

Implications

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Influence of Architectural Lighting on Health

Eve Edelstein, PhD

For over half a century, a growing body of knowledge termed **chronobiology** has described the influence of light exposure on human physical and mental health, as well as behavior and performance. This information is now being incorporated by the evidence-based design (EBD) movement to develop guidelines and best practices for informing clients about the value of design solutions that do not hinder, but rather promote health, well-being, and performance (Edelstein, 2008).

Franz Halberg at the University of Minnesota is widely referred to as the “father of chronobiology.” Halberg’s research, which emerged in the 1940s and continues today, was preceded by a legacy of discoveries related to light and its effect on living things. In the 1700s, Jean-Jacques d’Ortous de Mairan and Carl Linnaeus recorded plant movements that responded to the position of a light source. In the mid-1800s, Charles Darwin described the influence of light on animal behavior. As a result of ongoing research, it is now understood that most living species respond to changing patterns of light and dark. Not excluded from this effect are humans who operate on

daily (circadian) and seasonal/annual (circannual) patterns of light.

Effects of Lighting

We are all familiar with the sense of wakefulness transitioning into sleepiness when day changes to night. These feelings are accompanied by changing levels of melatonin, a naturally occurring hormone that promotes sleep and increases in darkness. In fact, multiple, interrelated systems in the body and brain influence complex physiological responses to light/dark patterns. The degree to which scientists understand the relationship between these systems continues to grow.

As recently as 2001, a new receptor cell (ganglion) was discovered in the human eye that senses slowly changing light patterns (Brainard et al., 2001; Thapan et al., 2001). These ganglion cells are neither rods nor cones and are not involved in vision per se. Instead, they signal light changes to nerves in the supra-chiasmatic nucleus, which synchronizes the brain’s and body’s response to circadian rhythms. This system provides cues that in turn affect the body’s endocrine, immune, cardiac, metabolic, emotional, cognitive, and behavioral responses.

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Influence of Architectural Lighting on Health

Related Research Summaries



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Substantial research has demonstrated that disruption of exposure to normal circadian light patterns for significant periods of time may lead to negative health effects. Prolonged exposure to inadequate levels of daylight is associated with Seasonal Affective Disorder (SAD). Also, sleep or behavioral disturbances in Alzheimer's patients have been altered with repeated exposure to bright, white light (Ancoli-Israel et al., 2003).

Inadequate light levels are associated with dysfunction in a number of systems including diminished immune and endocrine function and may contribute to problems such as diabetes, reproductive and growth disturbances, and symptoms associated with premature aging (Maestroni & Conti, 1996). Some of the most compelling findings are from epidemiological studies that demonstrate increased cancer rates among night-shift nurses who typically had almost constant exposure to a combination of electric and solar lighting (Schernhammer et al., 2004; Swerdlow, 2003). Studies of night-shift factory workers and flight crew have also revealed increased cancer rates. Cardiac function responds notably to circadian patterns. Heart rate variability (HRV) is a sensitive "indicator of stress, health, mortality, and morbidity"

(Thayer & Lane, 2007), and daily heart rate patterns can change under different environmental conditions. HRV changes are also associated with working-memory tasks, with less variability occurring during cognitive tasks. In a recent lab-controlled study, (Edelstein, Ellis, Sollers, & Thayer, 2007) HRV was measured while subjects were exposed to darkness followed by a working-memory task conducted in either red light or bright, white light with a peak in the blue spectrum. Subjects relaxed during 15 minutes in darkness—a period long enough to enable their eyes to adapt to darkness before and between light exposures. Results demonstrated HRV was reduced in bright light conditions, demonstrating the body's readiness for cognitive activation. HRV presented a statistically significant difference in red light conditions. Variability was more appropriate for the situation and task at hand, being greater during rest and reduced during the working-memory task with the red light.

Although much research on circadian rhythms has demonstrated a significant influence of bright white or blue light on the melatonin system and wakefulness response, a careful review of the literature reveals a small yet repeatable influence of red light on baseline measures in melatonin studies. By focusing on cardiac responses, rather than wakefulness or melatonin measures, the pattern of responses to red light becomes more apparent.

These findings highlight several observations that may be of interest to design professionals. First, they remind us that light influences myriad physiological, mental, and behavioral responses beyond those driven by the melatonin system alone. Second, results indicate that even brief exposure to electrical light may influence responses. Finally, the experiment reminds us that the body responds to a broad range of light spectra, intensities, and time patterns, perhaps in yet undiscovered ways.

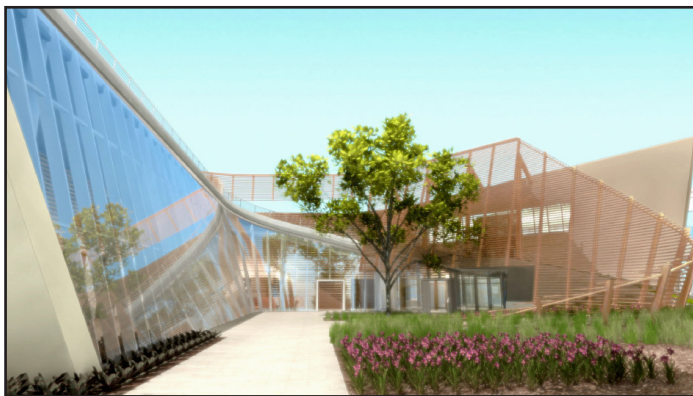
Application Overview

Research on the influence of light on health and behavior may be translated into guiding principles that inform changes in architectural and lighting solutions in built environments. Lighting solutions involve site planning, building orientation, architectural openings, shading and screening systems, as well as electrical lighting systems.

- Easy access to daylight or electrical light of sufficient levels to stimulate the wake/sleep system should be provided where and when possible.
- The programming of spaces for those who must work in darkness or in unnatural circadian patterns should prioritize easy access to daylight. Building orientation and openings should be designed to bring in controlled daylight where possible.

Controlling illumination is paramount, regardless of whether the source is from the sun or from electrical lamps. Furthermore, it is not appropriate to assume that more light is better.

- Light must be controlled for glare, discomfort, and temperature effects.
- Lighting for safety and egress is essential.
- Lighting for visual acuity must meet the requirements for task performance. However, individuals have differing needs for vision, and control of intensity, spectrum, and distance will provide for better lighting conditions.



Cucamonga Valley Water District, Rancho Cucamonga, CA.

- Health status, medical condition, and acuity influence individual needs and preference for lighting.
- Individual and controllable lighting systems are better able to meet the needs of a broad range of users, tasks, and abilities.
- There is a need for both darkness and light that is rarely accommodated in non-residential facilities.

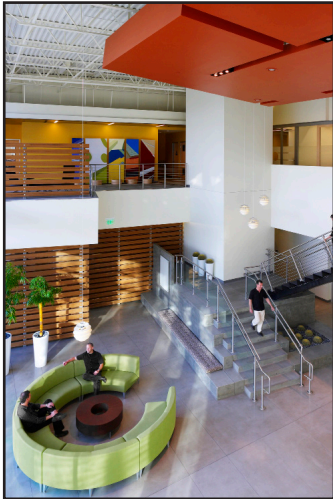
Healthcare Facilities

Applications of lighting in healthcare settings offer specific challenges. Referencing current best evidence on the influence of electrical lighting can inform the designers' selection of individual light sources that support normal circadian rhythms and health.

- Windows provide benefits in patient rooms; however, during acute illness or periods of recovery, darkened conditions that support rest or sleep are often required or preferred, even during the day.
- The provision of darkness for rest and sleep is rarely accommodated. Design should minimize infiltration from light sources in hallways, other patient rooms, nearby clinical stations, or windows.
- In hospitals and many other settings, individual staff may be subjected to very different light cycles by virtue of their changing work patterns and responsibilities. Therefore, individually-controlled light sources are likely to be most suitable for supporting individual needs and performance.
- Circadian light solutions should be carefully controlled to minimize overexposure.

In healthcare facilities where occupants are awake around the clock:

- Night staff workers may benefit from provision of individual light sources that help to stimulate wakefulness. Recent findings suggest that controlled, brief light exposure may serve this need. The choice of light frequency and intensity should be informed by the current and best ongoing research.



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- Night staff should be accommodated with dark and quiet spaces when rest is allowed or as their shifts end.

Conclusion

Although more research is required to fully define the influence of light on health and behavior, it is clear that typical electrical lighting systems do not emulate the natural patterns of daylight.

The spectrum of the sun extends far beyond that produced by lamps available today. Dimming and control systems have only recently been developed to mimic the rise and fall of light levels and full spectrum of light across the day or season. Still of concern are the inadequate levels of natural light in many workplaces once window film is applied to glazing or in workspaces without access to windows.

An increased prevalence of vitamin D deficiency may reflect such design conditions. The impact of lighting in healthcare environments is of particular importance. In such settings, user health status is already at risk, stress levels of both patients and staff may exacerbate such risks, and most users (patients, staff, and visitors) regularly face prolonged periods without natural circadian lighting.

Studies suggest that design be adapted to reduce “circadian disruption” and associated physiological imbalances that may be linked with health issues (Stevens & Rae, 2000). If the sun is considered the “gold standard” for human light needs, then “all or none” lighting and “one lamp fits all” systems are unlikely to support human health and function. Reflecting on physiological research that demonstrates different responses to varied spectra, one might hypothesize

about our emotional responses to the clear blue skies at sunrise or to the calm felt during a red sunset. As evidence-based designers, we can become inspired to utilize our research, intuition, and experience to test such hypotheses so that we can create environments that promote healthy work places and healing spaces.

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About the Author

Eve Edelstein, PhD, brings a background in neuroscience, clinical practice, and architecture to explore the influence of architectural environments on human responses, as Senior Vice President of Research & Design at HMC Architects, and Visiting Scholar at the University of California, San Diego. Her work as Principal Investigator for the 2005-2007 Latrobe Fellowship of the AIA College of Fellows used EBD principles to explore the influence of



light on health and demonstrated significant cardiac changes under different light conditions. Her current collaborations has included the synchronization of brainwave recordings with subject movement through 3D renderings of architecture in a 360° immersive virtual reality StarCAVE at Calit2, UCSD. Edelstein's clinical service and research included electrophysiologic intra-operative monitoring of brain and spinal surgeries, diagnostic testing of balance and hearing disorders, and development of neonatal and infant hearing screening programs.

Related Research Summaries

InformeDesign has many Research Summaries about the diverse affects of lighting, and other related topics. This knowledge will be valuable to you as you consider your next design solution and is worth sharing with your clients and collaborators.

“Controlling Daylight for People with Alzheimer’s Disease”

—*Journal of Architecture and Planning Research*

“Designing Neonatal Intensive Care Units”

—*Critical Care Nurse*

“Visual Comfort and Daylight Dimming Systems”

—*Indoor and the Built Environment*

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