Lighting isn’t just for vision anymore

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A growing body of evidence suggests that the effects of light on the body’s circadian rhythms could have profound implications on human health and well-being.

All organisms on the planet have adapted to the world’s daily rotation by developing circadian (Latin: circa, about; dies, a day) rhythms, the physiological cycles—based on patterns of light and dark—that repeat about every 24 hours. Upsetting such patterns in humans affects performance, well-being, and, it seems, basic health. Although all lighting technologies, standards, measurement devices, and applications have been based solely on the visual response to light,1 our understanding of how light impacts our daily rhythms is expanding. Thus, it becomes interesting, and perhaps commercially important, to begin to more-rigorously investigate how light affects the circadian system.

Light is optical radiation that provides visual sensation in humans. Photoreceptors in the eye convert radiant energy into neural signals for the brain to process, a phenomenon called phototransduction. Until recently, four types of photoreceptors had been identified: short, middle, and long wavelength cones, and rods. In 2002, intrinsically photosensitive retinal ganglion cells (ipRGCs), novel retinal photoreceptors, were discovered.2 These are central to an important ‘non visual’ response to light by the retina: most notably, the cells help regulate circadian rhythms.

For the purposes of this article, we can consider light as having five characteristics: quantity, spectrum, timing, duration, and spectral distribution.1 The human visual and circadian systems respond differently to these characteristics: essentially, more white light is necessary to activate the circadian system than the visual. The combination of rods, cones, and ipRGCs results in a circadian system that is essentially a ‘blue sky’ detector with a peak spectral sensitivity at about 450–480nm.3 The visual system, on the other hand, is most sensitive to the middle wavelength portion of the visible spectrum, with a peak sensitivity at approximately 507nm at night and 555nm during the day.1

Recently, a model for human circadian phototransduction was developed3 that, for any light source, can be used to calculate the amount of circadian stimulus produced. This model, based on the neuroanatomy and neurophysiology of the human retina, accounts for the high threshold of the circadian system as well as spectral opponency.3, 4 This is a phenomenon where certain neurons in the eye are excited by some wavelengths and inhibited by others. Because of this, a polychromatic ‘white’ light source is a relatively weaker stimulus to the circadian system than would be assumed by summing the effectiveness of narrow-band light presented alone (for a detailed discussion, see reference 3). As seen in Table 1, a 7500K lamp and a 3000K lamp with the same electrical power produce the same amount of lumens, but the former is twice as effective in activating the circadian system, assuming that the duration and circadian timing of the exposure is identical.

While the visual system responds to light stimulus in less than one second, up to 10 minutes of exposure may be necessary to produce a measurable response in the circadian system.3 The visual system relies on an accurate spatial correspondence between the environment and perception. The circadian system, however, simply responds to changes in overall retinal light exposure—although it seems to be more responsive to light from above the line of sight,6 which reinforces the notion that the circadian system is a ‘blue sky’ detector.
Perhaps the largest difference between the visual and circadian systems is their reaction when light registers on the retina at particular times. The visual system responds nearly equally throughout the day or night. However, depending on the timing of light exposure, the circadian clock ‘hands’ can be moved forward (phase advance) or backwards (phase delay), resulting in earlier or later bed times.

These scientific findings represent more than just academic interest. Light of the appropriate characteristics and applied at the appropriate timing can reduce symptoms of seasonal affective disorder and increase sleep efficiency of older adults, including those with Alzheimer’s disease. It can also improve circadian entrainment of premature infants, help teenagers wake up earlier in the morning, and increase the alertness and well-being of night-shift workers. Some have even suggested that particular cancers are linked to the disruption of normal circadian rhythms. Although we may be years away from a complete understanding of the impact of circadian light on human health, commercial products are already becoming available with a wide range of associated claims. Time will tell whether such claims are justified in the context of clinical studies, but the science is clearly indicating that lighting isn’t just for vision anymore.

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References