WHITE PAPER by BRAINLIT

ALERTNESS

BIOCENTRIC LIGHTING™ AND ALERTNESS

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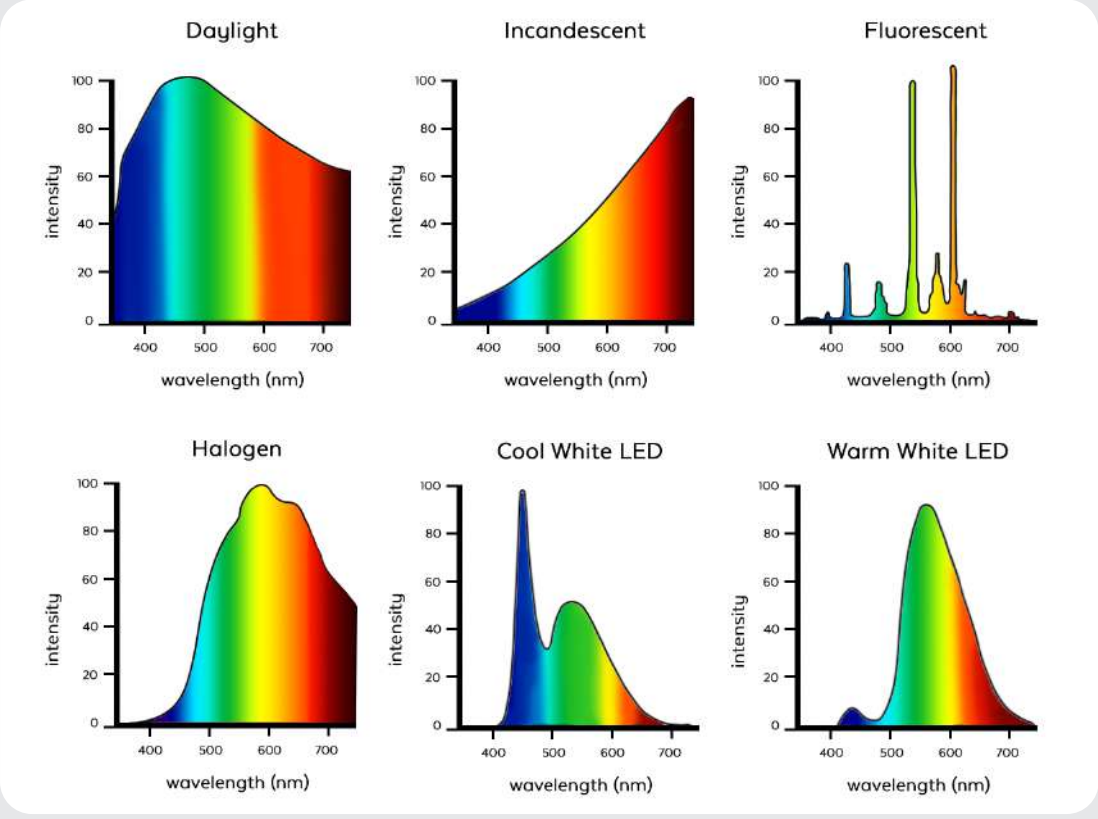
Alertness describes a state of environmental awareness and high sensitivity of incoming stimuli[1]. Alertness is closely related to vitality, the feeling of being alive and having energy. An increasing body of research point to the acute alerting effect of light both at night and during the day. Adequate lighting is therefore of importance in environments and situations requiring us to be in an alert state, such as at work, in school, or while driving. Here, the research on the alerting effects of light is summarized.

High light intensity induces daytime alertness

Several studies have shown the impact of high-intensity light on alertness. The majority of studies demonstrate improved subjective alertness with higher light intensity[1,2]. Positive effects on alertness can be attained by increasing the intensity levels in offices and other indoor environments. Compared to 200 lux, morning bright light at 1,000 lux can lower subjective measures of sleepiness, increase vitality, and shorten reaction times[3]. Similarly, using even brighter morning light (5000 lux) with a high correlated color temperature (CCT) of 6,500K improves subjective alertness compared to standard white light at 400 lux and 4,000K[4]. Moreover, there is a positive relationship between light exposure and feelings of vitality[5].

Spectral distribution of light

The alerting effect of light is not simply a function of the intensity, but also the color composition – also known as the spectral distribution – of the light source. Two white light sources that appear similar may have completely different spectral distributions (see figure). This is important to keep in mind since the light sensitive photoreceptors in the eye respond to different colors of light.



Light-sensitive retinal ganglion cells respond to blue light and signal to brain areas that regulate non-visual functions, such as the sleep-wake cycle and mood. This has led scientists to test whether blue light influences our alertness levels more than other colors.

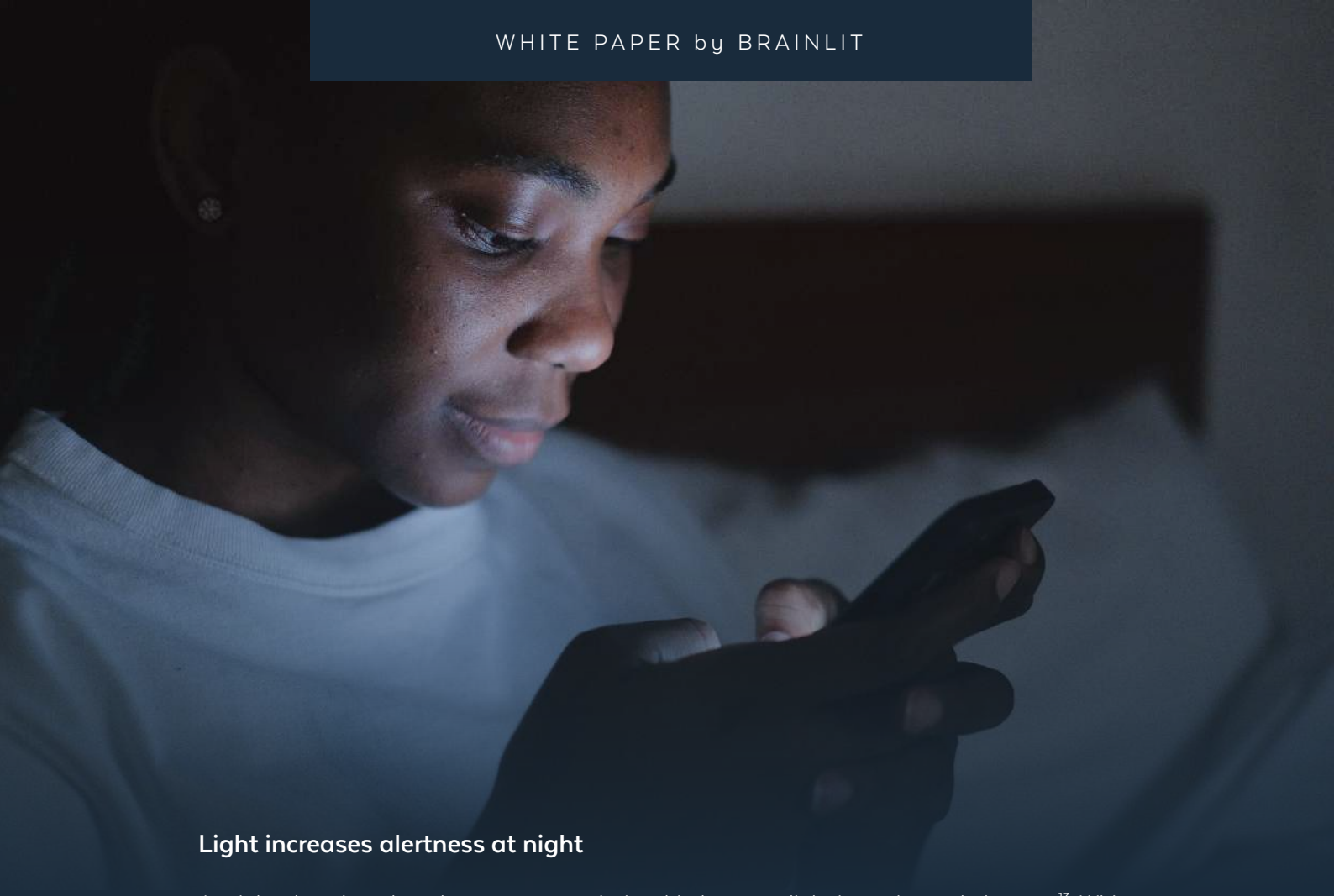
To test how the different colors affect us, pulses of violet (420 nm), blue (470 nm), and orange (600 nm) light were investigated for their effect on subjective alertness. The participants were kept in dim light, after which they were exposed to a 4-hour light pulse in the morning. The results showed that the shorter wavelengths had a stronger effect on alertness[6]. Considering this finding, a suitable choice in offices and similar environments could be to use blue-enriched white light to boost alertness.

Several studies have investigated the effect of blue-enriched light (17,000 K) on alertness in comparison to regular white light (about 4,000 K). These studies have been performed on different groups of people, such as in office workers[7] or in crew members of the Concordia Polar Base station during the polar winter[8]. The studies support the notion that blue-enriched light improves subjective measures of alertness[7-9]. They also suggest improvements in performance and concentration[7,9] and reduced fatigue and daytime sleepiness[9] when using blue-enriched lighting.

Alertness can be thought of as readiness to react to environmental stimuli, which is important when driving. Life commitments sometimes require us to drive or perform other tasks during times of the day when we are less alert. Evening people are usually sleepier and less alert in the morning and vice versa. In a simulated driving task, blue-enriched white light attenuated the decrement of reaction times in evening-type people when tested in the morning[10].

Although blue light has received attention in the scientific community for its non-visual effects on sleep and alertness, it is interesting to note that some studies have shown alerting effects of red light, too. One study compared the effects of short- or long-wavelength light compared to darkness on electroencephalogram (EEG) in the early morning. EEG alpha power was lower after 30 minutes of light exposure in both light conditions compared to the dark condition, indicating a positive effect on alertness[11].

Low levels (40 lux) of blue and red light have also been tested during the post-lunch hours with similar results, but the effect appeared significant only in the red light condition[12].



Light increases alertness at night

At night, there is a clear dose-response relationship between light intensity and alertness[13]. White light with blue wavelengths also suppresses the production of the sleep hormone melatonin, which can create an unwanted side effect by phase shifting our circadian rhythm. Research shows that red light at night can influence our brain activity, as measured by EEG, towards an alert state without suppressing melatonin[14,15].

Moreover, red light has been shown to decrease reaction times at night compared to dim light[14]. The capacity of red light to influence alertness may be of great importance since it allows us to promote alertness without disturbing our circadian rhythm.

Light after sleep deprivation

Light can be used to counteract the effects of sleep deprivation on alertness. Thirty minutes of light therapy with a light box (10,000 lux) or blue-enriched LED glasses (2,000 lux) both reduce sleepiness in the early morning hours (5 to 7 am) after one night of sleep deprivation[16]. Another study demonstrated that 1,000 lux bright light can reduce the impact of sleepiness after two nights of sleep restriction, compared to dim light[17].

These studies underscore the usefulness of light to people working night shifts or experiencing sleep deprivation for other reasons. Importantly, white and blue-enriched light after sleep deprivation can induce an alerting response in both older and younger adults[18], which shows that light can be used to induce alertness in a wide population.

Natural daylight and dynamic lighting

Natural daylight indoors appears to be preferrable over electric lighting to maintain alertness in the afternoon[19]. When natural daylight is not available, it is important to supplement with adequate electrical lighting to receive the desired amount of light to remain alert. One option is to use dynamic lighting that changes in intensity and color temperature throughout the day. A 4-month study has shown that dynamic lighting (up to 700 lux and 3,500-6,000 K) increased alertness at 1 pm compared to static lighting (500 lux at 5,000 K), suggesting that dynamic lighting may be used to avoid the post-lunch dip[20].

In another study, participants were either allowed to choose their own light settings or were exposed to constant bright light (1,000 lux) or dim light. Both bright light and self-selected lighting significantly improved alertness in evening types, whereas only bright light significantly improved alertness in morning types[21].

Summary

- **Alertness is a state of awareness and high sensitivity to incoming stimuli, which is important at work and while performing other daily tasks**
- **Blue-enriched bright light improves alertness**
- **Light toward the red wavelengths can induce alertness without suppressing the sleep hormone melatonin at night**
- **Dynamic lighting may be used to avoid the post-lunch dip**

A state of alertness is desirable for optimal performance at work and when carrying out other daily tasks. The level of alertness varies naturally throughout the day and is sensitive to sleep deprivation. Blue-enriched white lighting show advantages over regular white light during daytime, whereas light towards the red tones may be better at night.

Emerging research provide new understandings of the beneficial effects of light for inducing alertness and how a light environment can be adapted for optimal results. 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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