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By Michael Siminovitch and Nicole Graeber

In any field or occupation, forward-leaning education programs prepare the next generation of professionals to work with emerging technologies. One such example is the Betty Irene Moore School of Nursing at UC Davis where students are provided with the necessary skills to lead their field by training with emerging healthcare technology. The training in this case relates to both the tools to provide care and the environment in which staff anticipate their students will be asked to work.

The design team for the School of Nursing facility is including daily living areas for home healthcare training, as well as mock-up exam rooms and clinical spaces including exam rooms and hospital rooms for student training in traditional healthcare environments. Each of these space types presents unique lighting design challenges. Today's advanced lighting and control technologies present an opportunity to overcome these challenges.

Three key elements of emerging healthcare lighting design are *circadian wellness*, *dark adaptation* and a *high-fidelity visual environment for patient care*. Solid-state lighting solutions with spectral control capabilities can be seamlessly integrated into healthcare lighting designs using advanced controls and sensor geometry to create a patient-friendly experience. For patients who need to sleep during the day, these technologies can be manually enacted, along with appropriate window shading, to create a nighttime environment at any hour.

Based on these design elements and lighting principles, the California Lighting Technology Center developed the *Five Key Circadian and Lighting Quality Design Strategies* appropriate for use in healthcare environments (**Figure 1**).

CIRCADIAN WELLNESS

The support of human circadian wellness through the dynamic tuning of solid-state light sources includes dynamic spectrum variations defined by ideal color temperature and intensity control to support the natural circadian rhythm relative to melatonin production over the course of a day. Dynamic spectrum variations are achieved by implementing control signals defined to more closely emulate daylight's spectral characteristics. Biologically, the daylight spectra characteristics are what humans expect. Our eyes have evolved under this kind of intensity and spectral variation, and with today's technology we now have the ability to replicate the variation in a supportive manner for healthcare environments.

To support the natural circadian rhythm, the idealized color temperature variation over the course of a day follows our normal expectations for daylight and light exposure in the natural environment. During the day we expect to see higher color temperatures and higher intensities as compared to those at night.

To fully support the natural circadian rhythm, electric lighting should also meet our core need to minimize the overall intensity, as well as minimize the blue portion of the lighting spectrum, during evening hours. Our melanopsin receptors are particularly sensitive to blue light and exposure to blue light at night can significantly upset our hormonal balance leading to sleep disturbances and other adverse health effects (**Figure 2**).

Today, lighting systems can be made circadian sensitive with relative ease. Systems can replicate daylight color and intensity during the morning, increasing over the course of the day to a peak, then decreasing toward evening and into the night to minimize blue-light disruption (**Figure 3**).

DARK ADAPTATION

Dynamically tunable solid-state lighting technology is also ideal for mitigating issues associated with dark adaptation. Typically, healthcare rooms are unfamiliar to patients with nighttime visual barriers, making room navigation difficult under lowlight conditions. The use of typical fluorescent or LED lamps with high intensity and high blue spectrum content creates a significant, negative impact on the melanopsin receptors. This leads to circadian disruption. In addition, this significantly bleaches the eye's rhodopsin, a photochemical necessary for night vision. These visual challenges can lead to unsafe and uncomfortable conditions.

"The natural 24-hour cycle of light and dark helps maintain precise alignment of circadian biological rhythms, the general activation of the central nervous system and various biological and cellular processes, and entrainment of melatonin release from the pineal gland. Pervasive use of nighttime lighting disrupts these endogenous processes and creates potentially harmful health effects and/or hazardous situations with varying degrees of harm."

American Medical Association

There is opportunity to provide healthcare environments with circadian sensitive lighting layers. The baseline layer of light is a room-wide layer of red-amber LEDs at a relatively low intensity level. This layer is controlled manually by occupants and automatically by occupancy sensors. It provides a pathway of light throughout the room for nighttime navigation and comfort (**Figure 4**). Based on its amber spectral content, this layer of amber LEDs does not disrupt our eye's melanopsin receptors and thereby eliminates circadian difficulties, as well as allows our eyes to maintain dark adaptation by not bleaching rhodopsin.

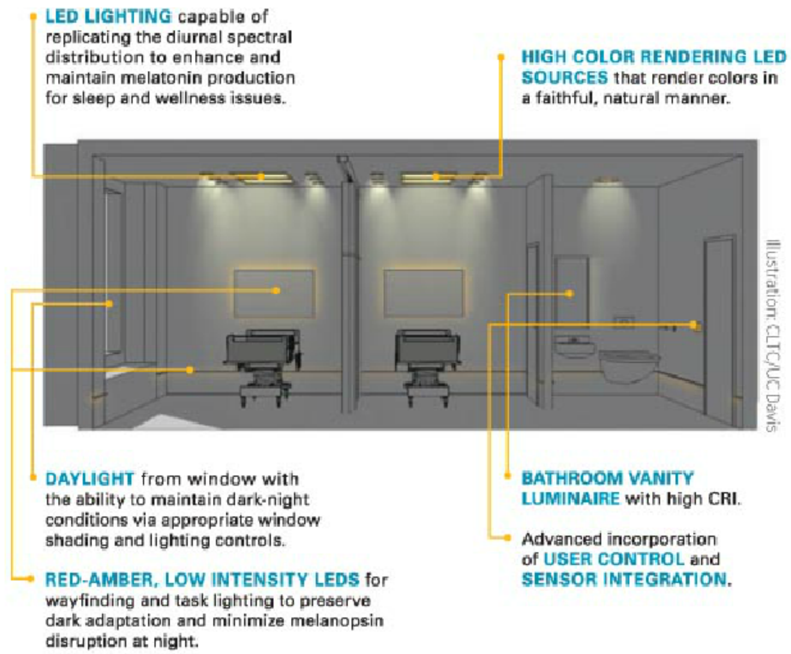


Figure 1. The Five Key Circadian and Lighting Quality Design Strategies applied to a healthcare patient room.

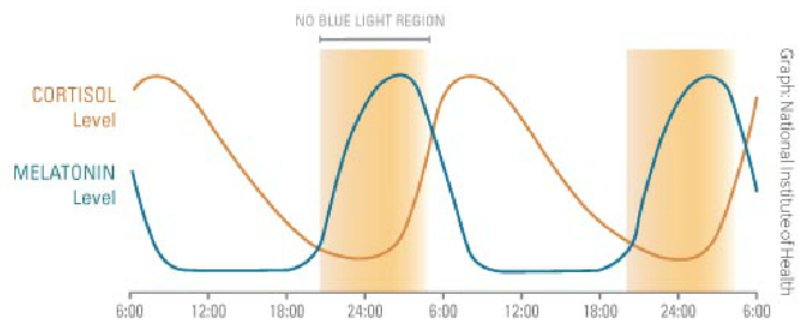
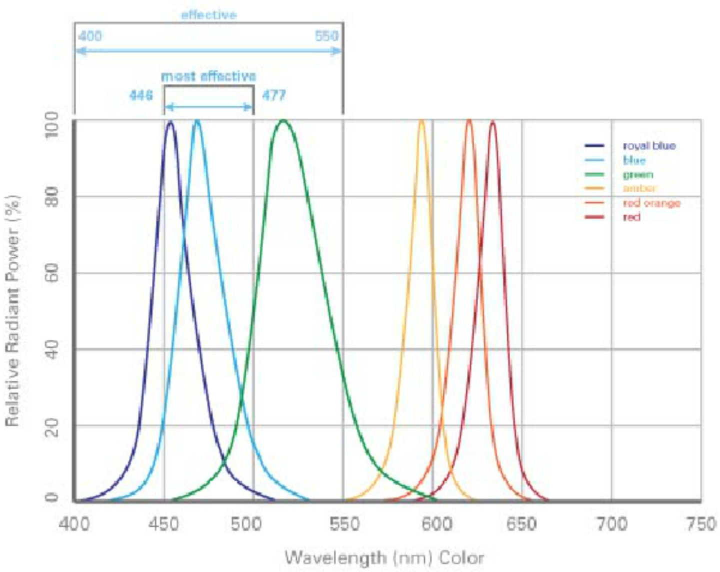


Figure 2. Circadian rhythms.

HIGH-FIDELITY ENVIRONMENTS

In addition to circadian wellness and dark adaptation, there are additional opportunities to improve the healthcare environment by addressing color rendering and delivering natural, high color-fidelity environments. Today, most readily available commercial fluorescent and LED technologies have relatively poor spectral characteristics relative to rendering color in a natural manner. The average color rendering index (CRI) is a metric that describes how well a light source renders color with respect to natural daylight. New developments have resulted in solid-state products being produced with an



Graph: Thapan, K., Arendt, J., & Skene D.J. (2001)

Figure 3. An action spectrum for melatonin suppression—evidence for a novel non-rod, non-code photoreceptor system in humans.

Photo: Kathreen Fontecha/CLTC, UC Davis

Figure 4. Path finding amber LED lighting in a daily living application.

Photo: Kathreen Fontecha/CLTC, UC Davis

Figure 5. Left hand, 90 CRI and R9 of 60; right hand, 80 CRI and R9 of 5; camera settings: f/3.2, 1/250, ISO 1600

average CRI of 90 and greater. Specifically, new products have focused on their ability to accurately render saturated red objects. This metric is known as R9 and is a key to understanding the differences in most skin tones when lit by 80 CRI and 90 CRI products in identical environments. Increases in R9 lead to increases in the average CRI metric.

This technological advancement provides us an unprecedented opportunity to install high color rendering, high efficiency light sources to maintain comfort and visual quality throughout our patient rooms. This is particularly important for patient room lighting, which is typically illuminated with trichromatic fluorescents. These fluorescents are often characterized by a highly distorted color spectrum and a relatively low CRI. Using newly available LED technologies with CRI between 90 and 95 enhances the environment to enable the occupant's color discrimination to be exceedingly high—ideal for visual inspections of patients by healthcare workers (**Figure 5**). Such a well-lit environment promotes occupant comfort, satisfaction and well-being.

OUTSIDE THE WINDOW

Any exterior lighting system from which light spills into living areas—such as residential roadways and commercial parking areas—is appropriate for circadian design strategies. Currently, select UC Davis Medical Center patient rooms and their window-adjacent corridors and parking areas are being designed with lighting systems that adhere to the *Five Key Circadian and Lighting Quality Design Strategies* and promoting the key design criteria of circadian wellness, dark adaptation and a high-fidelity visual environment for patient care.

Outside of the healthcare sector, early municipal adopters are specifying circadian-friendly lighting systems in exterior applications. For instance, the City of Davis has specified a low-wattage, 2700K roadway fixture for their residential roadways (**Figure 6**).

Photo: Kathreen Fontecha/CLTC, UC Davis

Figure 6. The City of Davis has specified a low-wattage, 2700K roadway fixture for their residential roadways.

"Davis residents have embraced the idea of better quality streetlights that save money and reduce GHG emissions. Davis is being contacted by major cities in the United States who are trying to figure this issue out – Honolulu, Denver, Phoenix, Houston, New York, Sebastopol, etc. In addition, the private sector is also starting to take notice as land developers looking for ways to improve the quality of their housing developments are incorporating Davis's LED lighting standards without having to be asked. Davis believes this shows the potential for a very visible triple bottom line victory – better lit neighborhoods that save money and reduce GHG emissions. This one hits the sustainability bulls-eye."

Mitch Sears, Sustainability Manager, City of Davis, CA

As with most early adopters, this design choice is a conscientious decision to reduce their greenhouse gas contribution to the built environment. Davis residents approached the streetlight change cautiously, participating in pilot installation surveys before the full project was installed. Post-installation feedback proved this to be a successful approach to ensuring residents' voices are part of the process:

"I have been dreading the day the new LED lights were to be installed on my street. I have been against them from the beginning. I participated in the test light survey and wasn't totally satisfied with any of the options. I came home after a weekend away and I'm happy to announce that I was sitting in my front yard at night for about an hour before I noticed that new LED lights had been installed. They are great! Warm and subtle. Nothing like the first round of lights that went in. I'm very pleased that my neighborhood is gently lit."

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Researchers continue to study the biological effects of light in an effort to improve the quality of life for humans and animals alike. ☐

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