Light at Night and Human Health

Recent studies have raised concerns over the possible health implications of light at night (LAN). But given the available research, should any changes be made to currently recommended lighting practices? Shift work has been associated with an increased risk of stress-related coronary heart disease.[1] Research of circadian rhythms suggests that their disruption can compromise the body's defenses against cancer. Studies also suggest that optical radiation is the primary regulating stimulus to the circadian system, and that the circadian system is most sensitive to short-wavelength blue light.[2] However, the significance of optical radiation exposure relative to other health factors (including abnormal sleep schedule, job stress, and diet) remains unclear. Further, since the current body of available research is inadequate for the purpose of characterizing and restricting exposure to LAN,[3] it is not clear at present that typical exposures are likely to pose a threat to human health.

Human rod and cone photoreceptors and their photopigments have been extensively studied, and action spectra and limits of application for photopic and scotopic vision are well established. Much of the current circadian stimulus research is related to the recent discoveries of a class of non-visual photoreceptors, the intrinsically photosensitive retinal ganglion cells (ipRGCs), and the associated photopigment melanopsin. Early circadian research was focused on treatment of cancer and maladies like seasonal affective disorder (SAD), recognizing the importance of synchronizing medications and light exposure with the body's biological rhythms. The utility of these early studies was limited by the methodologies used and the comparability of results in terms of exposure and species tested. Research methods have since been refined, yielding ipRGC action spectra and preliminary models of circadian phototransduction. However, there remains no standard model that incorporates all of the key parameters of exposure:

- **Duration**. Phase shift appears to increase exponentially with duration of exposure to LAN, and the first half of the exposure period appears to be more significant than the second half.
- **Timing**. Daytime exposure to high levels of blue-rich illumination (like daylight) appears to be strictly beneficial in terms of circadian phototransduction and visual performance. In contrast, excessive exposure to LAN appears to hinder synchronization to the natural light-dark cycle.
- **History**. Akin to the mechanism of visual adaptation, the sensitivity of the circadian system to LAN appears to be decreased if exposed to high levels of entraining illumination during the day.
- **Quantity**. Research indicates that circadian sensitivity is not accurately modeled by the photopic or scotopic functions. Also, since the amount of optical radiation reaching the retina depends on pupil size, simple measurements of optical radiation "at the eye" may be inadequate.

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[1] World Health Organization, *World Health Report 2002: Reducing Risks, Promoting Healthy Life*. Geneva: World Health Organization, 2002. Chapter 4, p. 75.

[2] Stevens et al., "Meeting Report: The Role of Environmental Lighting and Circadian Disruption in Cancer and Other Diseases," *Environmental Health Perspectives*, 2007. 115:1357-1362.

[3] IES Light and Health Committee, "Light and Human Health: An Overview of the Impact of Optical Radiation on Visual, Circadian, Neuroendocrine, and Neurobehavioral Responses," IES TM-18-08. New York: Illuminating Engineering Society of North America, 2008.

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Terms

Action spectrum – The quantitative actinic response of a chemical or biological substance or living organism as a function of an appropriate spectral parameter such as wavelength or photon energy.

Circadian rhythms – Biological processes, such as the nighttime production of melatonin, that cycle approximately every 24 hours.

Entraining – Synchronizing with the environment.

Mesopic vision – Fully adapted vision at luminance conditions between those of scotopic and photopic vision, i.e., between about 0.034 and 3.4 cd/m^2.

Optical radiation – Electromagnetic radiation having wavelengths between approximately 100 and 1,000 nm. Includes ultraviolet, visible light, and infrared.

Phase shift – The delay or advancing of biological rhythms relative to the natural light/dark cycle.

Phototransduction – The conversion of optical radiation signals into neural signals for vision and for other body functions.

Spectral opponency – The mechanism by which sensitivity to one wavelength is reduced (a sub-additive response) when the visual system is exposed to additional wavelengths.

- **Spatial distribution in the visual field.** Melatonin production appears most sensitive to exposure of the lower-inside portion of the retina to optical radiation.
- **Spectral content**. The circadian system is most sensitive to nearly monochromatic blue light. However, if a given blue light source is supplemented by light of non-blue wavelength(s), as in the case of broadband white light, this sensitivity is reduced. This appears to be due to spectral opponency.

Photo credit: PG&E Emerging Technologies, 2008

While the significance of optical radiation exposure relative to other health factors remains unknown, the potential implications of these preliminary findings are far-reaching. Since sensitivity to LAN appears to be a function of daytime exposure, all lighting systems may require scrutiny, whether interior or exterior, daytime or nighttime. Evening exposures to lighting in common interior environments may be of greater significance than typical exposures encountered outdoors.[4]

Nearly all light sources, including incandescent and fluorescent lamps, produce some blue light and thus may be affected by the outcomes of research on LAN. Because so little is understood now about how humans respond to LAN, even moonlight may require consideration as a source of exposure to LAN.

For most types of light sources, efficacy is not highly dependent on the correlated color temperature (CCT) selected. This is not the case with high-performance LED devices using current phosphor conversion technology, where typical photopic efficacy decreases of approximately 25% can be expected in choosing warmer 3000K over cooler (generally bluer) 6500K. While this may change with improvements in technology, a restriction on spectral content would currently prevent the use of more efficient light sources, with clear implications in terms of pollution from electricity production. Substantial gaps in the spectrum can also reduce visibility through reduced visual contrast and color rendition, thereby potentially compromising safety and security. Research into mesopic vision has shown that exterior light sources with greater scotopic content can improve peripheral detection without compromising on-axis vision,[5] suggesting an even greater performance gap between LEDs of high and low CCT in these applications. However, as with circadian stimulus research, mesopic vision research is ongoing and currently lacks the validation and consensus required to establish standardized design recommendations.

It would be irresponsible to encourage major changes in lighting practice without first establishing clear cause-and-effect relationships in these budding and very complex fields of science. A rush to judgment could result in tremendous and unnecessary lighting expenditures, while reducing safety at night and increasing the emissions of greenhouse gases, with no improvement in human health. Further research is needed and is already underway. In the meantime, those responsible for the selection of light sources are encouraged to follow local and federal regulations and the current and forthcoming safety guidelines offered by the Illuminating Engineering Society of North America (IES).

4 Figueiro, M.G., M.S. Rea, and J.D. Bullough, "Does architectural lighting contribute to breast cancer?" *Journal of Carcinogenesis*, 2006. 5:20.

5 IESNA Committee on Effects of Lamp Spectral Distribution, "Spectral Effects of Lighting on Visual Performance at Mesopic Levels," IESNA TM-12-06. New York: Illuminating Engineering Society of North America, 2006.

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