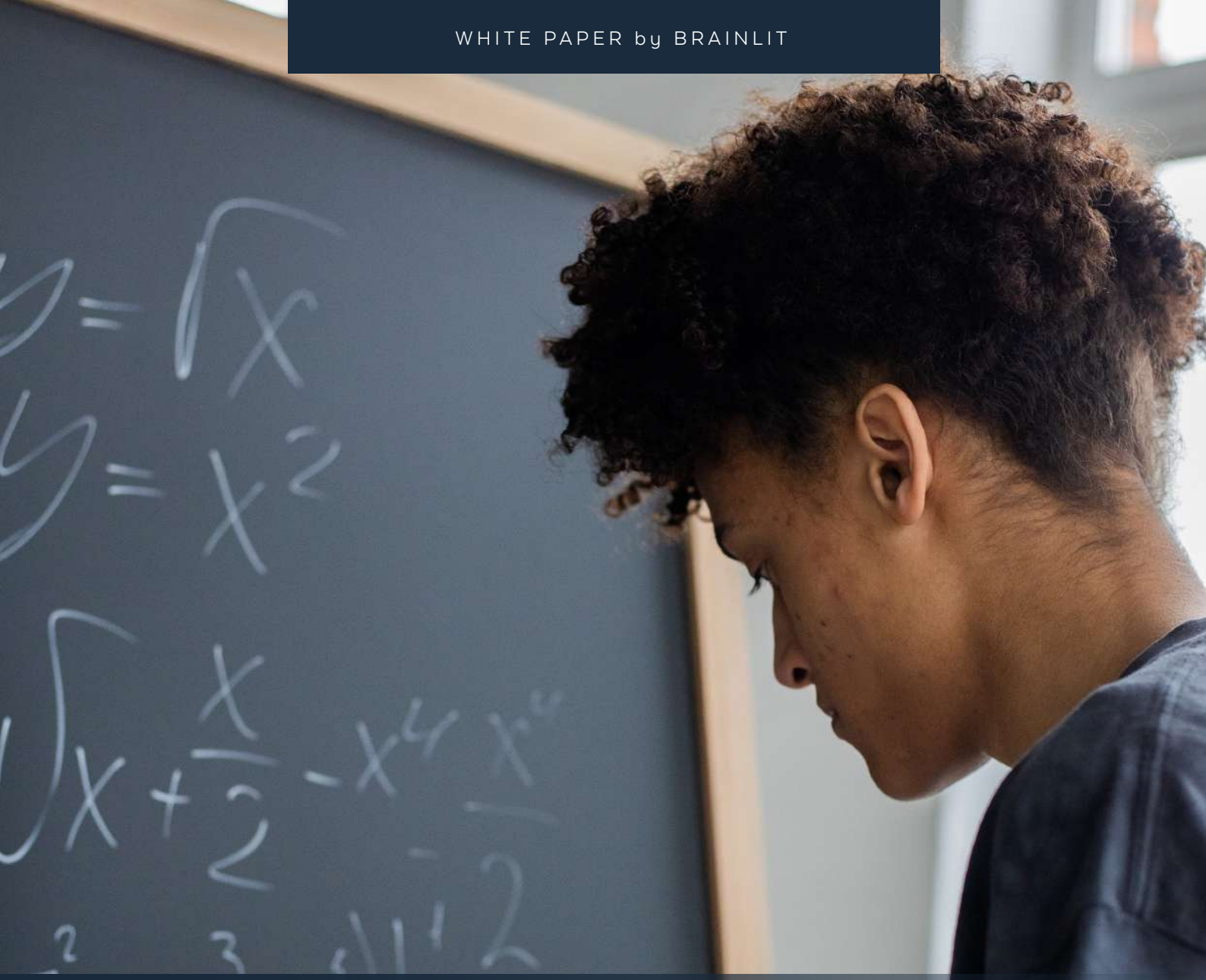
WHITE PAPER by BRAINLIT



COGNITION

BIOCENTRIC LIGHTING™ AND COGNITION

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Cognition describes higher-level mental processes, such as problem-solving, thinking, attention, memory, and learning. Maintaining a high level of cognitive performance is essential in many fields of work, in education, while driving, and for other day-to-day tasks. Cognition can be assessed through a variety of tests aimed at evaluating attention, reaction times, or working memory amongst others. Several scientific studies point to a role of light, especially blue or blue-enriched white light, in modifying and improving the timing and level of cognitive performance.

Light improves cognitive performance

Many of us experience dips at some point throughout the workday with lower levels of alertness and attention to the task at hand. It is common to use strategies to help maintain cognitive performance during these dips such as drinking coffee, taking an afternoon nap, or going for a short walk. The lighting of our environment is another element to consider, as light has been shown to influence our cognitive processes both at night and during the day.

Scientists have tested the impact of light in comparison to other common strategies to improve cognitive function. One hour of 40 lux blue light has been shown to be as effective as 240 mg caffeine in a reaction test. The blue light outperformed caffeine when distractions were presented[1]. For those who habitually take a post-lunch nap, a light boost may do the trick when a nap is not an option.

Undergraduate students who receive blue-enriched bright light instead of their usual post-lunch nap may experience improvements in working memory to a similar degree as after taking a nap.
Moreover, taking a nap or receiving a light boost of blue-enriched light is better than not taking a nap and remaining under standard lighting[2]. Even one minute of blue light exposure can affect certain aspects of cognitive performance in young adults[3].

The environment in which we work or study can strongly influence our performance. In an independent Danish study on school children, lighting from BrainLit was used to test the effects of dynamic bluish-white light compared to static yellowish-white light in combination with either a high or low ventilation rate. Students experienced improved processing speed, concentration levels and math skills when dynamic bluish-white lighting and a high ventilation rate was used[4].

A BioCentric Lighting installation in a classrom in Malmö, Sweden

“The environment in which we work or study can strongly influence our performance”

Scientists sometimes investigate the activation of certain brain areas known to be involved in cognitive performance while the study participants are performing a cognitive task. One such study combined a working memory task with fMRI, a method used to measure changes in blood flow associated with brain activity. Participants receiving blue (compared to amber) light responded faster on the task, indicating improvements in working memory. They also had increased activation in parts of the prefrontal cortex that are associated with executive functions[5].

Blue light entrains our circadian rhythm

Blue light appears to affect us in ways that other wavelengths of light do not. For instance, exposure to blue light improves auditory reaction time compared to green light exposure[6]. Blue light is also involved in entraining our circadian rhythm. It is received by melanopsin-containing retinal ganglion cells in the back of the eye, which submit signals from blue light to the internal master clock called the suprachiasmatic nucleus (SCN).

The SCN is involved in maintaining our biological circadian rhythm so that we sleep at night and are awake during the day. Light contributes to our cognitive performance both directly but also potentially by helping us maintain a regular daily rhythm and high-quality sleep. Light that stimulates our circadian system, in other words light that contain plenty of blue wavelengths, is sometimes described as having a high melanopic equivalent daylight illuminance (melanopic EDI).

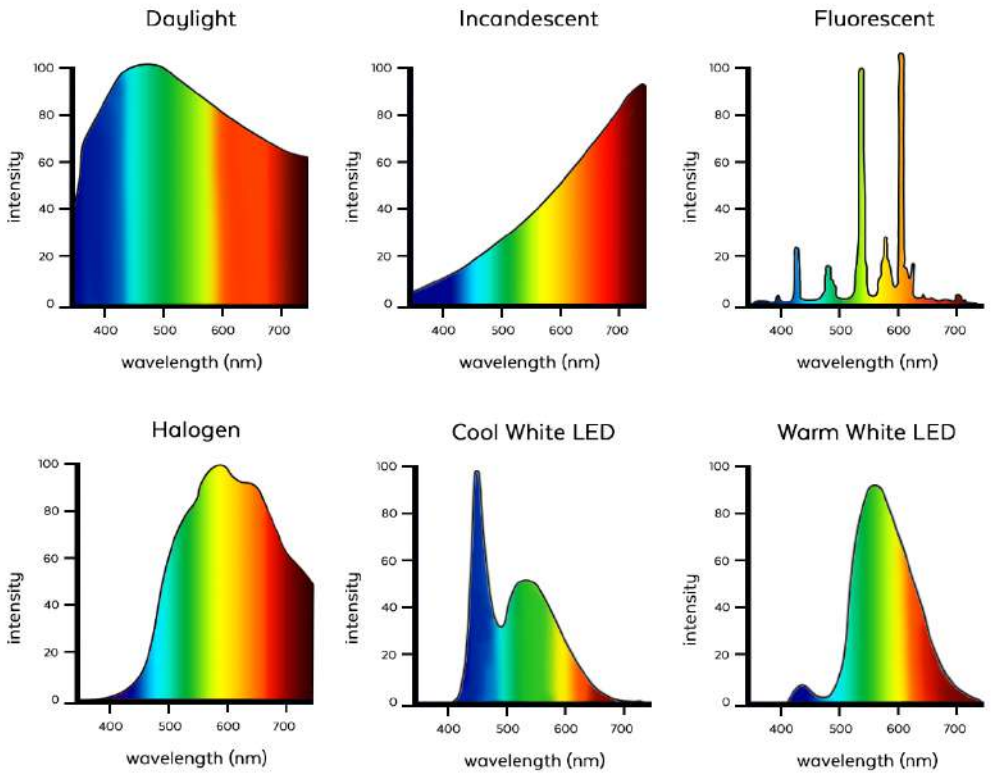

Figure: The spectral composition of different light sources

Light and sleep deprivation

A regular sleep/wake rhythm with sufficient sleep at night is desirable for health and wellbeing, but sometimes life commitments demand a different schedule. Sleep deprivation is a common problem in modern society and contributes to reduced cognitive performance[7]. The right light can help us in those cases when we need to perform well while we are sleep deprived. Young adults who are slightly sleep deprived may benefit from receiving light with a high melanopic EDI. In an experiment, students on a restricted sleep schedule who received daylight-like light with a high melanopic EDI had faster performance speed on a motor sequence learning task compared to those receiving conventional lighting with low melanopic EDI values. In other words, white light with a high melanopic EDI improves processing speed, working memory, and procedural learning in a motor sequence task[8]. Moreover, both bright and self-selected light have been shown to improve performance in more difficult cognitive tasks compared to dim light[9].

Light during shift work

Bright and blue-enriched light can help sustain alertness and attention during hours when we are normally asleep and can therefore be a powerful measure to temporarily improve performance during shift work. Using an LED-backlit screen when working in the evening can improve sustained attention, working memory, and declarative memory compared to using a white non-LED backlit screen[10]. Similarly, blue-enriched light can improve the sustained attention and decrease the number of errors amongst shift workers compared to conventional light[11].

”Light can be used to sustain performance in the morning after a night of complete sleep deprivation”

A four-hour bright light exposure during night shift hours has been shown to improve performance in a simulated assembly line task on the night after light exposure. This effect was not seen when using a shorter light exposure of two hours. The improvement in performance after a long bright light exposure could be a result of a phase delay of the circadian sleepiness-alertness rhythm[12].

Integrative lighting with a higher melanopic EDI than standard lighting can contribute to improved concentration and shorter reaction times in shift workers during the morning shift[13]. Similarly, dynamic lighting with a higher maximum illuminance and color temperature than standard lighting has also been shown to increase productivity of morning shift workers in the winter[14]. Bright light can potentially also be an effective tool to avoid incidents and accidents whilst driving home from a night of working[15]. Light can be used to sustain performance in the morning after a night of complete sleep deprivation. Morning bright or blue-enriched light has been shown to reduce the negative effects of sleep deprivation on sustained attention and reaction time[16]. Waking up to dawn-simulating light that gradually increases from 0 to 250 lux in the half-hour before wake-up time can also improve attention-based cognitive performance throughout the day[17].

Although light can acutely benefit our cognitive performance at night or when sleep deprived, we encourage caution. Light used at night to improve work performance can lead to decreased performance on the following day. For instance, bright light exposure before bedtime may impair right frontal lobe activation and response inhibition on the following morning[18]. Even dim light (10 lux) at night can reduce activation in some brain areas while performing a cognitively challenging task on the following day[19].

A potential solution to receive the beneficial effects of light at night whilst limiting the detrimental effects is to use light toward the red wavelengths. Both red and white light have been shown to improve some aspects of cognitive performance, such as reaction times, at night. Red light differs from white light in that it does not suppress our melatonin levels, thereby not signaling to the brain that it is daytime when it is in fact night[20].

Individual differences

The way each of us responds to light is influenced by our age, light history, and other factors. Vigilance levels prior to light exposure have been shown to influence how light affects cognitive performance. Individuals with a higher basal vigilance level benefited more from blue-enriched lighting in a task assessing reaction times[21].

Light influences our cognitive performance from our early years to later in life. A study in pre-school-age children showed that using LEDs with higher color temperatures was associated with greater improvements in a task switching test for children, indicating that light is linked to executive function early on in cognitive development[22].

Cataract is a common eye condition amongst elderly involving a clouding of the lens of the eye, leading to lower light levels reaching the retina. Treatment consists of surgery to replace the natural lens of the eye with an artificial intraocular lens. The increased amount of light entering the eye through the artificial intraocular lens is associated with improved reaction times[23].

Some visually blind individuals retain non-visual function of the eye through the photosensitive retinal ganglion cells, which convey light information to our internal master clock. Less than one minute of blue light can trigger activity in brain regions involved in alertness and cognition in some of these individuals[24].

Summary

- **Cognition involves mental processes such as thinking, learning, attention, and memory**
- **Light can be used as a complement to coffee, naps, and other strategies to avoid the post-lunch dip**
- **Light can improve cognitive performance during shift work**
- **Blue-enriched light helps synchronize our circadian rhythm, which in turn can help us sleep and perform better**

Cognition is essential for many of our work tasks and daily commitments. Cognitive performance varies naturally throughout the day and is sensitive to sleep deprivation or circadian disruption resulting from shift work. Light can be used as an alternative or complement to coffee, naps, and other measures to increase alertness and cognition temporarily.

Emerging research provide new understandings of the beneficial effects of light for improving cognition and how a light environment can be adapted to aid cognitive performance when needed. The BioCentric Lighting™ (BCL™) system is easily customized according to the latest science and to the unique needs of the individual workplace.

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