

## BioCentric Lighting™ in Industry

---



*In the modern, high-tech industries of today, precision and safety are two of the most highly prioritized areas. An increasing knowledge of the importance of the lighting environments influence on these issues has changed the way we look at lighting. Lighting needs to support visual needs and ergonomics but light is also important for well-being and sleep. New research has pointed out the importance of light as an enabler for well-being and the most important synchronizer of circadian rhythm and sleep.*

### **Light can improve attention and cognition**

Light and especially blue light exert an alerting effect on the human brain. The physiology behind this was understood only 20 years ago with the discovery of a new type of photoreceptor in the retina, a subpopulation of retinal ganglion cells (intra photoreceptive retinal ganglion cells ipRGCs), activated primarily by blue light<sup>1</sup>. When blue light hits the eye the ipRGCs project through the optic nerve and affect non-visual forming areas in the brain important for alertness and cognition such as the prefrontal cortex and the

hippocampal area in the midbrain<sup>2</sup>. MRI-experiments illustrating increased activity in these specific brain regions have shown that light, and especially blue light, can modulate brain responses already after a few minutes exposure<sup>3</sup>.

In an experiment with 21 individuals, 1 hour exposure to 40 lx blue light (470 nm) was found to be as effective as 240 mg caffeine in a reaction test and the blue light outperformed caffeine when distractions were presented<sup>4</sup>. In another study acute wake-promoting effects and faster reaction times was seen with blue enriched light in the first half of the day (8-11 am) than with warm-white light from incandescent bulbs. Some of these effects even persisted until the evening. The blue-enriched light was also shown to be protective against detrimental melatonin-suppressing light at nights<sup>5</sup>. The alerting effect of short-wavelength light has thus led to the suggestion that light can be used as a non-pharmacological countermeasure for sleepiness and to improve reaction times among employees.

## Light has a positive impact on mood

Bright light indoors can increase the level of vitality and energy. It can also decrease the intensity of depressive symptoms even in persons not having seasonal change in mood or behavior<sup>6</sup>. It has been shown in



### *Light makes us happy*

experiments with MRI chambers that light affect areas in the brain important for our feelings<sup>3</sup>. Adequate lighting is associated with a feeling of happiness while dark lighting induces feelings of depression. Blue-toned white light has shown a direct subjective mood enhancing effect<sup>7</sup> and when grown ups and young adults rate their mood, it is the blue light that is given the highest mood scores<sup>8</sup>.

## Many people are sleep deprived

In the evening the sleep hormone melatonin makes us tired and it peaks in the middle of the night. When we wake up, daylight has a suppressing effect on the release of melatonin and we feel awake and alert. This circadian sleep-wake rhythm needs to be aligned with light daily not to fall out of sync with the solar day.

Our modern lifestyle with 90% of time spent indoors, most of the time provides insufficient light for synchronization with the solar day. Without this synchronization, the release of melatonin in the evening gets delayed and sleep gets pushed to a later hour. A vicious circle with later bedtime and less sleep becomes



*Many people are sleep deprived*

the result. We have diminished our sleep by 1 hour only the last 10 years and most of us get less than the required 7 hours of sleep per night<sup>9</sup>.

Sleep deprivation leaves the brain exhausted and makes it more difficult to concentrate and learn new things. Impaired reaction time and disturbed cognitive abilities may contribute to the increased risk of accidents with sleep loss<sup>9</sup>, 10.

Also, in the long term lack of sleep is a problem, as sleep deprivation may lead to obesity, diabetes and cardiovascular diseases<sup>9</sup>.



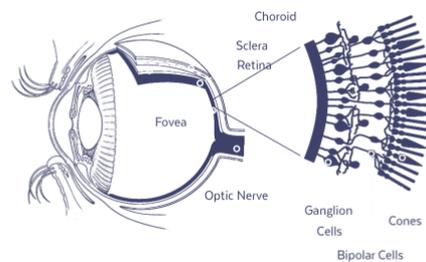
*Many workers are depending on artificial lighting*

Industrial premises are often windowless; consequentially employees rely on their

workplace for getting the light they need for entrainment to the solar day.

## Light to restore a disturbed sleep

When activated with light, the retina and more precisely the ipRGCs, send signals to time-keeping centra located in the suprachiasmatic nuclei, the Master clock, in the hypothalamus in the brain that uses this information to direct the body for its daily activities.



### *Light sensitive retinal ganglion cells*

When stimulated, the brain gets alert and the body clock is set to daytime and productivity mode. This time-keeping system dictates our circadian sleep/wake cycle. For it to be efficient, it needs enough light to be activated, often more light than is needed for vision. Furthermore, the system is more sensitive to light with shorter bluer wavelengths (480 nm)<sup>11</sup>.

The timing of light is also important as blue light sources as in handheld devices at night is detrimental to the circadian rhythm as this confuses the system in believing it is daytime.

The human circadian system is also influenced by prior lighting environment. Light during daytime can protect against aberrant light in the evening. In studies by

Kozaki et al, 900 lx of white light (4523 K) or 79 lx of bluish white light (9584K) in the first half of the day were enough to protect against 90 min night light exposure (300 lx) that would otherwise have induced a suppression of night-time melatonin<sup>12, 13</sup>.

Taking the knowledge regarding human physiology further, researchers are also investigating the effect of dynamic lighting. In one experiment, a dynamic lighting environment was shown to be superior to constant light (400 lx, 750 lx 5 000 K) in promoting higher levels of melatonin at night beneficial for sleep. According to the authors this could be because dynamic light would more mimic daylight.



#### *Dynamic light can prevent “post-lunch dip”*

Another interesting fact the researchers reported was that with dynamic light no “post lunch dip” was seen as was seen in all the other lighting conditions<sup>14</sup>. Disrupting sleepiness during the post-lunch

dip may result in a decrease in human errors and accidents.

## **Shift work**

Shift work is a common practice in the industrial sector. It is widely known that this has a negative effect on sleep quality and on the diurnal (circadian) rhythm. Many shift workers experience symptoms of sleep such as excessive sleepiness or insomnia, and drowsiness at work leads to human errors. The Chernobyl nuclear disaster and space shuttle Challenger accident are both thought to have been caused by poor judgment as a result of extended shift work and loss of vigilance<sup>9</sup>.

Those working the night shift are susceptible to debilitating health effects due to lack of sleep and poor eating habits. Shift work is associated with cardiovascular disease, diabetes and cancer<sup>9</sup>.

Studies have shown that exposure to high levels of bright light at night increases alertness but this has to be balanced with the effect that light has on suppression of the sleep hormone melatonin. Emerging research has shown possible alternatives with reduction of lower wavelengths with lower impact on melatonin suppression while preserving the alerting effect of light<sup>15</sup>.

We all know that some perform better in the morning whereas others prefer nighttime work. Research among athletes have shown physical performance differences up to 26% over the course of the day depending on the type<sup>16</sup>. Measures of diurnal preference or “chronotype” might therefore also be important in scheduling shift work and timed light exposure according to the individual’s circadian rhythm.

## Lighting as a tool at the workplace

Industrial workplaces require numerous solutions for different locations with specialized layouts. The lighting needs to provide correct lighting allowing personnel to focus on their task and retain energy, despite potentially unsociable hours of work. Dynamic lighting system can be adapted to the special requirements of the industrial sector, providing correct lighting conditions and safe environments.

At times, tasks may require a much higher level of concentration and wakefulness. In these cases, the alerting effect of light can be used in “light showers” as a mean to boost attention and alertness.

## Summary

- Lighting in industrial workplaces are often weak and insufficient to stimulate circadian rhythm
- Adequate lighting promotes sleep and well-being
- Light can promote alertness and has a positive impact on mood

## References:

1. Hattar S, Liao HW, Takao M, Berson DM, Yau KW *Melanopsin-containing retinal ganglion cells: architecture, projections, and intrinsic photosensitivity* Science (2002) Feb 8;295(5557):1065-70
2. Alkozei A, Smith R, Dailey NS, Bajaj S, Killgore WDS. *Acute exposure to blue wavelength light during memory consolidation improves verbal memory performance* PLoS One (2017) Sep 18;12(9):e0184884

- Many people are sleep deprived
- Light can be a tool in the workplace

Lighting plays a key role in creating an efficient environment to ensure that employees reach their full potential. Industry premises are often without daylight and rely on artificial lighting. Our advanced natural light environments provide the appropriate conditions for a safe and secure workplace. Lighting in a workplace influences our state of mood and lighting environments must create conditions that motivates personnel and promotes well-being. With BioCentric Lighting™ system (BCL™), staff is healthier, employee turnover has reduced, and the employer appeal has increased.

With BCL™, interior light can be controlled so that it dynamically changes during the day in the way daylight does and provides synchronization with the bodily rhythms. The BCL™ system is easily customized according to the unique needs of the individual workplace. The light environment provides the employees with the light that they need each day, regardless of season. This research is still evolving and continues to provide new understandings of the beneficial effects of different lighting environments in an industrial setting. The BCL™ system is easily adaptable to meet these new insights.

3. Vandewalle G, Maquet P, Dijk DJ *Light as a modulator of cognitive brain function*. Trends Cogn Sci (2009) Oct;13(10):429-38
4. Beaven CM, Ekström J *A comparison of blue light and caffeine effects on cognitive function and alertness in humans* PLoS One (2013) Oct 7;8(10):e76707
5. Münch M, Nowozin C, Regente J, Bes F, De Zeeuw J, Hädel S, Wahnschaffe A, Kunz D *Blue-Enriched Morning Light as a Countermeasure to Light at the Wrong Time: Effects on Cognition, Sleepiness, Sleep, and Circadian Phase* Neuropsychobiology. (2016);74(4):207-218
6. Grimaldi S, Partonen T, Saarni SI, Aromaa A, Lönnqvist J *Indoors illumination and seasonal changes in mood and behavior are associated with the health-related quality of life* Health Qual Life Outcomes (2008) Aug 1;6:56
7. Choi K, Shin C, Kim T, Chung HJ, Suk HJ *Awakening effects of blue-enriched morning light exposure on university students' physiological and subjective responses* Sci Rep (2019) Jan 23;9(1):345
8. Viola AU, James LM, Schlangen LJ, Dijk DJ *Blue-enriched white light in the workplace improves self-reported alertness, performance and sleep quality* Scand J Work Environ Health (2008) Aug;34(4):297-306
9. <http://healthysleep.med.harvard.edu>
10. Simpson NS, Gibbs EL, Matheson GO *Optimizing sleep to maximize performance: implications and recommendations for elite athletes* Scand J Med Sci Sports (2017) Mar;27(3):266-274
11. Duffy JF, Czeisler CA *Effect of Light on Human Circadian Physiology* Sleep Med Clin (2009) Jun;4(2):165-177
12. Kozaki T, Kubokawa A, Taketomi R, Hatae K *Effects of day-time exposure to different light intensities on light-induced melatonin suppression at night* J Physiol Anthropol (2015) Jul 4;34:27
13. Kozaki T, Kubokawa A, Taketomi R, Hatae K *Light-induced melatonin suppression at night after exposure to different wavelength composition of morning light* Neurosci Lett (2016) Mar 11;616:1-4
14. Yasukouchi A, Toda N, Noguchi H *Optimal lighting conditions for officeworkers from the perspective of non-visual effects* Int Confer Occupational Health and Safety (ICOHS-2017). Bali: KnE Life Sciences (2018) p. 451–61
15. Figueiro MG, Bierman A, Plitnick B, Rea MS *Preliminary evidence that both blue and red light can induce alertness at night* BMC Neurosci (2009) Aug 27;10:105

16. Facer-Childs E, Brandstaetter R. *The impact of circadian phenotype and time since awakening on diurnal performance in athletes* Curr Biol (2015) Feb 16;25(4):518-22



BrainLit® products and services are not intended to diagnose, treat or prevent any medical conditions. BrainLit® is not responsible for any healthcare related decisions made by the end user, including healthcare professionals while utilizing BrainLit® products and services.