Physiological effects of blue and red lights

Circadian rhythms, melatonin, light and illness

Almost all living things on earth show a 24-hour circadian and biological rhythm, due to the earth's rotation. This rhythm has a profound impact on biochemical, physiological, and behavioural processes in living organisms (Reppert and Weaver 2002, Reddy and O'Neill 2010). The suprachiasmatic nucleus (SCN) of the hypothalamus in the brain, is primarily responsible for maintaining this 24-hour rhythm, using light as its main cue (Dunlap 2004).

Melatonin is a hormone which is primarily synthesized in the pineal gland and then it goes into the blood. Its 24-hour rhythm is directly driven by the circadian clock from the SCN to the pineal gland. So pineal melatonin is synthesized during the night (normal peak 1-3 a.m.), and during the day, production virtually stops.

Melatonin has been shown in studies in vitro to have antioxidant properties, including scavenging free radicals, preventing tumour cell growth, and enhancing the immune response (Brzezinski 1997, Korkmaz 2009, Reiter 2010).

The response of the circadian system to light is dependent on the timing and quality of light exposure (Rimmer 2000, Thapan 2001, Lockley 2003, Gronfier 2004, 2007, Ozkan 2012, Rüger 2013).

Ill-timed light exposure may result in disruption of circadian rhythms dependent on the type of light (Stevens 2011). Ill-timed exposures to even low levels of light in household settings may be sufficient for circadian disruptions. Bedrosian & Nelson (2013) in a review on the effects of light on mood, concluded that night time exposure to light disrupts circadian organisation and contributes to depressed mood.

A comparison between the effects of living room light and dim light before bedtime showed that exposure to ordinary levels of room light suppressed melatonin levels and shortened the duration of melatonin production in healthy volunteers (18-30 years) (Gooley 2011). Wada (2013) found that low levels of evening lighting improved melatonin secretion at night, which induced easy onset of sleep and better quality of sleep in students, including athletes.

It has been suggested that circadian disruptions play an important role in the development of chronic diseases and conditions such as cancer (breast, prostate, endometrial, ovarian, colo-rectal, skin and melanomas and non-Hodgkin's lymphomas), cardiovascular diseases, reproduction, endometriosis, gastrointestinal and digestive problems, premature ageing, diabetes, obesity, depression (especially during winter months when daylight exposure is often reduced for those primarily working in artifical light), sleep deprivation, and cognitive impairment (Haus and Smolensky 2006, Stevens 2007, Frost 2009, Bass and Takahashi 2010, Boyce and Barriball 2010, IARC 2010, Kvaskoff and Weinstein 2010, Mahoney 2010, Rana and Mahmood 2010, Ortiz-Tudela 2012, Poole 2011).

Breast cancer risk has been consistently associated with various aspects of circadian disruptions including being exposed to high ambient light during the night (Stevens 2009). Three studies link breast cancer risk to exposure to non-occupational light-at-night (LAN) in the home (Davis 2001, Kloog 2011, O'Leary 2006), and significant associations were found for women who did not sleep during the period of the night where melatonin levels are normally peaking (Davis 2001), or who

frequently turned on the light during the night. An increased breast cancer risk was also found with increasing bedroom light levels (Kloog 2010).

Dauchy (2011) found that even very low levels of LAN in their animal laboratory disrupted circadian rhythms and stimulated cancer growth. Reducing LAN restored these aspects of metabolism.

Pauley, in a meta-analysis (2004), suggested that the proper use and colour of indoor lighting is important to the health of humans. Kent (2009) found that decreased exposure to sunlight was associated with an increased probability of cognitive impairment. We do not know whether daylight spectrum bulbs would have a similar effect.

People with many medical conditions, e.g. lupus, ME and ES, cannot tolerate "blue" lighting, whether fluorescent or otherwise.

Timing of blue lights

Our circadian system is especially sensitive to blue light even at low light levels.

Blue-enriched light is more efficient in melatonin suppression than other wavelengths (Figueiro and Rea 2010, Gooley 2011) and the effects persist (Wahnschaffe 2013), even into sleep (Münch 2006). Computer use at night did not affect melatonin levels as long as there was no blue light nearby (Figueiro 2011).

The threshold level of low wavelength light required to inhibit melatonin production in the horse lies between 3 and 10 lux. Melatonin inhibition can be achieved by exposing a single eye to low wavelength blue light (Walsh 2012).

The good side of blue light (Lockley 2003), is that it enhances alertness, (Cajochen 2005, Phipps-Nelson 2009) and gets you ready for the day ahead (Lockley 2006). Blue light also activates the parts of the brain involved in thinking, memory and mood (Vandewalle 2007a, Vandewalle 2007b, Vandewalle 2009, Vandewalle 2010). Several studies report that shorter wavelengths, such as blue light are significantly more efficient in generating alertness responses than longer wavelengths (red lights) (Cajochen 2005, Lockley 2006, Revell 2006, Vanderwalle 2007a).

Disruption of circadian rhythms by insufficient light exposure seems to be involved in a subgroup of depressed patients (Monteleone 2011). Several studies have shown that light therapy may be an efficient treatment for seasonal affective disorder (SAD) (Monteleone 2011, Westrin and Lam 2007, Wirz-Justice 2005). Recent reports have shown that short wavelength blue light from LED sources (Anderson 2009, Glickman 2006, Howland 2009, Strong 2009) has similar clinical effects to white light sources. Blue light may be even more effective than the bright white light currently used in light boxes to treat SAD and other forms of depression. Maybe it is the lack of exposure to blue sky in the short, often overcast days of winter that make some of us prone to emotional downturns and SAD. Brainard's 2006 study found that blue light also worked better than red light in treating SAD symptoms.

Viola (2008) performed an occupational study where subjects spent the working day for 4 weeks either in a blue-enriched white light environment or in a white light environment. A number of subjective measures of alertness, mood, performance, fatigue, etc. improved in the blue-light condition as compared to the white light condition.

Srinivasan (2008) also suggest that light (especially blue light Figueiro 2009, Lerchl 2009) at night reduces melatonin production, although the low level used in car lights' LEDs did not do so. However, short-wavelength 'blue' light in the ***morning*** helps entrain the circadian system, helpful

in promoting alertness in adolescents, delaying melatonin-induced sleepiness (Rea & Figueiro 2010).

The neurologist George Brainard, of the Light Research Program at Thomas Jefferson University in Philadelphia has shown that blue light strengthens and stimulates connections between areas of your brain that process emotion and language. The researchers suspect that blue light may, in turn, help people to better handle emotional challenges and regulate mood over time.

Using blue light in light therapy might be a good thing, but we may also want to think about changing the lighting in our homes and offices, says Vandewalle, one of the foremost researchers into the health effects of lighting, pointing to previous studies that found that people feel better, perform better, and sleep better when working under blue-enriched light as opposed to the light given off by standard bulbs.

"*We ultimately need to be thinking about a revolution in lighting,*" Brainard adds. "*It is in our best interest to have not only light that's adequate for vision but light that's also optimal for our biology and behaviour.*"

Timing of red/amber lights

There have been suggestions that light that is not too bright in the evening and at night time, at the red end of the spectrum, is less likely to disrupt melatonin production during the following hours of sleep (Stevens 1993a, 1993b, 1996, 2006 Schernhammer 2004, 2005 Higuchi 2011). The intensity, duration and wavelength of lighting seems to be significant (Glickman 2002, Lockley 2003, Hanifin 2006, Jasser 2006, Carazo 2013).

Alpert (2009) suggested that it is primarily the blue wavelengths of light that are responsible for loss of melatonin. They believe that using blue-free light bulbs for a few hours before bedtime maximises melatonin production and reduces the risk of breast, ovarian and prostate cancer. Bennett (2009) suggested that these red bulbs may be helpful in preventing postnatal depression in women who get up at night to feed their new-born babies.

References

Alpert M et al 2009 – *Nighttime use of special spectacles or light bulbs that block blue light may reduce the risk of cancer* Med Hypotheses 73(3):324-5 PMID: 19375243

Anderson JL et al 2009 - *Lux versus wavelength in light treatment of Seasonal Affective Disorder*. Acta Psychiatr Scand 2009; 120:203-12 PMID: 19207131

Bass J & JS Takahashi 2010 - *Circadian integration of metabolism and energetics*. Science 330:1349-54 PMID: 21127246

Bedrosian TA & RJ Nelson - *Influence of the modern light environment on mood* Mol Psychiatry 18(7):751-7 PMID: 23711982

Bennett S et al 2009 – *Use of modified spectacles and light bulbs to block blue light at night may prevent postpartum depression* Med Hypotheses 73(2):251-3 PMID: 19329259

Boyce P & E Barriball 2010 - *Circadian rhythms and depression* Aust Fam Physician 39:307-10 PMID: 20485718

Brzezinski A 1997 - *Melatonin in humans*. N Engl J Med 336:186-95 PMID: 8988899

Cajochen C et al 2005 - *High sensitivity of human melatonin, alertness, thermoregulation, and heart rate to short wavelength light*. J Clin Endocrinol Metab 90:1311-6 PMID: 15585546

Carazo I 2013 - *The effect of night illumination, red and infrared light, on locomotor activity, behaviour and melatonin of Senegalese sole (Solea senegalensis) broodstock* Physiol Behav 118:201-7 PMID: 23711567

Dauchy RT et al 2011 - Eliminating animal facility light-at-night contamination and its effect on circadian regulation of rodent physiology, tumor growth, and metabolism: a challenge in the relocation of a cancer research laboratory J Am Assoc Lab Anim Sci 50(3):326-36 PMID: 21640027

Davis S et al 2001 - N*ight shift work, light at night, and risk of breast cancer*. J Natl Cancer Inst 93:1557-62 PMID: 11604479

Dunlap JC, Loros JJ, DeCoursey PJ, editors. C*hronobiology, Biological Timekeeping*. Sunderland, Massachussetts, USA: Sinauer Associates Inc. Publishers; 2004.

Figueiro MG et al 2011 - *The impact of light from computer monitors on melatonin levels in college students* Neuro Endocrinol Lett 32(2):158-63 PMID: 21552190

Figueiro MG & MS Rea 2010 - *The effects of red and blue lights on circadian variations in cortisol, alpha amylase, and melatonin* Int J Endocrinol 829351 PMID: 20652045

Figueiro MG et al 2009 - *Preliminary evidence that both blue and red light can induce alertness at night* BMC Neurosci 10:105 PMID: 19712442

Frost P et al 2009 - *Shift work and the risk of ischemic heart disease - a systematic review of the epidemiologic evidence* Scand J Work Environ Health 35:163-179 PMID: 19387517

Glickman G et al 2006 - *Light therapy for seasonal affective disorder with blue narrow-band light-emitting diodes (LEDs)* Biol Psychiatry 59:502-7 PMID: 16165105

Glickman G et al 2002- *Ocular input for human melatonin regulation: relevance to breast cancer* Neuro Endocrinol Lett 23 Suppl 2:17-22 PMID: 12163843

Gooley JJ et al 2011 - *Exposure to room light before bedtime suppresses melatonin onset and shortens melatonin duration in humans* J Clin Endocrinol Metab 96:E463-72 PMID: 21193540

Gronfier C et al 2007 - *Entrainment of the human circadian pacemaker to longer-than-24-h days* Proc Natl Acad Sci U S A. 104(21):9081-6 PMID: 17502598

Gronfier C et al 2004 - *Efficacy of a single sequence of intermittent bright light pulses for delaying circadian phase in humans* Am J Physiol Endocrinol Metab 287:E174-81 PMID: 15039146

Haus E & M Smolensky 2006 - *Biological clocks and shift work: circadian dysregulation and potential long-term effects* Cancer Causes Control 17:489-500 PMID: 16596302

Higuchi S et al 2011 - *Effectiveness of a Red-visor Cap for Preventing Light-induced Melatonin Suppression during Simulated Night Work* J Physiol Anthropol 30(6):251-8 PMID: 22197958

Howland RH 2009 **-** *An overview of seasonal affective disorder and its treatment options* Phys Sportsmed 37:104-15 PMID: 20048547

IARC (International Agency for Research on Cancer) 2010 - Painting, Firefighting, and Shiftwork. IARC Monographs on the Evaluation of Carcinogenic Risks to Humans: Volume 98. Lyon: IARC Press

Jasser SA et al 2006 - *Dim light adaptation attenuates acute melatonin suppression in humans* J Biol Rhythms 21(5):394-404 PMID: 16998159

Kent ST et al 2009 - *Effect of sunlight exposure on cognitive function among depressed and non-depressed participants: a REGARDS cross-sectional study* Environ Health 8(1):34 PMID: 19638195

Kloog I et al 2011 **-** *Does the modern urbanized sleeping habitat pose a breast cancer risk?* Chronobiol Int 28:76-80 PMID: 21182407

Kloog I et al 2010 - *Nighttime light level co-distributes with breast cancer incidence worldwide* Cancer Causes Control 21:2059-68 PMID: 20680434

Korkmaz A et al 2009 - *Role of melatonin in metabolic regulation* Rev Endocr Metab Disord 10:261-70 PMID: 19911281

Kvaskoff M & P Weinstein 2010 - *Are some melanomas caused by artificial light?* Med Hypotheses 2010; 75:305-11 PMID: 20347530

Lerchl A et al 2009 **–** *Indirect blue light does not suppress nocturnal salivary melatonin in humans in an automobile setting* J Pineal Res 47(2):143-6 PMID: 19555449

Lockley SW et al 2006 - *Short-wavelength sensitivity for the direct effects of light on alertness, vigilance, and the waking electroencephalogram in humans* Sleep 29:161-8.

Lockley SW et al 2003 - *High sensitivity of the human circadian melatonin rhythm to resetting by short wavelength light* J Clin Endocrinol Metab 88:4502-5 PMID: 12970330

Mahoney MM 2010 - *Shift work, jet lag, and female reproduction* Int J Endocrinol 2010:813764 PMID: 20224815

Monteleone P et al 2011 - *Circadian rhythms and treatment implications in depression* Prog Neuropsychopharmacol Biol Psychiatry 35(7):1569-74 PMID: 20691746

Münch M et al 2006 - *Wavelength-dependent effects of evening light exposure on sleep architecture and sleep EEG power density in men* Am J Physiol Regul Integr Comp Physiol 290:R1421-8.

O'Leary ES et al 2006 **-** *Shift work, light at night, and breast cancer on Long Island, New York* Am J Epidemiol 164:358-66.

Ortiz-Tudela E et al 2012 - *[Chronodisruption and ageing]* Rev Esp Geriatr Gerontol 47(4):168-73 PMID: 22177973

Ozkan S et al 2012 - *Photoperiodic lighting (16 hours of light:8 hours of dark) programs during incubation: 1. Effects on growth and circadian physiological traits of embryos and early stress response of broiler chickens* Poult Sci 91(11):2912-21 PMID: 23091150

Pauley S 2004 - *Lighting for the human circadian clock\; recent research indicates that lighting has become a public health issue.* Med Hypotheses 63(4):588-96 PMID 15325001

Phipps-Nelson J et al 2009 - *Blue light exposure reduces objective measures of sleepiness during prolonged nighttime performance testing* Chronobiol Int 26(5):891-912 PMID: 19637049

Poole EM et al 2011 - *Rotating night shift work and risk of ovarian cancer* Cancer Epidemiol Biomarkers Prev 20:934-8 PMID: 21467237

Rana S & S Mahmood 2010 - *Circadian rhythm and its role in malignancy* J Circadian Rhythms 8:3 PMID: 20353609

Reddy AB & JS O'Neill 2010 - *Healthy clocks, healthy body, healthy mind* Trends Cell Biol 20:36-44 PMID: 19926479

Reiter RJ et al 2010 - *Melatonin: a multitasking molecule* Prog Brain Res 181:127-51 PMID: 20478436

Reppert SM & DR Weaver 2002 - *Coordination of circadian timing in mammals* Nature 418:935-41 PMID: 12198538

Revell VL et al 2006 - *Alerting effects of light are sensitive to very short wavelengths* Neurosci Lett 399:96-100

Rimmer DW et al 2000 - *Dynamic resetting of the human circadian pacemaker by intermittent bright light* Am J Physiol Regul Integr Comp Physiol 279:R1574-9 PMID: 11049838

Rüger M et al 2013 - *Human phase response curve to a single 6.5-h pulse of short-wavelength light* J Physiol 591(Pt 1):353-63 PMID: 23090946

Schernhammer ES & SE Hankinson 2005 - *Urinary melatonin levels and breast cancer risk* J Natl Cancer Inst 97(14):1084-7

Schernhammer E et al 2004 - *Epidemiology of urinary melatonin in women and its relation to other hormones and night work* Cancer Epidemiol Biomarkers Prev **13** (62): 936-43

Srinivasan V et al 2008 - *Melatonin, environmental light, and breast cancer* Breast Cancer Res Treat 108(3):339-50

Stevens RG et al 2011 - *Considerations of circadian impact for defining 'shift work' in cancer studies: IARC Working Group Report* Occup Environ Med 68:154-62 PMID: 20962033

Stevens RG 2009 - *Light-at-night, circadian disruption and breast cancer: assessment of existing evidence* Int J Epidemiol 2009; 38:963-70 PMID: 19380369

Stevens RG et al 2007 **-** *Meeting report: the role of environmental lighting and circadian disruption in cancer and other diseases* Environ Health Perspect 115:1357-62 PMID: 17805428

Stevens RG 2006 - *Artificial lighting in the industrialised world: circadian disruption and breast cancer* Cancer Causes Control 17(4):501-7

Stevens RG & S Davis 1996 - *The melatonin hypothesis: electric power and breast cancer* Environ Health Perspect 104(S1):135-40

Stevens RG 1993a - *Breast cancer and electric power* Biomed Pharmacother 47(10):435-8

Stevens RG 1993b - *Biologically based epidemiological studies of electric power and cancer* Environ Health Perspect 101(S4):93-100

Strong RE et al 2009 - *Narrow-band blue-light treatment of seasonal affective disorder in adults and the influence of additional nonseasonal symptoms* Depress Anxiety 26:273-8

Thapan K et al 2001 - *An action spectrum for melatonin suppression: evidence for a novel non-rod, non-cone photoreceptor system in humans* J Physiol 535:261-7 PMID: 11507175

Vandewalle G et al 2010 - Spectral quality of light modulates emotional brain responses in humans. Proc Natl Acad Sci U S A 107:19549-54.

Vandewalle G et al 2009 - *Light as a modulator of cognitive brain function* Trends Cogn Sci 13:429-38

Vandewalle G et al 2007a - *Wavelength-dependent modulation of brain responses to a working memory task by daytime light exposure* Cereb Cortex 17:2788-95.

Vandewalle G et al 2007b - *Brain responses to violet, blue, and green monochromatic light exposures in humans: prominent role of blue light and the brainstem* PLoS ONE 2:e1247.

Viola AU et al 2008 - *Blue-enriched white light in the workplace improves self-reported alertness, performance and sleep quality* Scand J Work Environ Health 34:297-306

Wada K et al 2013 - *A tryptophan-rich breakfast and exposure to light with low color temperature at night improve sleep and salivary melatonin level in Japanese students* J Circadian Rhythms 11(1):4 PMID: 23705838

Wahnschaffe A et al 2013 - *Out of the lab and into the bathroom: evening short-term exposure to conventional light suppresses melatonin and increases alertness perception* Int J Mol Sci 14(2):2573-89 PMID: 23358248

Walsh CM et al 2012 - *Blue light from light-emitting diodes directed at a single eye elicits a dose-dependent suppression of melatonin in horses* Vet J 196(2):231-5 PMID: 23079244

Westrin A & RW Lam 2007 - *Seasonal affective disorder: a clinical update* Ann Clin Psychiatry 19:239-46.

Wirz-Justice A et al 2005 - *Chronotherapeutics (light and wake therapy) in affective disorder*. Psychol Med 35:939-44.