WHITE PAPER by BRAINLIT

SLEEP

BIOCENTRIC LIGHTING™ AND SLEEP

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Light plays an important role not only for vision but also in the regulation of our sleep-wake cycle. A small portion of the light-sensitive cells in the eye signal to our master clock in the brain, which ensures that our circadian rhythm stays synchronized to the 24-hour solar rhythm. Light is considered the most important 'zeitgeber' – an external cue that tells the body when it is day and when it is night. Through this system, light can be used to help us sleep better at the right time, or it can impair our sleep if provided at the wrong time. BioCentric Lighting™ (BCL™) has been developed to give us the right light at the right time.

Our sleep quantity and quality vary naturally over a lifetime and are affected by many factors in life, such as seasonal changes in light exposure[1]. A short daily exposure to natural light has been linked to insufficient sleep amongst people in both the arctic part of northern Sweden and in the equatorial region of Brazil[2]. It is important to reach sufficient light levels on a daily basis as the amount of light entering the eye during one day positively affects our subjective sleep quality on the following night[3]. A growing body of research is making it increasingly clear that light impacts our sleep, and sleep in turn is a cornerstone for our health and well-being.

A growing number of scientific studies have investigated the importance of daylight for our sleep quality and rhythm. A common set-up of these studies is to compare one group of people who receive plenty of daylight during the day to one group receiving little or no daylight.

People experiencing a lack of daylight more commonly express sleep complaints such as difficulty falling asleep, nightly awakenings and insomnia[4], whereas those who receive more daylight have longer sleep durations, better sleep quality[5], and a more regular sleep rhythm[6].

”Light impacts our sleep, and sleep in turn is a cornerstone for our health and well-being.”

In summary, the research shows how important daylight is for a good night's sleep. In modern society, most of us spend about 90% of our time indoors[7] and as a result we are deprived of natural daylight. Windows and indoor electric lighting are often used to reach sufficient light levels for visual purposes, but the biological effect of light is often overlooked. To understand how light influences our biology we must first introduce a type of light-sensitive cells in the eye called ipRGCs (intrinsically photosensitive retinal ganglion cells). When light hits the retina in our eyes, the ipRGCs signal to the master clock (a brain region called the suprachiasmatic nucleus) that it is daytime, and the master clock responds by suppressing the production of the sleep hormone melatonin.

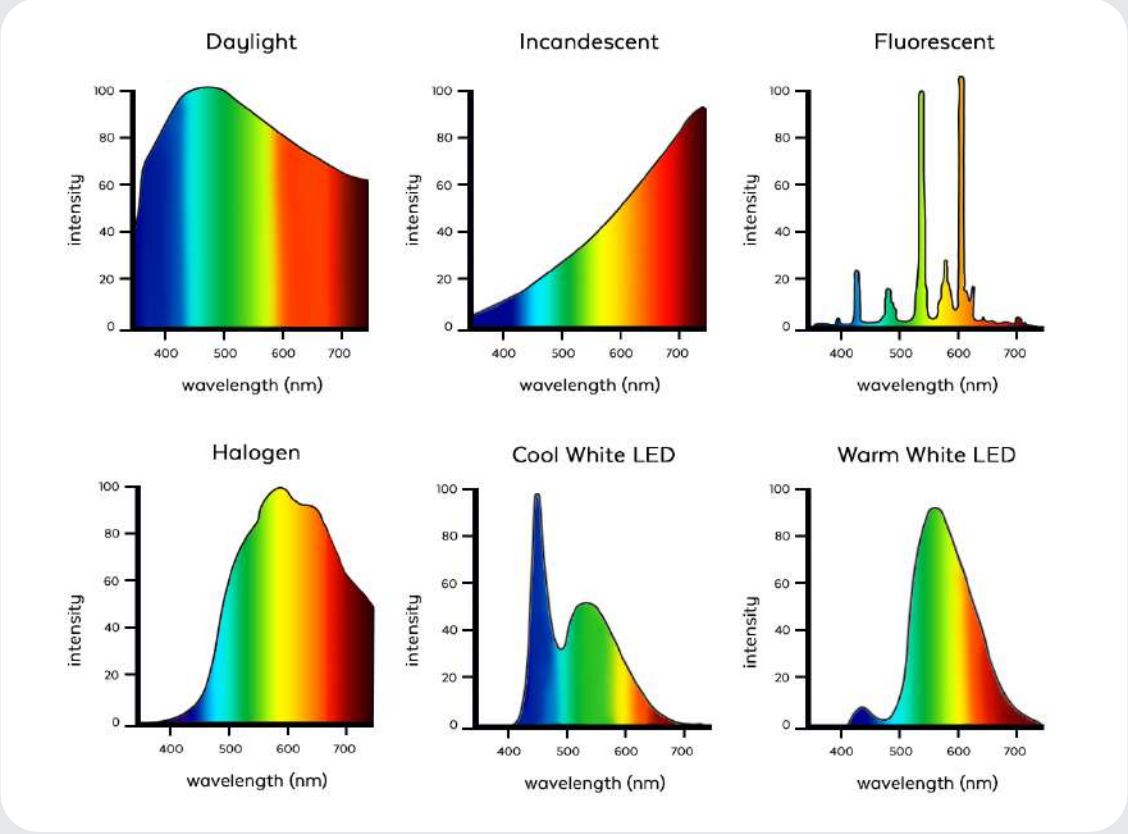


Figure: The spectral composition of different light sources

When the sun sets and we turn down our indoor lighting, the master clock instead signals to the pineal gland in the brain to start producing melatonin to help us fall asleep. The ipRGCs are especially sensitive to light of blue wavelengths (around 480 nm). Therefore, light sources that contain plenty of blue wavelengths are sometimes called circadian-effective light because they help us maintain a regular daily (circadian) rhythm.

White light sources – such as sunlight, fluorescent lights, and LEDs – may all appear similar but can have completely different spectral distributions (see figure). Sunlight is composed of all colors of the rainbow, whereas fluorescent lights are often lacking enough amounts of blue light.
BioCentric Lighting™ is a dynamic LED lighting system adapted to simulate sunlight to give us the right amount of light at the right time of day. BCL™ is enriched in the blue wavelengths to create a strong effect on our internal master clock early during the day.

Previous studies have shown that blue-enriched light can improve sleep quality compared to standard white light[8]. A higher light intensity can also be used to improve sleep efficiency, shorten sleep latency, and prolong sleep duration[9-12]. Moreover, dynamic lighting with higher intensity and color temperature (a higher color temperature generally means more blue light) during the day can help us fall asleep faster[13].

"Providing a boost of bright light early in the day can help patients suffering from a range of diseases to improve their sleep"

Scientists have developed various metrics to describe the degree to which a light source stimulates our circadian rhythm to help us evaluate light sources. One of these metrics is circadian stimulus (CS), which describes to what degree the light source would suppress melatonin levels if given for one hour at night. A high CS value is recommended early in the morning and throughout the day, and lower CS values are recommended in the evening, providing the best conditions to improve sleep quality[14].

Various light regulation methods can be used by themselves or in combination with a sleep schedule to help individuals with sleep disturbances or irregular rhythms. One such type of light regulation involves using light-emitting goggles that provide additional light in the morning and amber-lens glasses to filter out blue light before bedtime. This type of light regulation can help individuals fall asleep more easily, and when combined with a fixed sleep-wake schedule it may also improve perceived sleep quality[15].

Providing a boost of bright light early in the day can help patients suffering from a range of diseases, including burnout patients and patients with cancer-related fatigue, to improve their sleep[16-19]. As our eyes change with age, diseases of the eye itself become more common. A cataract is a clouding of the eye's lens, leading to lower light levels hitting the retina at the back of the eye. Surgery to replace the natural lens of the eye with an artificial intraocular lens has been shown to improve sleep quality in cataract patients[20].

Light affects our sleep-wake schedule

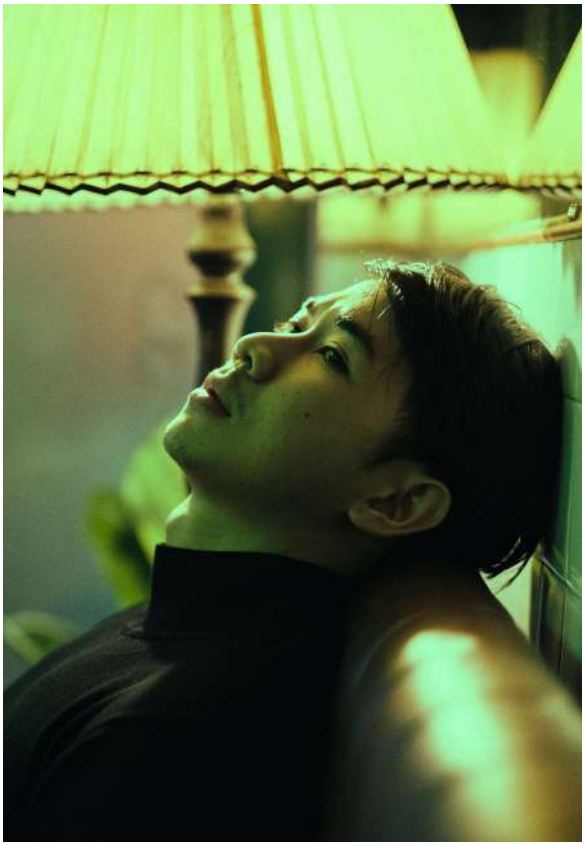
In the evening, our bodies prepare us for bedtime by increasing the production of the hormone melatonin. The levels of melatonin start rising 2-3 hours before habitual bedtime, and since this rise in melatonin generally appears in dim light, the time when this occurs is called dim light melatonin onset (DLMO). The timing of DLMO is often used in research as a measure of our circadian phase to see if an individual has a regular rhythm or not, or to see if the rhythm is shifting in any direction as a result of treatment.

A study on undergraduate students showed that those with highly regular sleep schedules generally had higher light levels during the day and earlier DLMO than those with irregular sleep. Regular sleep was also linked to better academic performance[21].

Lower light exposure in the early morning and afternoon has been associated with delayed sleep amongst adolescents[22]. In fact, increasing the light exposure by providing bright white light for 30-45 minutes per day in combination with scheduled rise times can help advance the sleep schedules of individuals with delayed sleep phase disorder[23]. Morning bright light can also be used in combination with afternoon melatonin administration to promote phase advance of the circadian rhythm[24].

Many of us spend our evenings in front of screens or with moderate levels of electrical lighting in our homes. Blue-enriched morning light can help stabilize the circadian phase by counteracting the effect of light exposure in the evening[25]. As with the effect of light on sleep quality, different properties of light determine its potential to advance or delay our rhythm. Higher intensities of light given in the morning has shown to be more effective in creating a phase advance[26]. As described above, the color of the light source is also relevant to consider. Flashing blue, but not red, light through closed eyelids of older adults with early awakening insomnia during the early part of sleep period significantly delayed DLMO without affecting sleep efficiency[27].

Removing short-wavelength light in the morning delayed the DLMO of 8th-grade students by 30 minutes after a five-day intervention[28]. In summary, DLMO can be delayed either by supplying blue light in the evening/early night or by removing short-wavelength light (blue light) in the morning. Conversely, DLMO can be advanced by providing bright light in the morning. Light is therefore a powerful tool to help us adjust our circadian rhythm when it is misaligned because of jet lag, insomnia, or other reasons.



Summary

- **Light is the most important environmental cue that helps us realign our circadian rhythm to the solar day**
- **Getting plenty of daylight during the day will help us improve our sleep quality and fall asleep faster**
- **Light in the early morning will advance our rhythm and help us fall asleep earlier**
- **Higher intensity blue-enriched light in the evening will delay our rhythm so that we fall asleep later.**

Most of us do not get the right amount of light at the right time to sleep well. Emerging research provide a better understanding of the beneficial effects of light on sleep and are continuously integrated in our BioCentric Lighting™ (BCL™) solutions. BCL™ is easily customized to provide the user with the light that they need. Our vision is to create individualized solutions that meet the specific needs of each user to improve sleep, health, and well-being.

References

1. Figueiro, M. G. R., M.S. Office lighting and personal light exposures in two seasons: Impact on sleep and mood. Lighting Res. Technol. 48, 352-364, doi:https://doi.org/10.1177/1477153514564098 (2016).

2. Marqueze, E. C. et al. Natural light exposure, sleep and depression among day workers and shiftworkers at arctic and equatorial latitudes. PLoS One 10, e0122078, doi:10.1371/journal.pone.0122078 (2015).

3. Hubalek, S. B., M.; Schierz, C. Office workers' daily exposure to light and its influence on sleep quality and mood. Lighting Research & Technology. 42, 33-50, doi:10.1177/1477153509355632 (2010).

4. Leger, D., Bayon, V., Elbaz, M., Philip, P. & Choudat, D. Underexposure to light at work and its association to insomnia and sleepiness: a cross-sectional study of 13,296 workers of one transportation company. J Psychosom Res 70, 29-36, doi:10.1016/j.jpsychores.2010.09.006 (2011).

5. Boubekri, M., Cheung, I. N., Reid, K. J., Wang, C. H. & Zee, P. C. 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, 603-611, doi:10.5664/jcsm.3780 (2014).

6. Nagare, R. et al. Access to Daylight at Home Improves Circadian Alignment, Sleep, and Mental Health in Healthy Adults: A Crossover Study. Int J Environ Res Public Health 18, doi:10.3390/ijerph18199980 (2021).

7. Klepeis, N. E. et al. The National Human Activity Pattern Survey (NHAPS): a resource for assessing exposure to environmental pollutants. J Expo Anal Environ Epidemiol 11, 231-252, doi:10.1038/sj.jea.7500165 (2001).

8. Viola, A. U., James, L. M., Schlangen, L. J. & Dijk, D. J. Blue-enriched white light in the workplace improves self-reported alertness, performance and sleep quality. Scand J Work Environ Health 34, 297-306, doi:10.5271/sjweh.1268 (2008).

9. Ma, J. et al. Decreased functional connectivity within the salience network after two-week morning bright light exposure in individuals with sleep disturbances: a preliminary randomized controlled trial. Sleep Med 74, 66-72, doi:10.1016/j.sleep.2020.05.009 (2020).

10. Estevan, I., Tassino, B., Vetter, C. & Silva, A. Bidirectional association between light exposure and sleep in adolescents. J Sleep Res, e13501, doi:10.1111/jsr.13501 (2021).

11. Dautovich, N. D. et al. A systematic review of the amount and timing of light in association with objective and subjective sleep outcomes in community-dwelling adults. Sleep Health 5, 31-48, doi:10.1016/j.sleh.2018.09.006 (2019).

12. van Maanen, A., Meijer, A. M., van der Heijden, K. B. & Oort, F. J. The effects of light therapy on sleep problems: A systematic review and meta-analysis. Sleep Med Rev 29, 52-62, doi:10.1016/j.smrv.2015.08.009 (2016).

13. Canazei, M. D., P.; Staggl, S.; Pohl, W. Effects of dynamic ambient lighting on female permanent morning shift workers. Lighting Res. Technol. 46, 140-156, doi:https://doi.org/10.1177/1477153513475914 (2014).

14. Figueiro, M. G. et al. The impact of daytime light exposures on sleep and mood in office workers. Sleep Health 3, 204-215, doi:10.1016/j.sleh.2017.03.005 (2017).

15. Knufinke, M. et al. Dim light, sleep tight, and wake up bright - Sleep optimization in athletes by means of light regulation. Eur J Sport Sci 21, 7-15, doi:10.1080/17461391.2020.1722255 (2021).

16. Formentin, C. et al. Effect of Morning Light Glasses and Night Short-Wavelength Filter Glasses on Sleep-Wake Rhythmicity in Medical Inpatients. Front Physiol 11, 5, doi:10.3389/fphys.2020.00005 (2020).

17. Gimenez, M. C. et al. Patient room lighting influences on sleep, appraisal and mood in hospitalized people. J Sleep Res 26, 236-246, doi:10.1111/jsr.12470 (2017).

18. Canazei, M. et al. Effects of an adjunctive, chronotype-based light therapy in hospitalized patients with severe burnout symptoms - a pilot study. Chronobiol Int 36, 993-1004, doi:10.1080/07420528.2019.1604539 (2019).

19. Wu, L. M. et al. The Effect of Systematic Light Exposure on Sleep in a Mixed Group of Fatigued Cancer Survivors. J Clin Sleep Med 14, 31-39, doi:10.5664/jcsm.6874 (2018).

20. Alexander, I. et al. Impact of cataract surgery on sleep in patients receiving either ultraviolet-blocking or blue-filtering intraocular lens implants. Invest Ophthalmol Vis Sci 55, 4999-5004, doi:10.1167/iovs.14-14054 (2014).

21. Phillips, A. J. K. et al. Irregular sleep/wake patterns are associated with poorer academic performance and delayed circadian and sleep/wake timing. Sci Rep 7, 3216, doi:10.1038/s41598-017-03171-4 (2017).

22. Gasperetti, C. E., Dolsen, M. R. & Harvey, A. G. The influence of intensity and timing of daily light exposure on subjective and objective sleep in adolescents with an evening circadian preference. Sleep Med 79, 166-174, doi:10.1016/j.sleep.2020.11.014 (2021).

23. Danielsson, K., Jansson-Frojmark, M., Broman, J. E. & Markstrom, A. Light Therapy With Scheduled Rise Times in Young Adults With Delayed Sleep Phase Disorder: Therapeutic Outcomes and Possible Predictors. Behav Sleep Med 16, 325-336, doi:10.1080/15402002.2016.1210150 (2018).

24. Crowley, S. J. & Eastman, C. I. Phase advancing human circadian rhythms with morning bright light, afternoon melatonin, and gradually shifted sleep: can we reduce morning bright-light duration? Sleep Med 16, 288-297, doi:10.1016/j.sleep.2014.12.004 (2015).

25. Munch, M. et al. Blue-Enriched Morning Light as a Countermeasure to Light at the Wrong Time: Effects on Cognition, Sleepiness, Sleep, and Circadian Phase. Neuropsychobiology 74, 207-218, doi:10.1159/000477093 (2016).

26. Kozaki, T., Toda, N., Noguchi, H. & Yasukouchi, A. Effects of different light intensities in the morning on dim light melatonin onset. J Physiol Anthropol 30, 97-102, doi:10.2114/jpa2.30.97 (2011).

27. Figueiro, M. G. Individually tailored light intervention through closed eyelids to promote circadian alignment and sleep health. Sleep Health 1, 75-82, doi:10.1016/j.sleh.2014.12.009 (2015).

28. Figueiro, M. G. & Rea, M. S. Lack of short-wavelength light during the school day delays dim light melatonin onset (DLMO) in middle school students. Neuro Endocrinol Lett 31, 92-96 (2010).

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