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LIGHTING
FOR MAXIMAL HEALTH AND WELL-BEING

Description:
Lighting is not neutral, but has either a positive or negative effect on health. Correct spectrum and timing of lighting is essential because lighting modifies brain neurotransmitters and neuropeptides which, in turn, alter both mood and the human immune response. Proper lighting can improve health and well-being while poor lighting can alter mood and increase stress and the risk of disease.

All life, including humans, evolved being exposed to a different spectrum of light in the morning, afternoon and evening; and human health and well-being is profoundly affected by the different spectrums of morning, afternoon and evening light. Natural day lighting offers a smooth spectrum of visible light with a high intensity of light in the blue visible range (400 – 500 nm).[1] However, as the day progresses, blue visible light is scattered and lost from the incoming sunlight, and as the sun sets it emits visible light in the orange and red range (600-700 nm). At night, there is natural darkness with the exception of starlight, although the full moon releases significant blue visible light. Because of the significant impact of lighting, when developing homes, health care facilities, public buildings, and public spaces, it is important to maximize natural lighting and, when designing artificial lighting, it is important to mimic the spectrum and timing of natural lighting.

Until ten years ago, it was thought that the only function of the visible light received by the eye was for sight. It was known that light received by the human eye was transmitted to the retina and received by the rods and cones, which then sent a signal through the optic nerve to the visual cortex in the brain to "translate" an image. It is now known that visible light in the long blue range (480nm +/- 20 nm) triggers a circadian response—which is the body's roughly 24-hour cycle or rhythm of waking and sleeping in synchronization with the sun rising and setting.[2]

This blue visible light is transmitted to the eye's retina, received by melanopsin in the intrinsic photosensitive Retinal Ganglion Cells, and a signal passed through the

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[1] Wave Express, "What is Light" (2012): For the most part, visible light is discussed in terms of wavelengths—with the unit being nanometers (nm)—rather than frequencies. Our brains recognize these wavelengths as different colors, where 750 nm is approximately the longest wavelength of red light and 380 nm is approximately the shortest wavelength of violet light, with all the other visible colors in between these two wavelengths. http://library.thinkquest.org/C005705/English/Light/light1.htm

[2] The Free Dictionary (2012): The term "circadian" refers to the body's cyclical daily biological functions (for example, sleep-wake cycle or eating at a certain time) and psychological processes (such as mental alertness), which are influenced by regular variations in the environment such as the alternation of night and day.

http://www.thefreedictionary.com/circadian+rhythm

optic nerve to the brain's hypothalamus—which triggers the production of a cascade of neurohormones.[3] Equally important is the lack of this circadian blue light in the evening. In darkness, a completely different set of neurohormones is produced.

Proper blue visible lighting in the morning and lack of circadian blue visible light in the evening modulates the sleep/wake cycle, growth, blood pressure, reproduction, stress, and metabolism. If the body's circadian rhythm is balanced, there is maximum morning alertness and productivity, and deep (delta) restorative sleep in the evening. If circadian rhythm is disrupted, this can lead to behavioral problems such as depression, agitation, and/ or psychosis.

Biological age is an important risk factor for impaired vision, making proper lighting to insure health and well-being particularly important for those over 50 years of age. Because of the age-related changes in the human lens, there is less visible light transmitted to the human retina of older adults. This not only results in visual impairments but disruptive circadian responses. In addition, at middle age the eye's natural antioxidant protection against light and ultraviolet-radiation-induced damage is lost, while, at the same time, there is an increase in production of the photochemically active pigments in the human lens and retina that damage the eye when activated by light. These changes in the lens lead to enhanced sensitivity to glare and eventual cataract (clouding of the lens) formation, and accumulative retinal damage leads to transient or permanent blindness (macular degeneration). Thus, lighting in individuals' homes, apartment buildings, assisted living facilities, nursing homes, and other health care settings must be specifically designed to compensate for the decrease in visible light reaching the retinas of those who are over 50 years old, as well as for those individuals of younger ages who have visual impairments.

Compensatory lighting for older adults and others with visual impairments:

- *Natural daylight:*
  - Increase exposure to outdoor natural daylight (for example, activity in gardens and parks and other public spaces), particularly outside morning sunlight— 6:00 am – 9:00 am is the timing for the most powerful circadian stimulation.
  - Maximize indoor natural daylight (for example, using skylights and increasing window area—using glass that filters and removes ultraviolet radiation.

- *Overall VISIBLE light levels***:** should be raised by 25% - 50%.

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[3] David Currie, East Tennessee State University (2012), "A Lecture, Higher Brain Function: Activation of the Brain and Levels of Consciousness"**:** Neurohormones are produced and secreted by neurons and act upon the nervous system. Their influence can be described in behavioral terms, such as the ability to think and the kind of thoughts we have, or can be described in terms of brain wave activity. http://faculty.etsu.edu/currie/ras.htm

- *Light levels:* should be uniform, but *NOT* directed into the eye.

- *Task lighting:* use task lighting to illuminte specific work and activity areas as a means of reducing glare and increasing vision.

- *Evening darkness:* To avoid disruption of circadian rhythms, remove or filter TV screens, computer screens, and gadget lights that contain blue visible light. After 10:00 pm, bedrooms should be in total darkness or red light (600 nm and above).

The impact of lighting affects health, achievement, and productivity in all spheres, including homes, schools, work places, health care facilities, public spaces, and public buildings. Photobiology, the study of the interactions of light and living organisms, "can be used to define threshold values for illumination in terms of spectrum, intensity, and timing of light at the human eye. The outcome of such study can be translated into goals for simulation—and ultimately for building design. Initial efforts in this direction are based on the annual Daylight Autonomy (DA) metric,[4] which was chosen to simulate the potential of daylight for human health needs. This method can be applied to study the impact of key architectural decisions for achieving prescribed stimulus of the circadian system—decisions such as building orientation, window size, and glazing material . . . but also to study the influence of human activity and viewing directions."[5]

Benefits:
For older adults and people with disabilities:
- An appropriate lighting environment enhances physical and mental health and well-being.
- Falls and other accidents due to poor lighting design are decreased.
- Proper lighting in multi-use spaces encourages strong socialization and active life-style opportunities.
- Lighting intensity and wavelength can be easily controlled for maximal comfort, depending on light sensitivity of different individuals.

For the community:
- The benefits of good lighting design can be successfully implemented in private homes, residential facilities, health and long-term care facilities, public buildings, and public spaces.
- Emphasis on natural day lighting and removing inappropriate lighting in the evening can:
  - Improve energy-efficiency without being harmful to human health.
  - Decrease health care costs that are related to circadian-related sleep and immune-system disruption.

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[4] Daylight Autonomy metric: a measurement standard for defining good and effective daylighting design.

[5] C. Pechacek, S. Gochenour, M. Andersen (on line, March 30, 2012), "Healthy Lighting," Daylighting Lab, Department of Architecture, Massachusetts Institute of Technology.

For the developer, architect, and lighting designer:
- Resident satisfaction is enhanced at no increase in cost.
- Energy efficiency is enhanced at no increase in cost.

Impediments or barriers to development or implementation:
- For development and design, emphasis is more often on energy-efficiency lumens/watt without consideration for the impact of lighting on health.

- Federal, state, and local building standards for energy efficiency do not take age and visual impairment into account, assuming that one size fits all when considering lighting for homes, buildings, and public spaces.

- There is a lack of awareness among consumers and professionals about the impact of lighting on physical and mental health.

- Laudable efforts to minimize the "carbon footprint" can sometimes lead to a poor choice of light bulbs in residential spaces—for example, compact fluorescent lamps (CFLs) work well for vision only (and, therefore, are good for non-residential areas such as closets or garages), but do not have the proper action spectrum emission for appropriate circadian rhythm.

- The lack of awareness about the differences in wavelengths emitted by different lamps, as well as lack of awareness of the direct relationship between light and the body's biological function can inadvertently lead to uninformed decision-making regarding lighting and poor choices in lamps and lighting. For example, greater education would increase awareness that the action spectra of some "cool" LED's (light-emitting diode) is appropriate for both vision and circadian morning alertness, and incandescent and "warm" LED's are appropriate for afternoon light and task lighting.

Resource—examples:
- Stella Niagara Health Center, Stella Niagara, NY 14144—a complex that includes permanent housing (convent) for 40 Sisters of St. Francis, a school for elementary-age students, a health center, and a hospitality center that hosts retreats held by diverse individuals and groups. The lighting for the Health Center (which includes 20 Sisters who are both elderly and suffering from dementia) was modified according to the principles described above in this article, including exposure to enhanced indoor and outdoor daylight during the day and red light installation for the evening. Modifications resulted in all residents, including those with dementia: sleeping through the night and staying awake longer during the day; blood pressure positively modified; and there was an overall calming effect on all residents.

  N. H. Waff, L. C. Kimberly, R. Mercier, P. Eng, B. Miller, and J. E. Roberts; Trautman Associates, Buffalo, NY: (http://www.trautmanassoc.com/); Lighting Design Innovations, Batavia, NY; Stella Niagara Health Center, Niagara, NY; Fordham University, NY.: 35th Meeting of the American Society for Photobiology, "Modified Lighting and Sleep," Providence, RI, 2010.

- *Royal Netherlands Academy of Arts and Sciences*, Amsterdam, The Netherlands—12 different health care facilities housing 189 residents (average age: 86 years), 87 per cent of whom presented with dementia. Over a three-and-one-half-year period, a research project examined the effects on residents of daily supplementation with bright light for an average of 15 months per resident. In six of the facilities, bright lighting was installed on ceiling fixtures, which were turned on every day between 9:00 am in the morning and 6:00 pm in the evening. Results showed that the bright light had a positive effect on stemming cognitive deterioration by 5 per cent compared to those without the light; depressive symptoms were reduced by 19 per cent; and functional limitations usually experienced by those with dementia were decreased by a relative 53 per cent.

  R. Riemersma-van der Lek, D. F. Swaab, J. Twisk, E. M. Hol, W. J. G. Hoogendijk, and E. J. W. Van Someren (2008), "Effect of Bright Light and Melatonin on Cognitive and Non-Cognitive Function in Elderly Residents of Group Care Facilities: A Randomized Controlled Trial," Journal of the American Medical Association, Vol. 299, pp. 2642-2655.

Resource—written and web:

Development and home/building design:

- R. W. Yeager, J. M. Halloin, et al. (1998), *Lighting and the Visual Environment for Senior Living:* IESNA RP-28-98, a review of available information on the special lighting requirements of older eyes and people with defective vision; available for purchase ($40) from the publisher: New York, NY: Illuminating Engineering Society of North America, 120 Wall Street, New York, NY 10005.

- C. S. Pechacek, M. Andersen, and S.W. Lockley (2008), "Preliminary method for prospective analysis of the circadian efficacy of (day) light with applications to healthcare architecture," *LEUKOS*, Vol. 5, No. 1, pp. 1-26.

- Gregg D. Ander, FAIA; U. S. Department of Energy (August 29, 2011), "Daylighting," *Whole Building Design Guide*. Washington, DC: National Institute of Building Sciences. Includes extensive information on strategies and resources for maximizing day lighting in homes and buildings, references to various calculating tools and models for analyzing a building's day lighting, and case studies on a range of day lighting applications: http://www.wbdg.org/resources/daylighting.php.

- C. Pechacek, S. Gochenour, and M. Andersen (on line, March 30, 2012), "Healthy Lighting: Concept, Development, Application." Cambridge, MA: Daylighting Lab, Massachusetts Institute of Technology. http://daylighting.mit.edu/research_detail.php?project=Healthy_Lighting.

- Patricia Plympton, Susan Conway, and Kyra Epstein (2000), *Daylighting in Schools: Improving Student Performance and Health at a Price Schools Can Afford.* Washington, DC: National Renewable Energy Laboratory, U. S. Department of Energy. http://www.nrel.gov/docs/fy00osti/28049.pdf.

- Kenneth J. Cooper (November 26, 1999), "Study says natural classroom lighting can aid achievement." Press release of the findings of the Heschong Mahone Group's research study: http://www.h-m-g.com/projects/daylighting/publicity%20daylighting.htm. To download copies of this research report and other research by the Heschong Mahone Group on the relationship between lighting and achievement and productivity: http://www.h-m-g.com/projects/daylighting/projects-pier.htm.

Impact of light on humans:

- Circadian Rhythm:
  - David M. Berson (2003), "Strange vision: ganglion cells as circadian photoreceptors," *Trends in Neurosciences*, Vol. 26, pp.314-320.
  - G. C. Brainard, J. P. Hanifin, J. M. Greeson, B. Byrne, G. Glickman, E. Gerner, and M. D. Rollag (2001), "Action spectrum for melatonin regulation in humans: evidence for a novel circadian photoreceptor," *Journal of Neuroscience*, Vol.21, pp. 6405-6412.
  - J. E. Roberts (2005), "Update on the positive effects of light in humans," *Photochemistry and Photobiology*, Vol. 81, pp. 490-492.

- Sleep/Wakefulness:
  - D. P. Cardinali, S. R. Pandi-Perumal (2005), *Neuroendocrine Correlates of Sleep/Wakefulness* (Editors: D. P. Cardinali and S. R Pandi-Perumal), New York, NY: Springer Publishing.
  - C. Cajochen, M. Münch, V. Knoblauch, K. Blatter, and A. Wirz-Justice (2006), "Age-related changes in the circadian and homeostatic regulation of human sleep," *Chronobiology International*, Vol. 23, No. 1-2, pp. 461-474.
  - J. Doljansky, H. Kannety, and Y. Dagan (2005), "Working under daylight intensity lamp: an occupational risk for developing circadian rhythm sleep disorder?" *Chronobiology International,* Vol. 22, No. 3, pp. 597-605.
  - G. A. Dowling, R. L. Burr, E. J. W. Van Someren, E. M. Hubbard, J. S. Luxenberg, J. Mastick, and B. A. Cooper (2008), "Melatonin and bright light treatment for rest-activity disruption in institutionalized patients with Alzheimer's disease," *Journal of the American Geriatric Society,* Vol. 56, pp. 239-246.
  - S. M. McCurry and S. Ancoli-Israel S (2003), "Sleep dysfunction in Alzheimer's disease and other dementias," *Current Treatment Options in Neurology,* Vol. 5, No. 3, pp. 261-272.
  - C. P. Pollack and D. Perlick (1991), "Sleep problems and institutionalization of the elderly," *Journal of Geriatric Psychiatry and Neurology*, Vol. 4, No. 4, pp. 204-10.

- Behavior and Cognitive Function:
  - P. V. Rabins (1996), "Behavioral disturbances of dementia: practical and conceptual issues," *International Psychogeriatrics,* Vol. 3(supplement), pp. 281–83.

  - R. F. Riemersma-van der Lek, D. F. Swaab, J. Twisk, E. M. Hol, W. J. G. Hoogendijk, and E. J. W. Van Someren (2008), "Effect of bright light and melatonin on cognitive and non-cognitive function in elderly residents of group care facilities," *Journal of the American Medical Association,* Vol. 299, No. 22, pp. 2642-2655.

  - J. A. Veitch, G. van den Beld, G. Brainard, and J. E. Roberts (2004), "Ocular lighting effects on human physiology and behavior," *Commission Internationale de l'Eclairage*, Publication #158, Vienna, Austria, ISBN #3 901 906 28 2.

- Disease:
  - Rheumatoid Arthritis—
    - M. Cutolo, G. J. Maestroni, K. Otsa, O. Aakre, B. Villaggio, S. Capellino, P. Montagna, L. Fazzuoli, T. Veldi, T. Peets, E. Hertens, and A. Sulli (2005), "Circadian melatonin and cortisol levels in rheumatoid arthritis patients in winter time: a north and south Europe comparison," *Annals of the Rheumatic Diseases,* Vol. 64, pp. 212–216.

  - Cancer—
    - S. Gery and H. P. Koeffler (2007), "The role of circadian regulation in cancer," *Cold Spring Harbor Symposia on Quantitative Biology*, Vol. 72, pp. 459–464.
    - R. G. Stevens, D. E. Blask, G. C. Brainard, J. Hansen, S. Lockley, I. Provencio, M. S. Rea, and L. Reinlib (2007), "The role of environmental lighting and circadian disruption in cancer and other diseases," Meeting Report, *Environmental Health Perspectives,* Vol. 115, pp. 1357–1362.

  - Eyes—
    - J. E. Roberts (2011), "Ultraviolet radiation as a risk factor for cataract and macular degeneration. *Eye & Contact Lens,* Vol. 37, pp. 246–249.

  - Immune System—
    - J. E. Roberts (2000), "Light and immunomodulation," *New York Academy of Science,* Vol. 917, pp. 435-445.

Resource—technical assistance contact names:

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