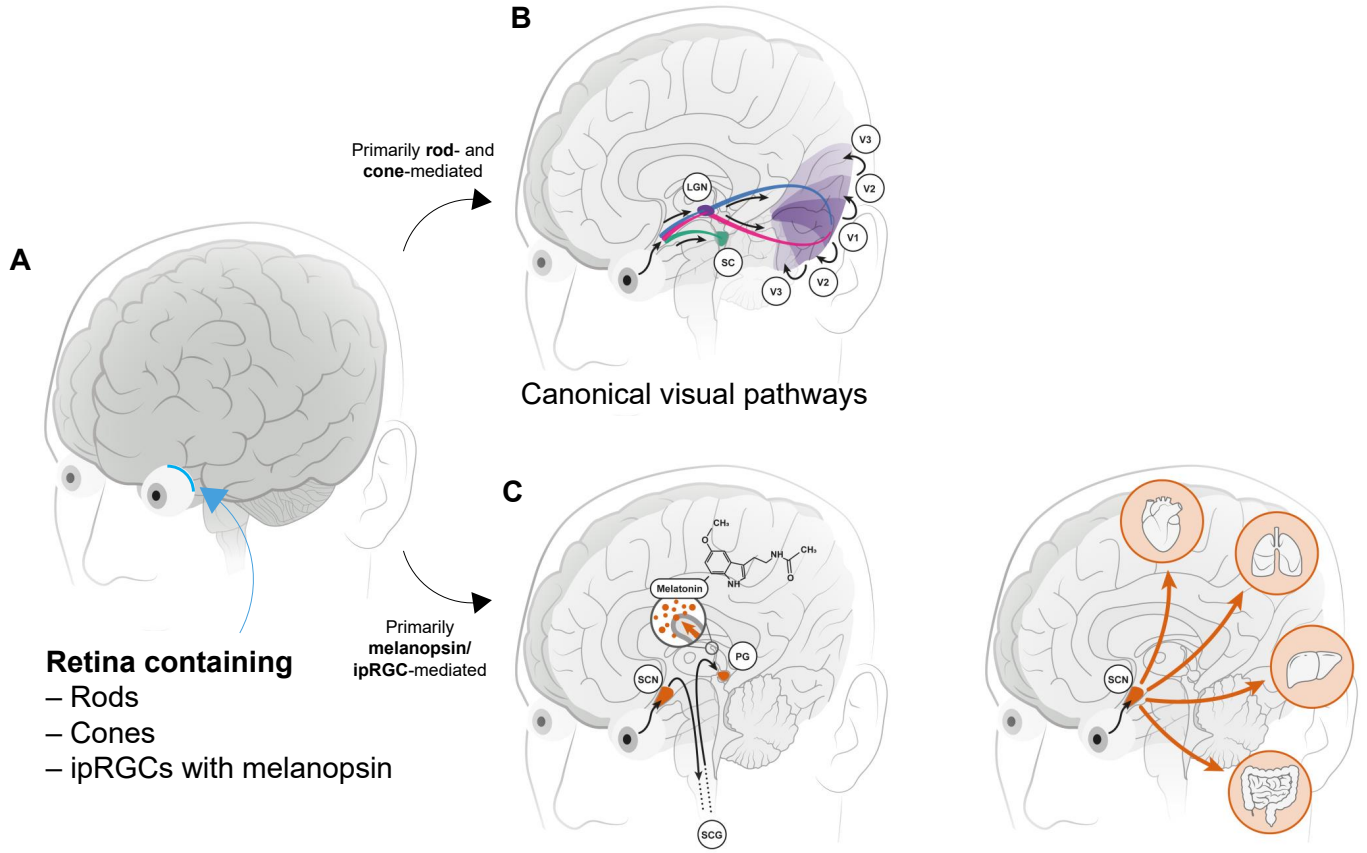
Exposure to light at different times of day alters the timing of sleep and wakefulness

Light is the main signal that ensures the circadian system is **synchronized** to the 24-hour cycles in the environment.



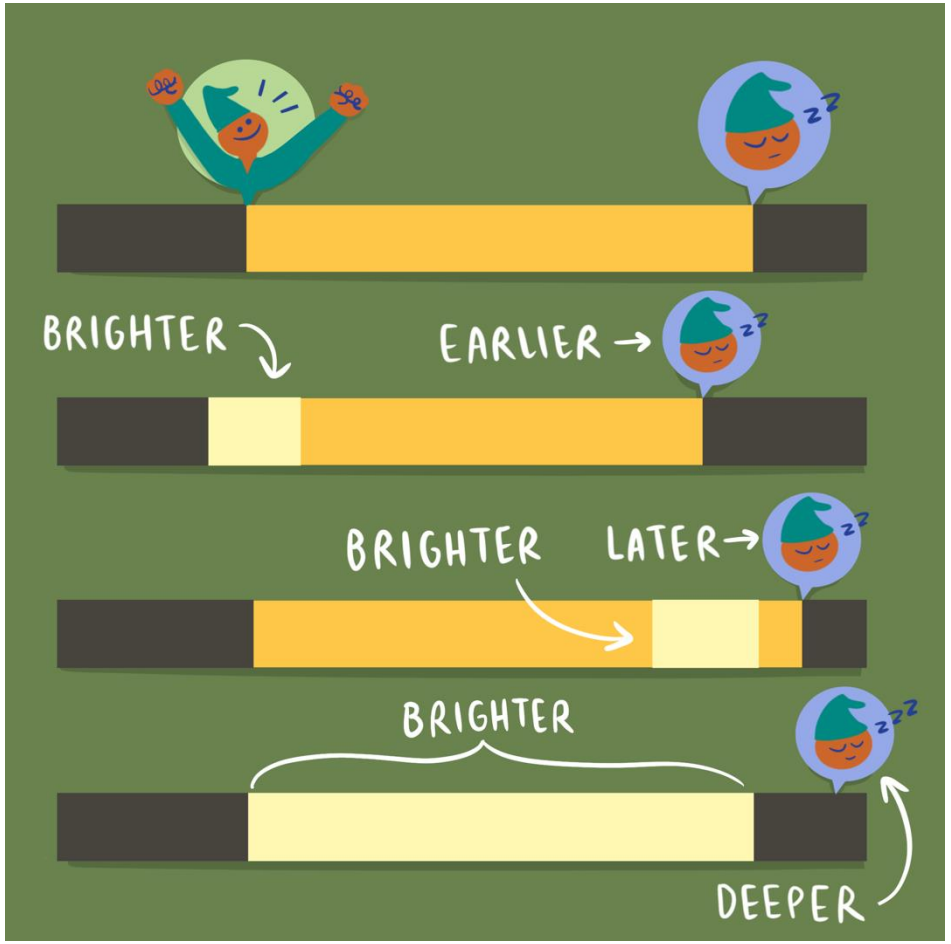
Exposure to light at different times of day alters the timing of sleep and wakefulness

Light **directly** influences the biological clock in the brain, regulating sleep-wake cycles and other daily physiological rhythms.



Exposure to light at different times of day alters the timing of sleep and wakefulness

Light in the morning can **advance** the circadian clock, and light in the evening can **delay** the circadian clock.



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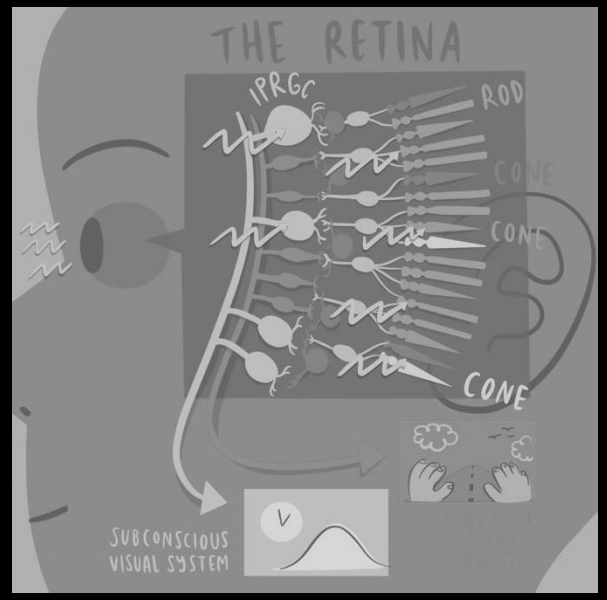

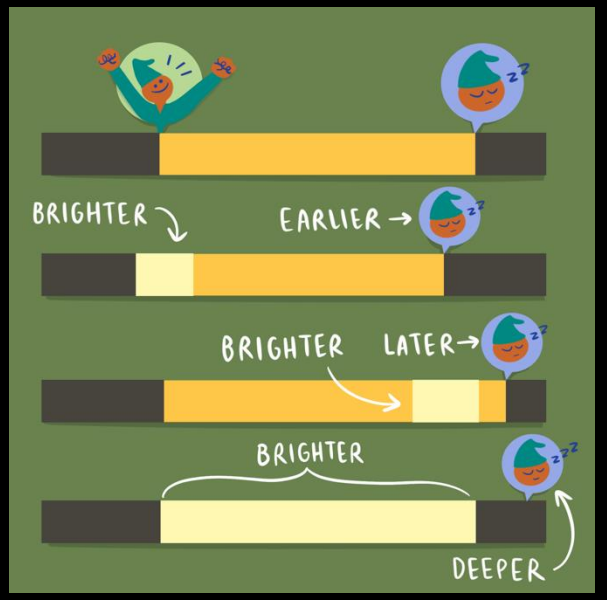

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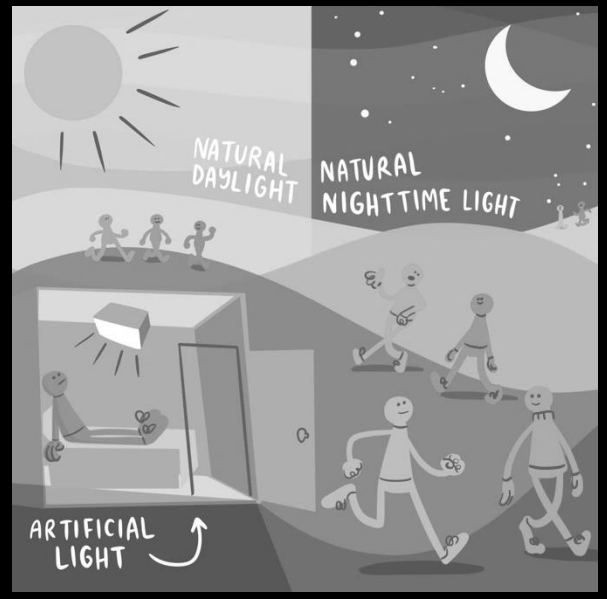
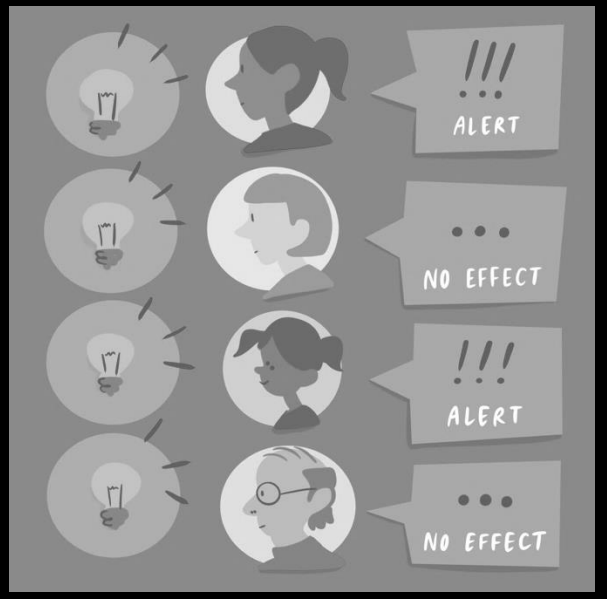
The types of light we see throughout the day: Daylight vs. electric light





Same light, different effects: How age, gender, and other factors influence the effects of light

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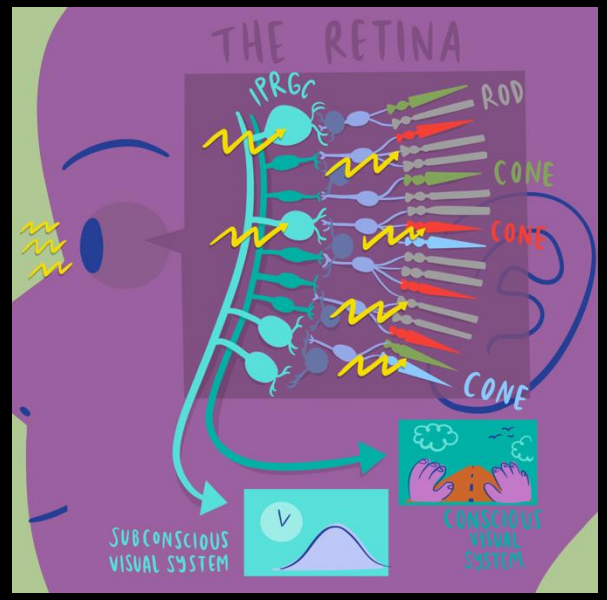

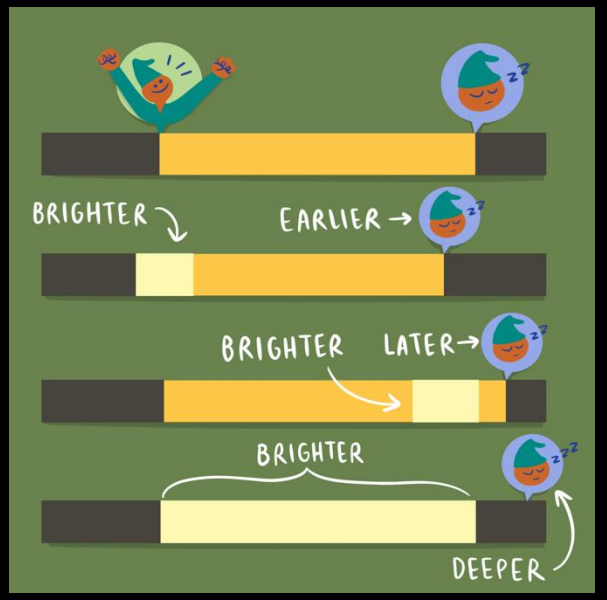

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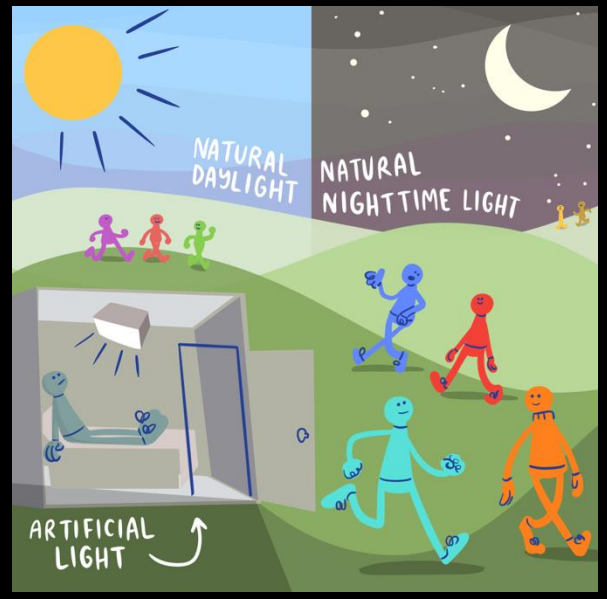

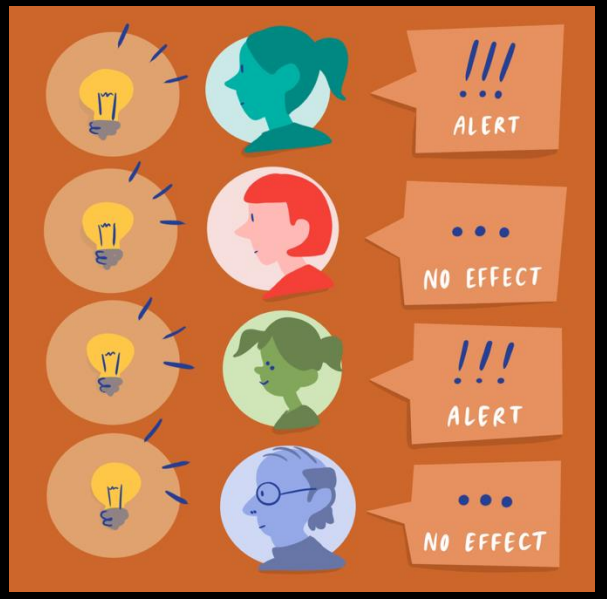

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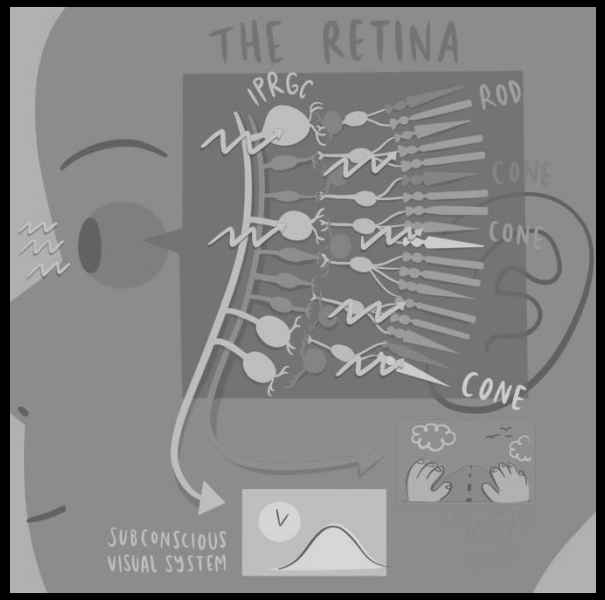

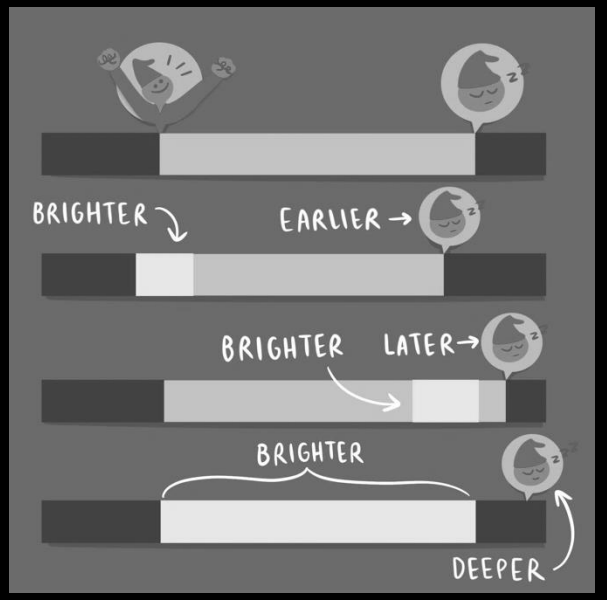

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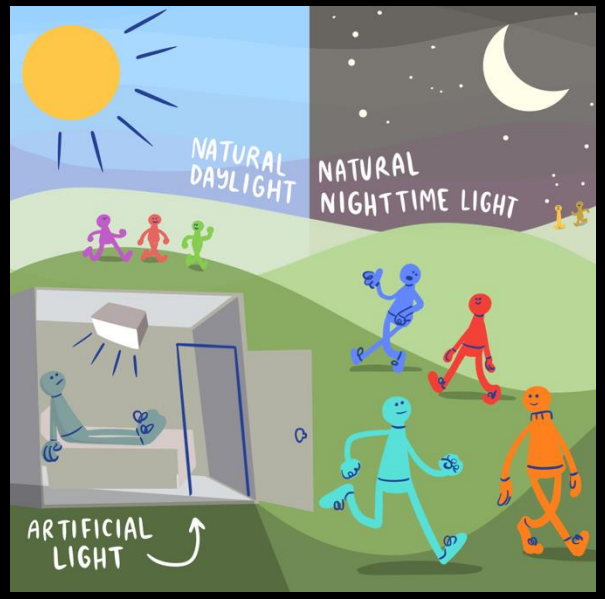
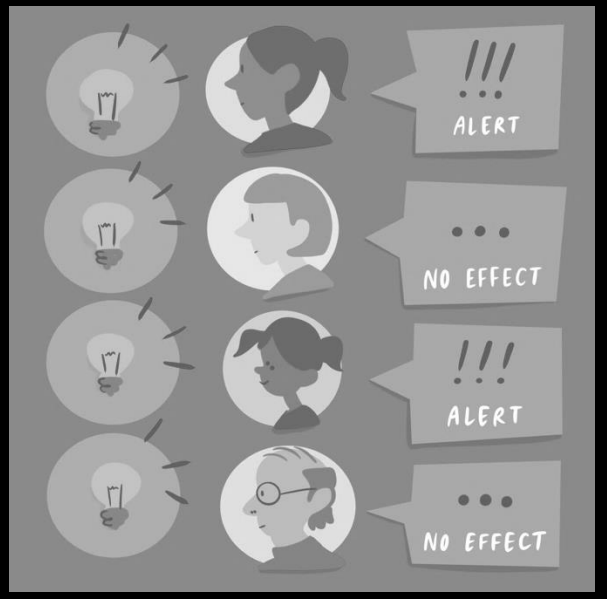
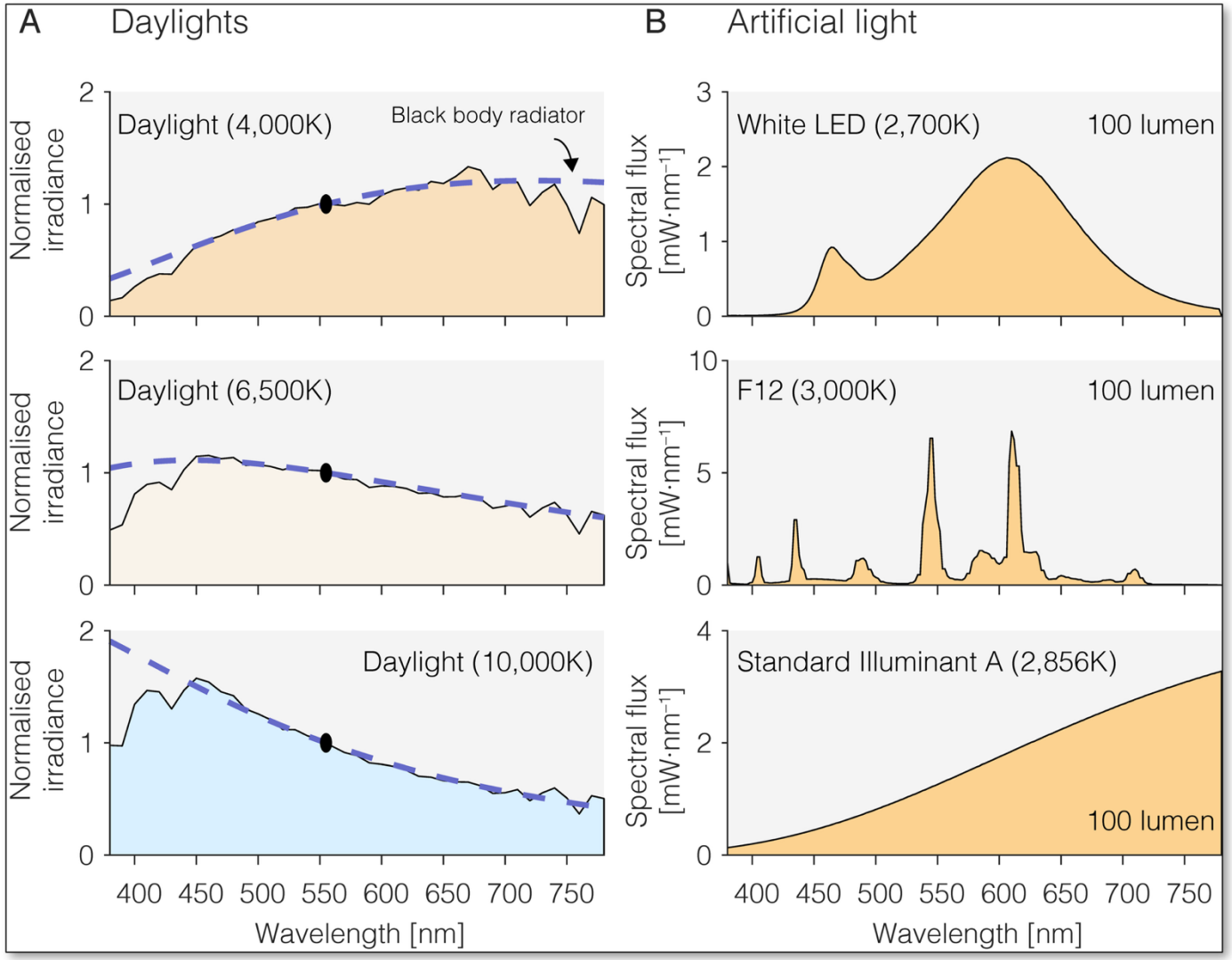




Same light, different effects: How age, gender, and other factors influence the effects of light

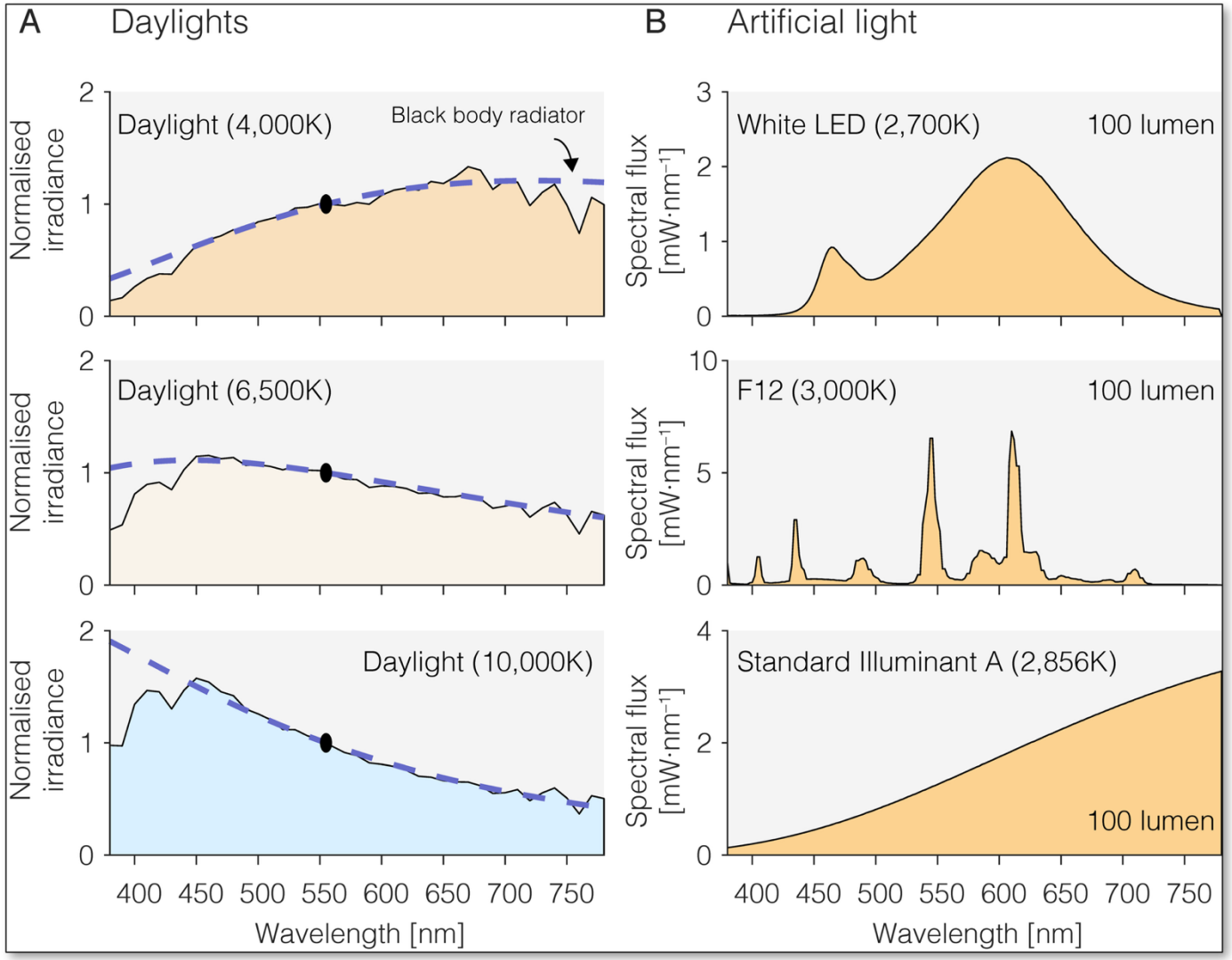
The types of light we see throughout the day: Daylight vs. electric light

Light can be described by its spectrum: how much energy there is at each **wavelength** across the **visible spectrum** (from approximately 380 to 780 nm).



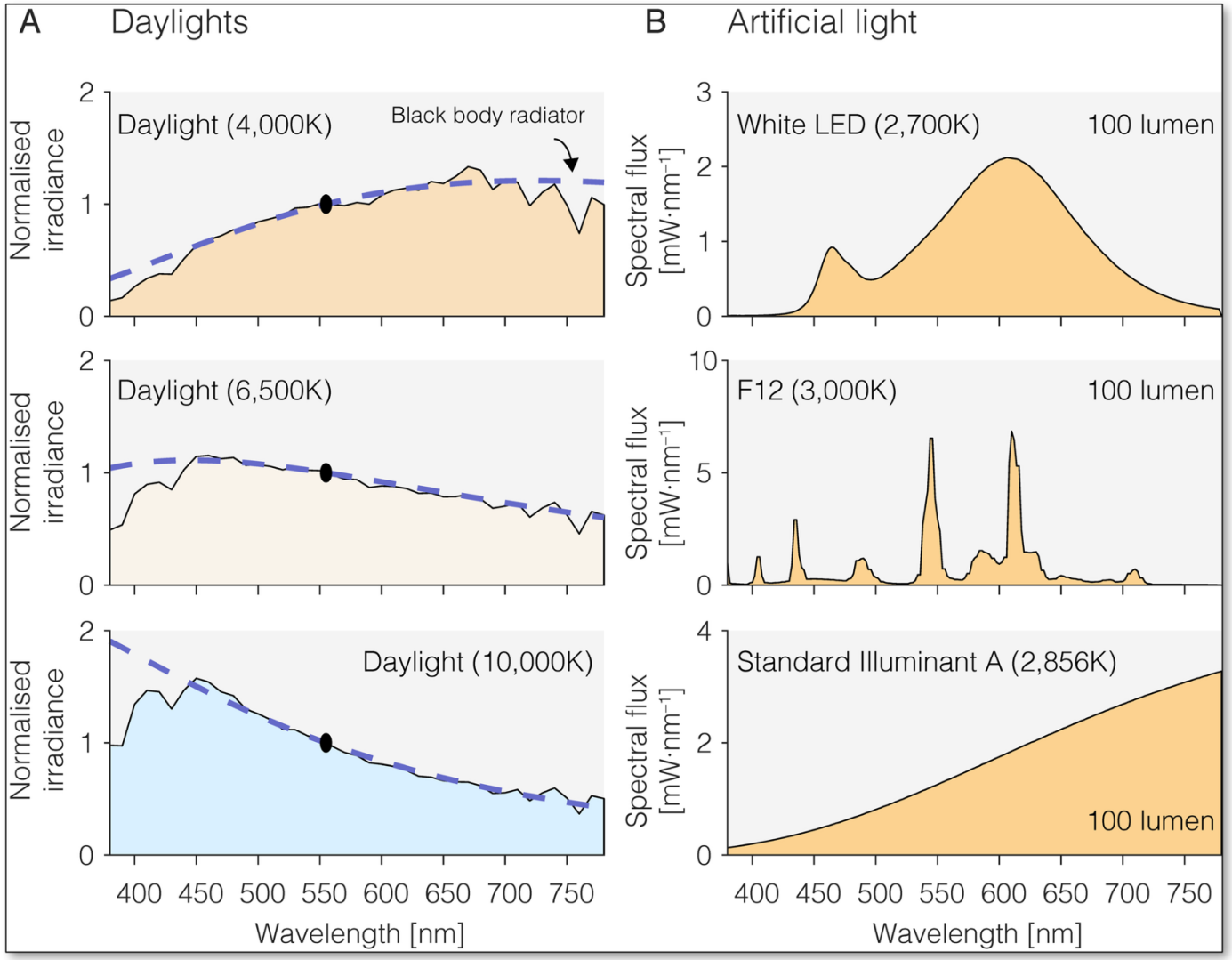
The types of light we see throughout the day: Daylight vs. electric light

Different electric light sources (e.g., LED or fluorescent lamps, etc.) have **different spectra**.



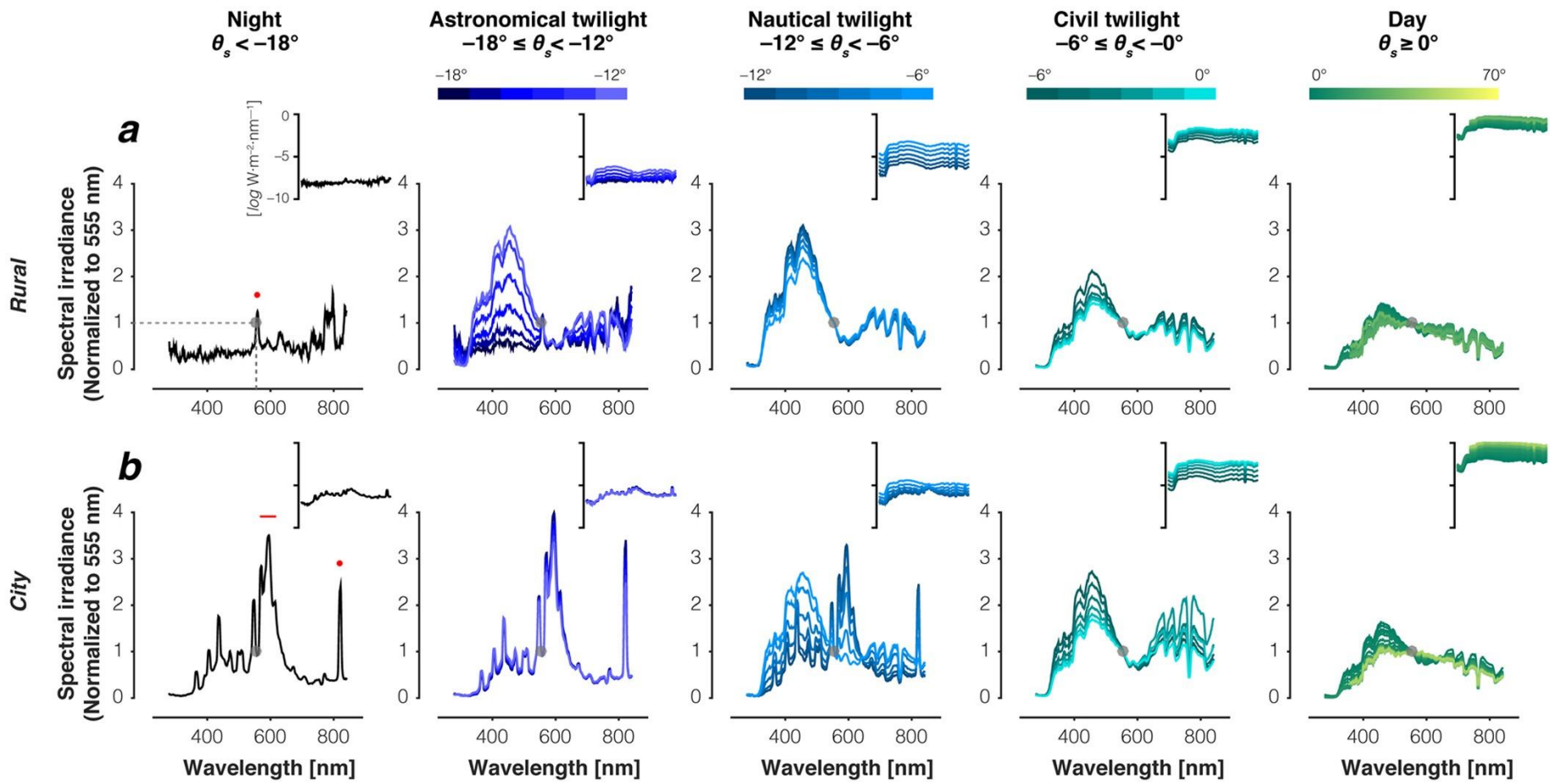
The types of light we see throughout the day: Daylight vs. electric light

Daylight has what we call a **broad spectrum**, with a lot of energy across many wavelengths.



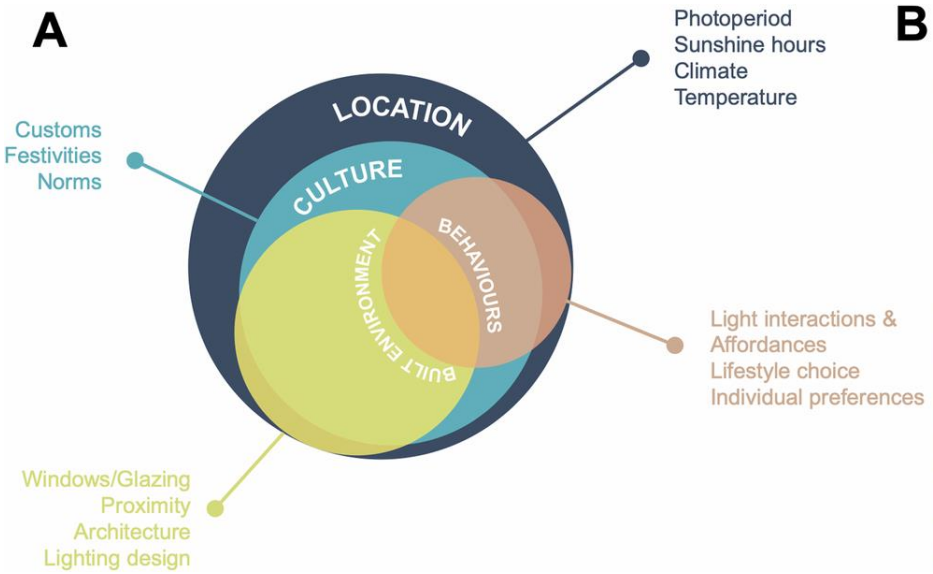
The types of light we see throughout the day: Daylight vs. electric light

The properties of daylight (spectrum, intensity and spatial distribution) vary throughout **the day and the year**, and with changing weather.



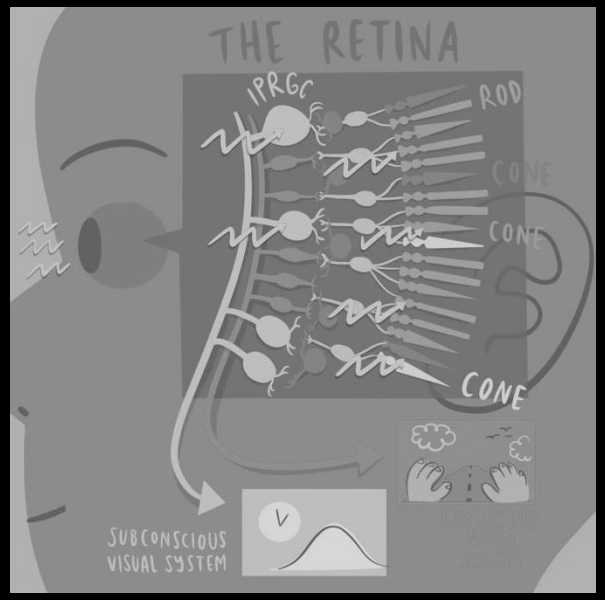
The types of light we see throughout the day: Daylight vs. electric light

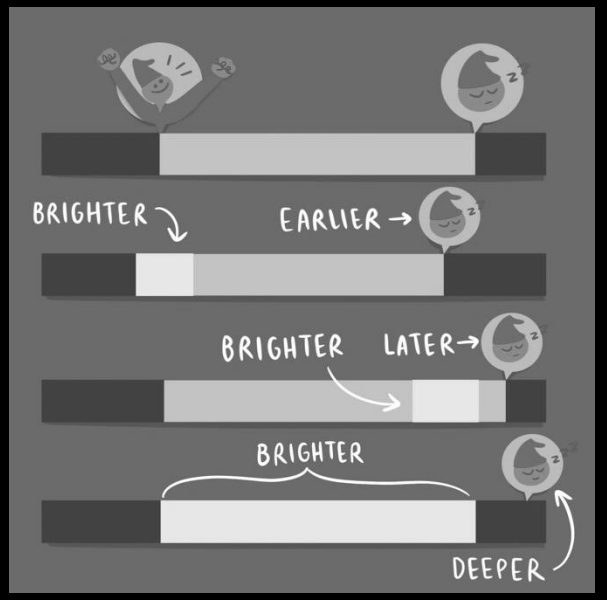
The pattern of one's light exposure across the day and the year can be quite **complex**, and depends on where one is and what one does.



Biller, Balakrishnan & Spitschan (2024)

How the eye talks to the brain: Light detection beyond vision





Exposure to light at different times of day alters the timing of sleep and wakefulness

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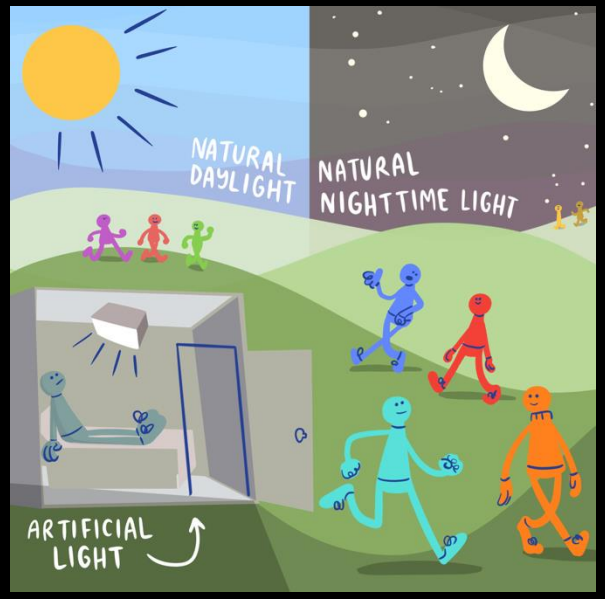

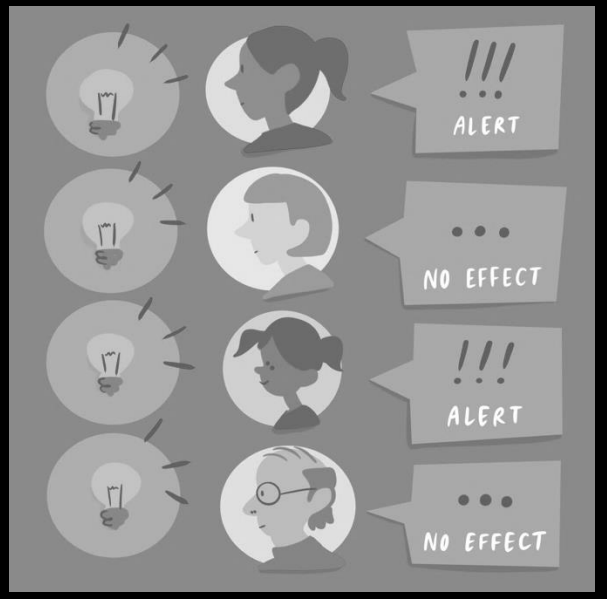

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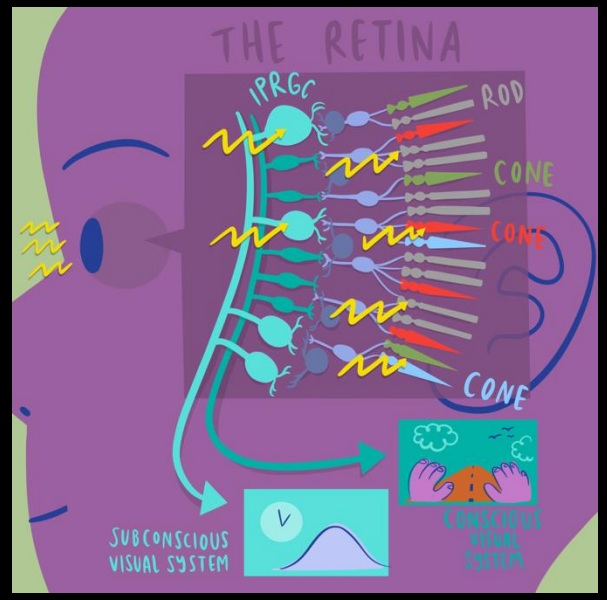

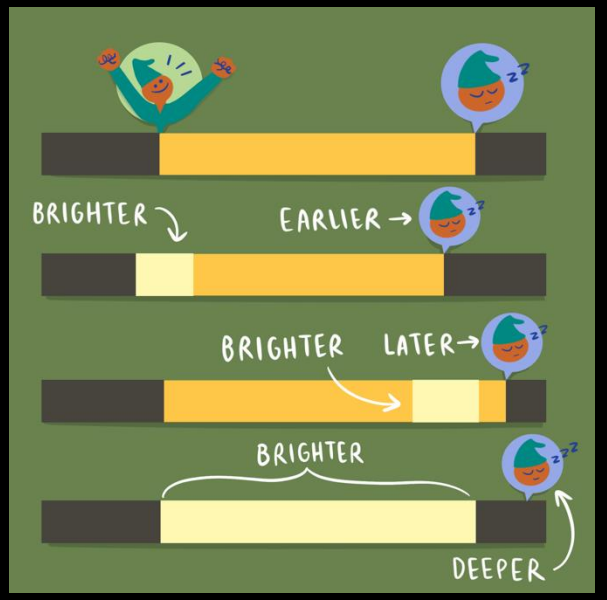

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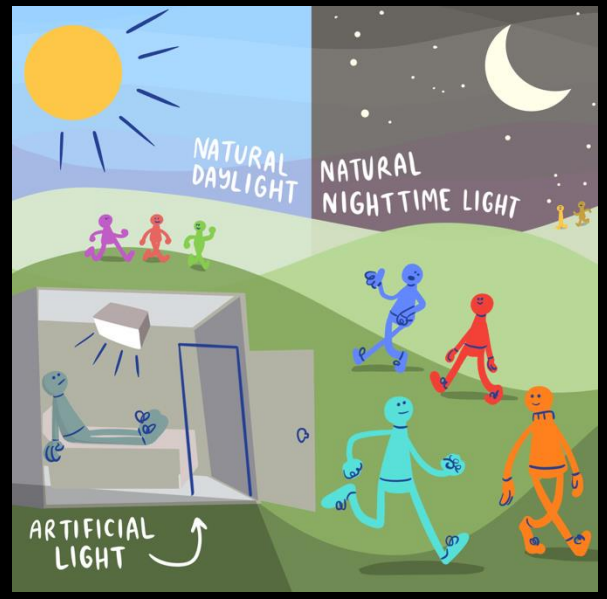

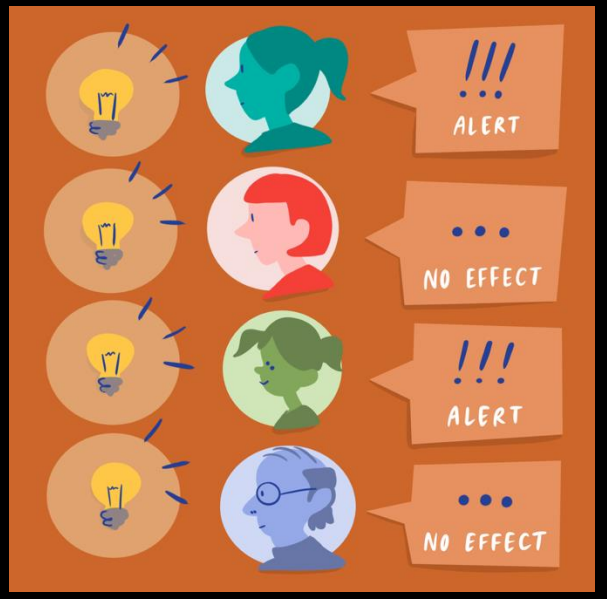

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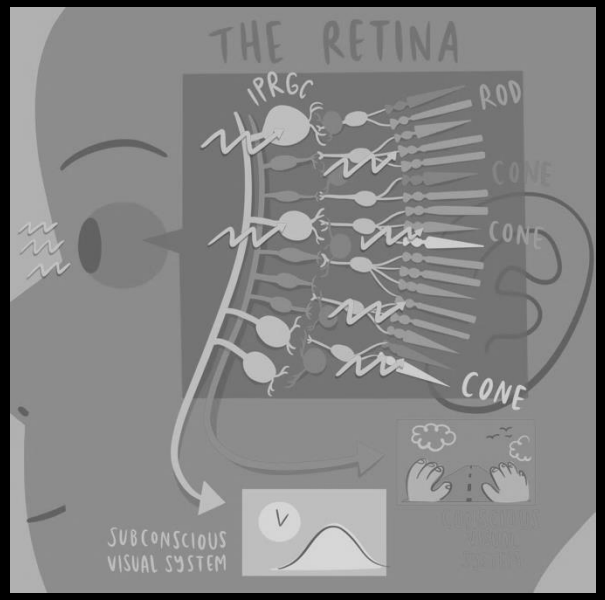

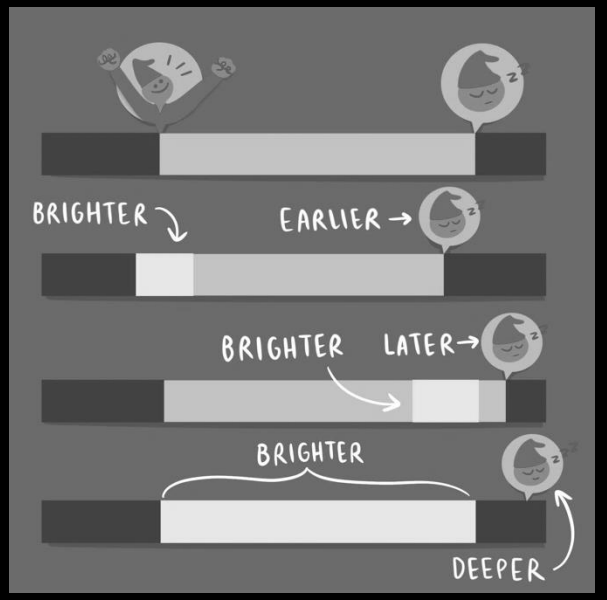

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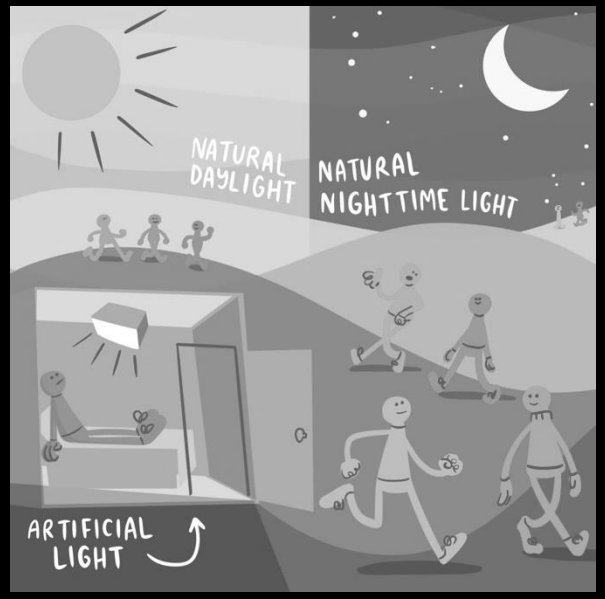
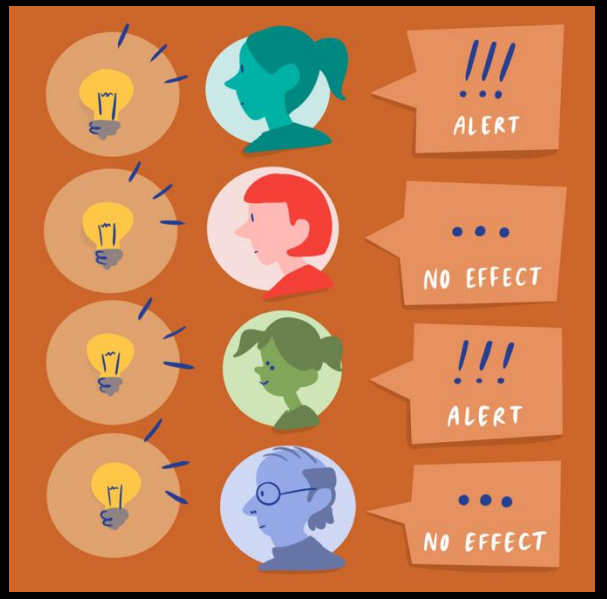




Same light, different effects: How age, gender, and other factors influence the effects of light

Same light, different effects: How age, gender, and other factors influence the effects of light

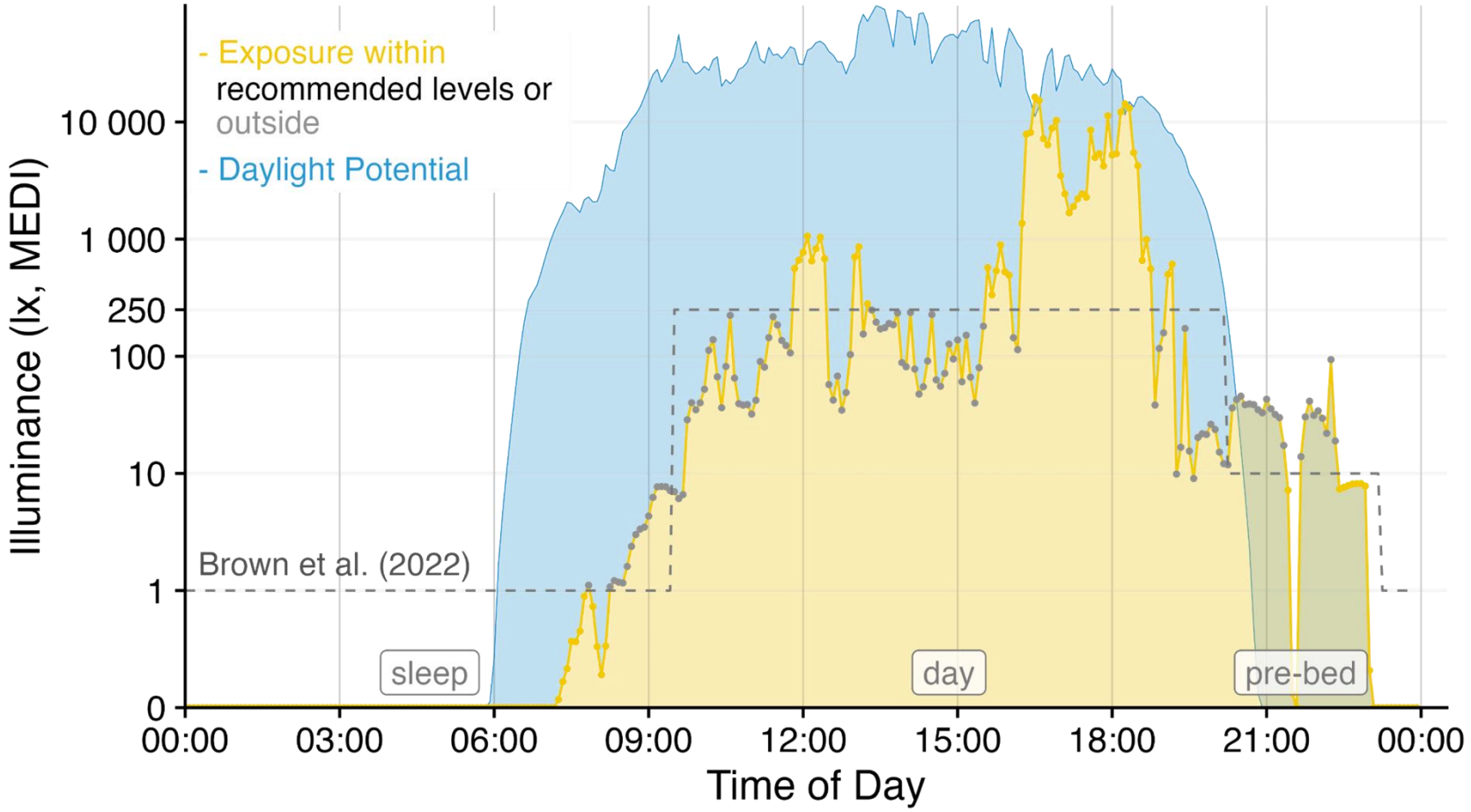
Higher light levels in the evening can **increase the time to fall asleep**.

Higher light levels during the daytime can improve **mood**.

Higher light levels during the daytime can **improve sleep quality** in the following night.

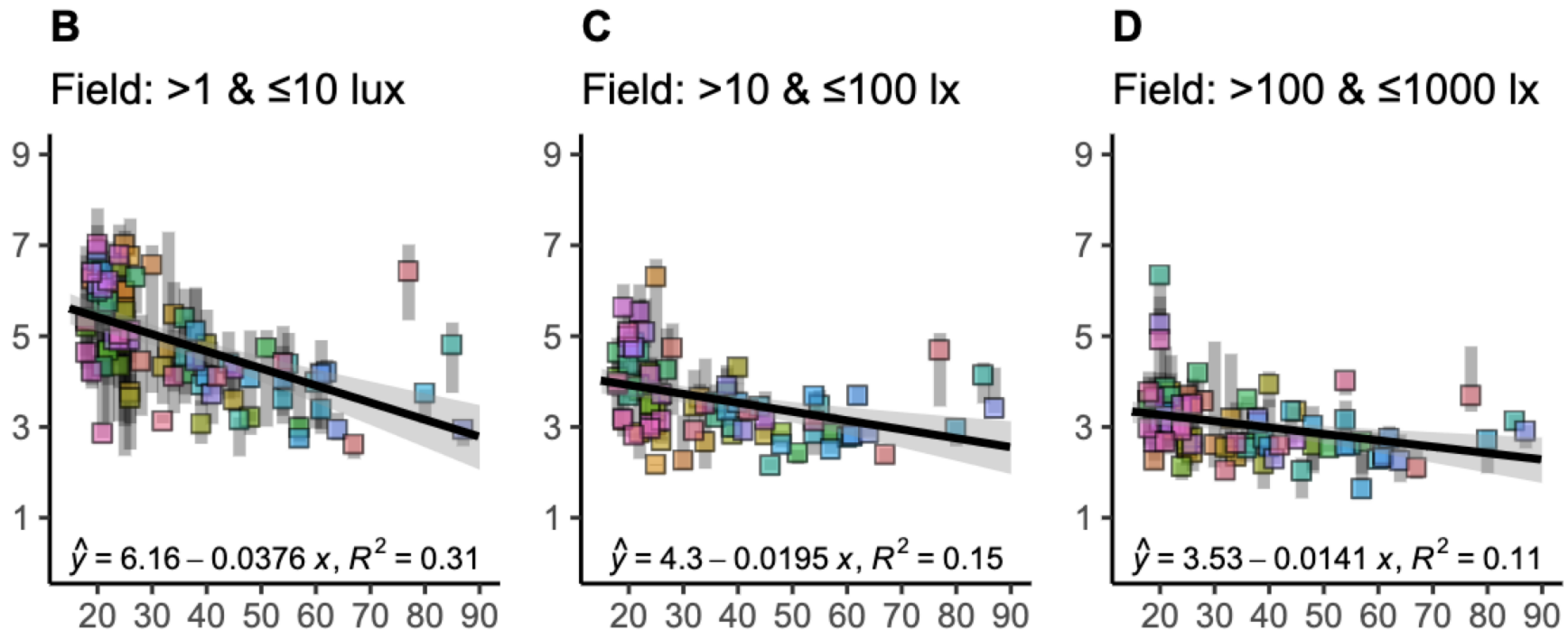
Same light, different effects: How age, gender, and other factors influence the effects of light

A healthy pattern of daily light exposure includes a rhythm of **bright light** and **darkness** every day



Same light, different effects: How age, gender, and other factors influence the effects of light

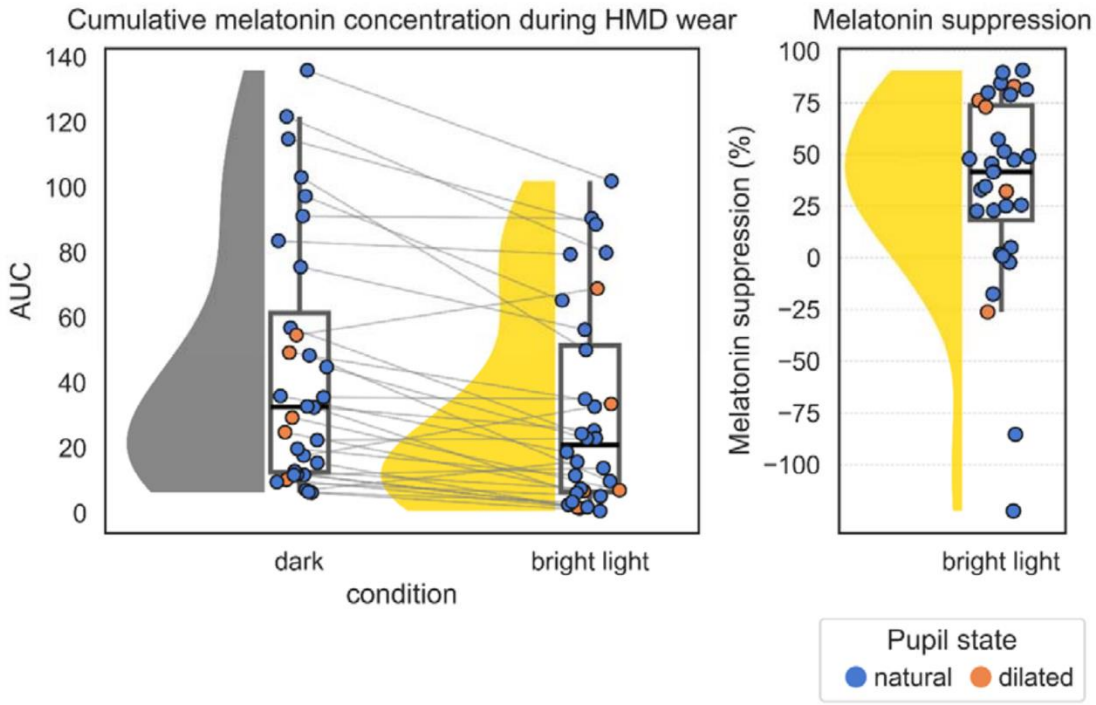
Age can influence the physiological effect of light on humans, as **less light** reaches the retina because of ageing.



Lazar et al. (2024)

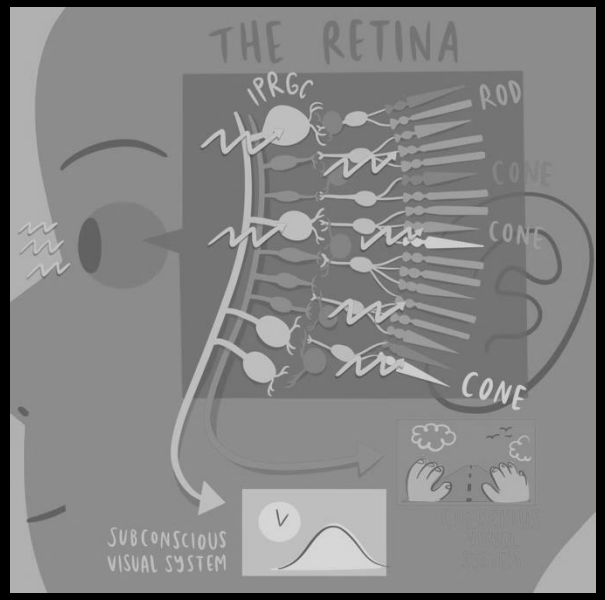
Same light, different effects: How age, gender, and other factors influence the effects of light

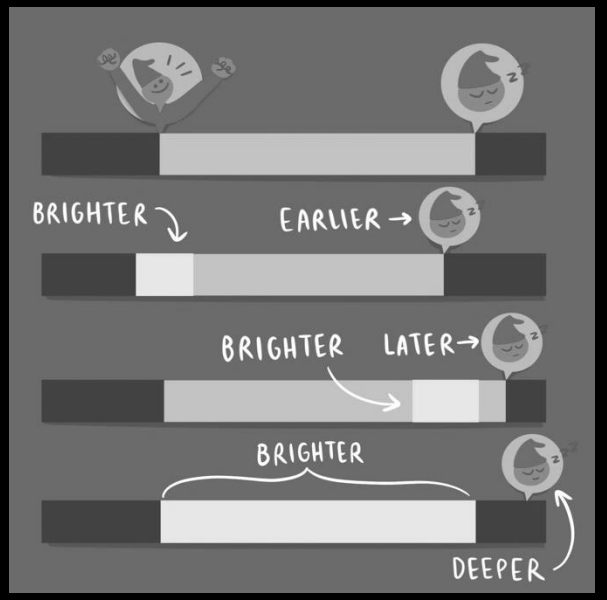
There are substantial **individual differences** in the physiological response to light



Fernandez-Alonso & Spitschan (2025)

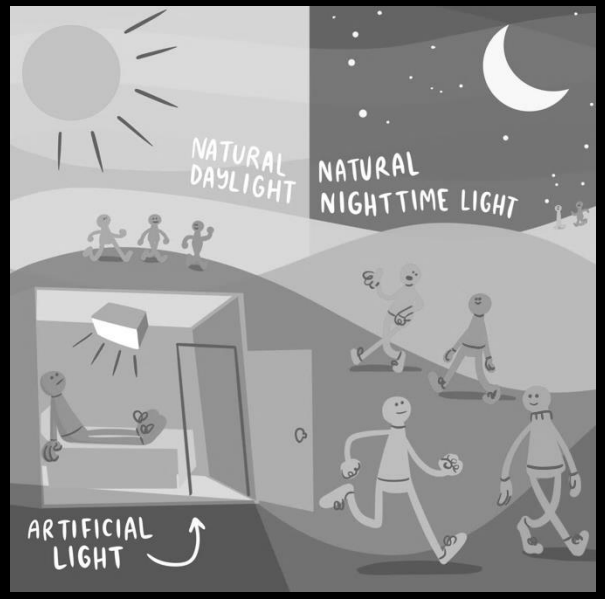
How the eye talks to the brain: Light detection beyond vision

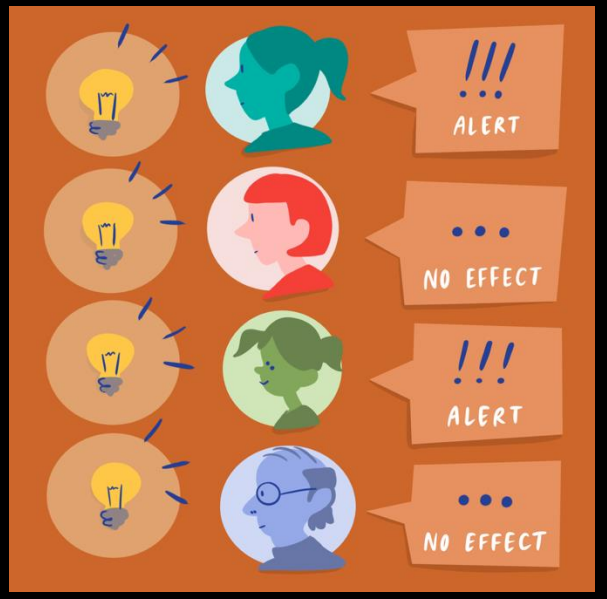




Exposure to light at different times of day alters the timing of sleep and wakefulness

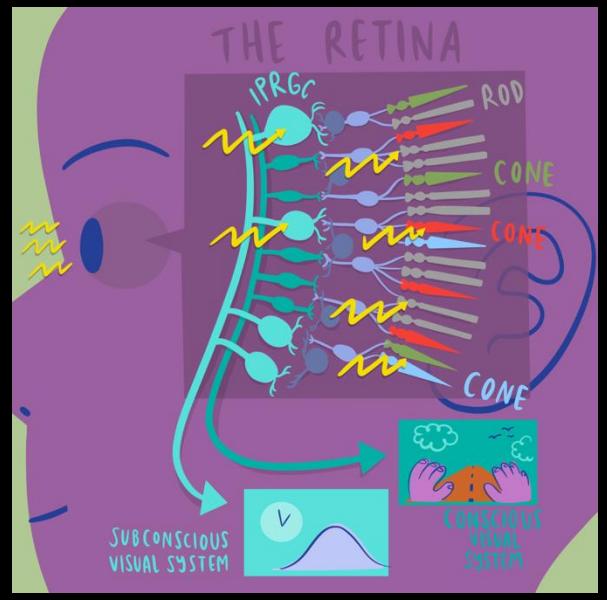
The types of light we see throughout the day: Daylight vs. electric light

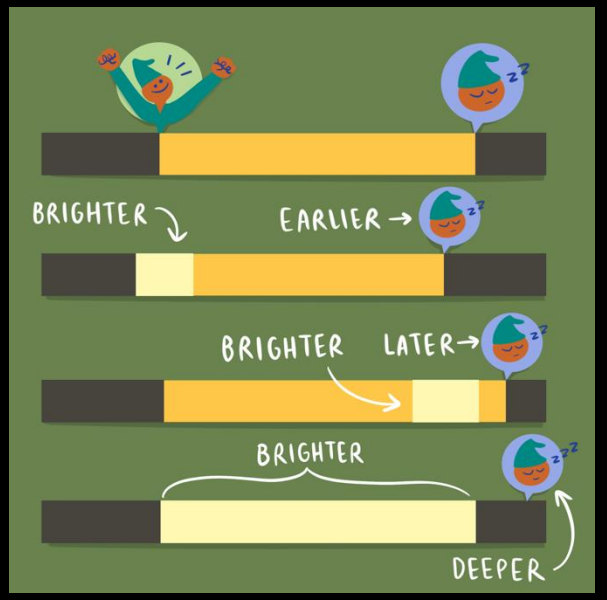




Same light, different effects: How age, gender, and other factors influence the effects of light

How the eye talks to the brain: Light detection beyond vision





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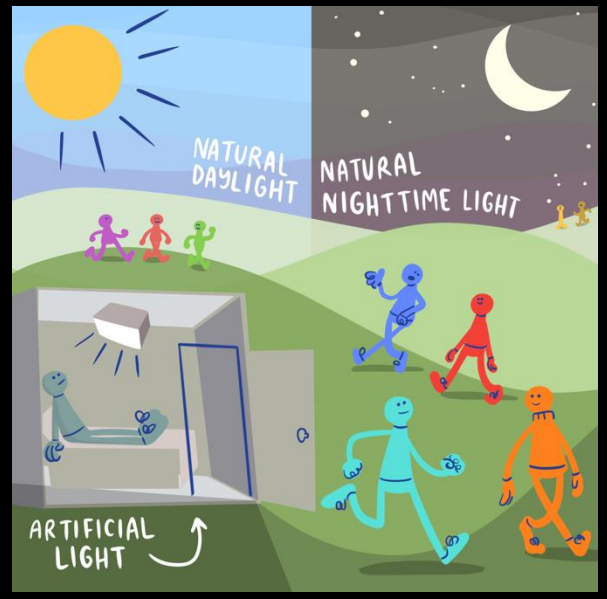

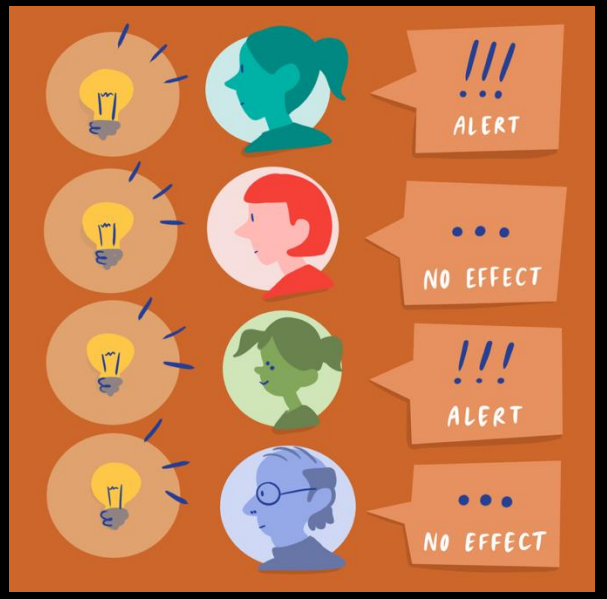

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Zooming out

The majority of studies on the physiological effects of light have been performed **in the laboratory**.

There is a need for studies on the physiological effects of light incorporating a **broad range of study populations**.

The physiological effects of light are – and remain – an area of **active** investigation.

lightforpublichealth.org

How does light affect human health? From biology to application

Prof. Dr. Manuel Spitschan

Technical University of Munich | Professor of Chronobiology and Health
TUMCREATE | Principal Investigator
Max Planck Institute for Biological Cybernetics | Research Group Leader

16 May 2025

International Day of Light

TRANSLATIONAL SENSORY & CIRCADIAN NEUROSCIENCE UNIT