

For many years, we may not have been looking under all of the “right rocks” when trying to link lighting to human performance and well-being or when trying to characterize lighting quality. The lighting quality matrix in Chapter 10 of the *IESNA Lighting Handbook* covers a wide range of visual criteria (performance, glare, color, etc.), but

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is that all there is to lighting quality?

Based on the rapidly emerging science of circadian photobiology, the simple answer must be, no, because light is not just for vision.

#### **Why isn't light just for vision?**

In 1980, Al Lewy showed that bright white light (2500 lux for two hours during the night between 02:00 and 04:00 hours) suppressed human melatonin to daytime levels (Lewy et al., 1980) and later showed that bright white light relieved symptoms of seasonal affective disorder (SAD). These discoveries were very important because they stimulated other clinical research. Eus van Someren (van Someren et al., 1997) has shown that exposing Alzheimer's patients to bright light during the day and darkness at night consolidated their rest/activity patterns, Miller et al. (1995) showed that cycled light, instead of continuous light, improved growth rate of premature in-

ants. Lewy's work was also the stimulus for more basic research. Badia et al. (1991), Boyce et al. (1997), and Figueiro et al. (2001) showed that bright light exposure at night increased brain activity, improved cognitive performance, and subjective alertness, respectively. Also, epidemiologists are hypothesizing that light at night may be associated with increased risk of certain types of cancer (Davis et al., 2001; Hansen, 2001; Schernhammer et al., 2001). In summary, I have been lecturing about light and health for a few years now, and it continues to surprise me how I must continuously update my lectures to reflect new and exciting research. It is now impossible to ignore the fact that *light is not just for vision*.

#### **What do we know about circadian photobiology?**

Biological rhythms that repeat at approximately every 24 hours are called circadian rhythms. These include cycles such as sleep/wake, body temperature, hormone production and alertness (Arendt, 1995). The human circadian timing is controlled by the circadian pacemaker, the biological clock located in the suprachiasmatic nucleus (SCN) of the brain. Light is the main input to synchronize the biological clock to the solar (24-hour) day (Brainard et al., 1997). If we are not exposed to sufficient amount of light of the right spectrum, for a sufficient amount of time, and at the right timing, our biological clock becomes desynchronized with the solar day and decrements in physiological functions, neurobehavioral performance and sleep usually occur. (It is important to note, however, that light is the main, but not the only synchronizer of the biological clock. Exercise, social activities, and scheduled meals have also been shown to synchronize the clock, although their impact on circadian rhythmicity is weaker than light).

It is now widely known that melatonin is a hormone produced by the pineal gland at night and under conditions of darkness. Generally, melatonin is used as a marker of the circadian clock. Melatonin is believed to be the hormone of darkness, the one that tells the body it is nighttime. Nocturnal animals, such as

mice will interpret this as being time to be active; humans, on the other hand, will interpret as being time to go to bed.

## RESEARCH RECAP

#### **Why propose a new framework for lighting practice?**

There are five basic characteristics of light: quantity, spectrum, distribution, timing and duration. The characteristics that are ideal for vision are quite different than those that are maximally effective for the circadian system. Certainly, we are years away from a complete understanding of the impact of light on circadian regulation, but an initial framework for the effects of light on vision and on the circadian system can be helpful in paving the way to



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practical applications where the circadian system as well as the visual system are considered in achieving good “lighting quality.”

1. Quantity: Typical light levels found in an office environment (500 lux from white light on the workplane) are more than sufficient for the visual system to process information. One hour exposure to this same white light, however, is barely sufficient to stimulate the circadian photobiological system.
2. Spectrum: The visual system is most sensitive to the middle wavelength portion of the spectrum, while the photobiological system is responsive to the short wavelength portion. For example, at 500 lux on the workplane, a 7500 kelvin (K) fluorescent lamp is almost 2.5 times more effective in suppressing melatonin (1 hour exposure) than a 3000 K fluorescent lamp. In terms of visual performance, they are the same (even though the 7500 K lamp would probably appear brighter).
3. Timing: Operation of the visual system does not depend on timing of light exposure; it responds to a light stimulus at any time of the day or night. Depending on the timing of light exposure, however, light can phase advance or phase delay the biological clock, or it can have no effect at all.

Phase advance resets the clock to an earlier time and phase delay resets the clock to a later time. Because our clock’s natural rhythm is a bit longer than 24 hours, we need to advance it every morning in order to be synchronized to the solar day.

4. Duration: The visual system responds to a light stimulus very fast (less than 1 second). The duration of light exposure needed to suppress melatonin is longer than the duration of light exposure needed to activate the visual system; suppression of melatonin content in the bloodstream starts at approximately 10 minutes after bright light exposure was initiated.
5. Spatial Distribution: For the visual system, light distribution is critical to visual performance. For example, the accurate rendition of the patterns of light and dark on this page are necessary to identify the words I have written - the circadian system does not respond to these patterns, only the overall amount of light reaching the retina.

**Table 1** summarizes a framework for visual and circadian functioning, based on what we know today. Much is still unknown about circadian photobiology and its interaction with lighting, but one thing cannot be denied: light is not just for vision.

### What can be recommended?

This initial framework clearly illustrates how light affects the two systems so differently. Unfortunately, we have limited understanding of the interactions between these lighting characteristics in affecting the circadian system. Until a more comprehensive framework is developed for the circadian system (in terms of light quantity, spectrum, timing, duration, and distribution) the various experiments reviewed above will remain isolated findings with limited implications for practice. For example, we know that exposure to light during the day affects the relative importance of light exposure at night (Lynch et al., 1985 and Hebert et al., 2002). Therefore, it is premature to recommend, as some have suggested, that people should not read books or watch television at night or that people should use red LEDs as night-lights. Until we better understand the significance of light exposure (quantity, spectrum, distribution, timing, and duration) during the preceding 24 hours, we cannot predict the impact of light exposure on a given night.

In effect, we can presently say very little about “lighting quality” for the circadian system, but it is absolutely necessary to begin to educate ourselves about this rapidly emerging area of science because it will dramatically affect lighting practice in the coming years. Hopefully, the framework in Table 1 is a helpful step in this direction.

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Brainard GC, Rollag MD, Hanifin

Lighting characteristics (broad-band light)	Application		
	vision	circadian - day shift work	circadian - night shift work
quantity	low (300-500 lux on task ~100 lux at eye)	high (~1000 lux at eye)	high (~1000 lux at eye)
spectrum	photopic (peak sensitivity 555 nm)	short-wavelength (peak sensitivity 420-480 nm)	short-wavelength (peak sensitivity 420-480 nm)
spatial distribution	distribution important (task luminance, contrast and size determine visibility)	independent of distribution (illuminance at eye)	independent of distribution (illuminance at eye)
timing	any time	subjective morning	periodically throughout shift
duration	very short (less than 1 s)	long (1-2 hr)	short (15 min pulses)

**Table 1—A proposed framework for lighting practice. For cells that are shaded, evidence is less certain, and the results of future research will be needed to refine and corroborate these preliminary guidelines (Rea et al., 2002).**

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**B**efore a stage show comes to Broadway it opens "on the road" to get the kinks out of it. Often the producers hire a "show doctor" to make changes that will help insure the play's success in New York.

Something similar happens with a developer's speculative office building. A construction cost of \$200/sq ft for a million square foot office building makes for a risky investment, even with a major tenant lined up before breaking ground. Since you can't try out an office building on the road, many developers engage an architect's architect

Energy conservationists recommend that available daylight be used to reduce the electric load, which can easily be done in an office only 15 ft deep

to configure the building so that when it is built in New York, or in any major US city, it gets the maximum yield in the form of rental to insure its success.

The best known of these building gurus is Der Scutt, who is a Fellow of the AIA as well as the IESNA. I turned to him for help in preparing a talk for the Master Class in Lighting for Architects and Designers, produced each year in New York by Sonny Sonnenfeld, in association with Paul Gregory and Jonathan Speirs. Scutt pointed out that the size of the plot and the zoning of the site determines the

footprint and size of the building and the spacing of the structural steel. The most economical module for a developer's building is five feet, which dictates the spacing of the columns and the size of the various offices.

Some tenants are large corporations with office buildings throughout the country. They have their own formula for space allocation. A large communication company has seven different sized private

## ENERGY CONCERNS

offices, one for each of its executive levels, and has rules for how many persons have to share a "private" office, and how many square feet to allow for each occupant in an open plan area.

Der Scutt told me that, in general, for a building to reach its maximum rental potential, it should have a 15 ft deep perimeter zone for private offices, each one a multiple of 5 ft, with the smallest office 10 ft wide along the window wall by 15 ft deep, and wider spaces for executives and conference rooms. Then, proceeding inward toward the core, the floor plan should allow 5 ft for a corridor and 10 feet for secretarial offices and records. If the perimeter offices have glass partitions onto the corridor, then everyone in that 30-ft-deep exterior zone has a visual connection to the outdoors, which we know from the Light Right Consortium study is highly valued by employees. Then Scutt recommends another 5-ft-wide corridor for passage and past that, interior offices and conference rooms, the employee cafeteria and utility areas and finally, the reception area and elevator lobby.

The glazing in the windowed perimeter offices will have coatings to reduce the sun load, which is highest in the winter when the sun is at its lowest, and to retain the heating or cooling on the inside—depending on the season. Energy conservationists recommend that available daylight be used to reduce



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