From Light to Cancer
A discussion of recent research and its implications

By David M. Keith, FIES

Introduction

Recent research into the relationships between light, the human diurnal cycle and cancer have indicated that these three physical phenomena may be related in previously unexpected ways. The research indicates that the current popular and professional views of light and lighting should be reviewed and revised appropriately.

This is a summary of the significant research, presenting the chain of relationships between light and cancer, including a brief discussion of the implications, with particular attention to the lighting industry and design decisions. At the end is a bibliography that includes all the papers discussed here, most of which are available through the web, and the remainder are in the archives of Leukos.

Background

In the 1990’s, research into the human diurnal cycle included work into the relationship between light and the hormone melatonin, which had already been identified as a significant element in the cycle. The presence of melatonin was recognized as one of the signals to sleep, and the suppression of melatonin corresponded to wakefulness. Early research into Seasonal Affective Disorder (SAD) and efforts to reduce the effects of “jet-lag” using light had indicated that there was an unknown relationship between light and human health in terms of general well-being. The diurnal cycle was considered to be part of that relationship, but the way in which light might affect those complex processes was not well understood at all.

Research

In 1993, research into the relationships between pupil size, light levels and the level of melatonin in the blood [1] reported that melatonin concentration in the blood was high at night and low during the day, and that the presence of melatonin promoted sleep. These were unsurprising results. What was surprising was that the research showed that pupil size did make a difference – but the theoretical illuminance on the retina did not! Pupil dilation significantly enhanced “low level white light-induced melatonin suppression” but there was no relationship between “theoretical retinal illuminance in Trolands and magnitude of melatonin suppression” found. So the eyes were recognized as playing a significant role, but the results were at odds with the existing theory about the response to radiation by the human visual system.

One observation to make here is that the research did describe the stimulus as “low level white light” but provided no more specific information about the radiation used.
The next link in the chain is a paper in 2001 [2] indicating that monochromatic radiation at 505 nm is about four times as strong as radiation at 555 nm in suppressing melatonin in humans. This paper concluded that human melatonin regulation is not mediated by the cone receptor system corresponding to the well-known photopic visual sensitivity function.

Further research also published in 2001 [3] concluded that the photopigment that transduces light for circadian regulation was unknown. However the authors did show an action spectrum – a relationship between the wavelength of radiation and the magnitude of its effect on melatonin suppression. This indicated that there was a novel opsin photopigment that mediates circadian photoreception. This means that “light exposure” can acutely suppress melatonin secretion, but neither rods nor cones participate! This leads to the conclusion that there are “separate photoreceptors for visual and circadian responses to light in humans.”

It is not every century that starts with the discovery of a new human sensory organ!

In 2004, another paper [4] reports on melatonin suppression by short wave radiation, including evidence to “.. suggest a change in the spectral sensitivity of circadian phototransduction mechanisms at two different times of the night.” Now, even time-of-day or time-of-night matters.

Reviews of Research

One review of research, published by researchers in 2002 [5], states that there was evidence of “.. an apparent relationship between light, melatonin and cancer, albeit complex.”

This paper [5] mentions that – in terms of the suppression of melatonin – humans have “.. a peak sensitivity between 446–484 nm ..” which means this system’s response is entirely different from previously determined sensitivity functions for either photopic or scotopic adaptation. Additionally, “[u]nder highly controlled exposure circumstances, less than 1 lux of monochromatic light elicited a significant suppression of nocturnal melatonin.” Citing “1 lux of monochromatic light” demonstrates that the conventional units for quantity of visually-evaluated radiation are inappropriate for this discussion, because “1 lux of monochromatic light” is not an adequate description.

For the sake of measuring the human response to radiation and related melatonin suppression, the unit of the lumen is meaningless, because its inherent photopic sensitivity function is irrelevant. Since ”light” is defined as “visually evaluated radiation” with the photopic sensitivity function as the basis for that evaluation, it is clear that we need to either redefine “light” or start talking in terms of radiation instead.

This paper [5] also reports on research that linked the absence of melatonin to increased development and growth of cancer. Considering earlier research, it appears that “light” may suppress melatonin and that without melatonin the likelihood of cancer increases. Specifically “.. the possible link between light exposure, melatonin suppression and cancer risk ..” makes it “.. necessary to reevaluate lighting strategies ..” because now we have information linking “light” to cancer.

Another review [6] of research states that because of its capacity to change melatonin levels, “light” should be treated as a drug. Reportedly “blue light” may have an effect even though eyes are closed.
In addition, applications of short wave radiation are reported to have therapeutic effects [7].

Summaries of the information

In the IESNA publication *Leukos*, the editor invited discussion of the recent research, and started the discussion by writing [8] that the primary task facing the lighting industry now is to “.. determine when we are prepared to let photobiology affect our recommendations and design practices.” and finds that “.. it is a greater mistake for our industry to wait too long.”

The next editorial [9] observed that “.. we have to start thinking differently .. because wrong lighting (and darkness) at the wrong moments can have a negative effect on our health.” This editorial presented a rough sensitivity function while reporting that there was “no true additivity law” and therefore “.. nonmonochromatic light sources cannot simply and easily be analyzed ‘biologically’ on the basis of the curve ..” that was shown. Spatial and temporal characteristics also matter, as well as spectral – and daylight should be considered indispensable.

Another in this editorial series [10] discussed what information is still needed, in particular “.. to describe the amount of light delivered to the occupant’s eye” (which seems to reinforce the confusion between the way light is defined and way radiation effects melatonin suppression.) Especially when discussing what new information is needed, current verbiage does not provide the necessary clarity.

The final entry in the editorial series [11] called “.. the enthusiasm for modifying lighting practice to take account of the impact of light on human health .. premature” and continued by stating that “.. it is as medical treatment that we should consider the use of light for enhancing human health. The first rule .. is ‘Do no harm’” and cautioned against relying on the current information because of the numerous issues still unresolved - such as definitions of “light” and “dark” – and much more.

Comments

One obvious result of this research is specific evidence for the health benefits of daylighting.

Another immediate result of all this research is to raise questions about how the terminology and units of lighting can be used or revised. We know lighting equipment produces the radiation that is a concern – but we do not have words yet to label, measure, report or compare that radiation. Existing sensitivity functions are irrelevant – and there may be no one “sensitivity function” for this anyway!

After all we know that – in terms of “dosage” – where-in-our-view and when-during-the-day matter – but again the necessary words and units are not part of our vocabulary – yet. What is desirable in the morning may not be desirable in the evening – or at some other time, depending on the diurnal cycle of the people involved. What is desirable for some people may not be for others. This would suggest that any one sensitivity function may not be appropriate – there might be “families” of them depending on the specifics of the situation.
It is also obvious that developing some sort of sensitivity function is important, because no matter how small any disruption of melatonin is at any moment, the long term and cumulative effects may be significant and life-threatening, and decisions made now may be affecting people for decades.

**Extrapolation**

Based mostly on data from earlier experiments with monochromatic radiation, Jan Hollan produced a “meltoptic” sensitivity function. I combined this in the conventional way with spectral power distributions from typical light sources, using the assumption that Abney’s Law applies, which may not be entirely correct. However this does provide a first-order approximation of the magnitude of the effect of different source types, and may provide guidance in designing lighting while considering the health effects that result from disruption of the diurnal cycle and suppression of melatonin.

The table below shows the source type and watts of energy to produce 100 photopic lumens, along with the corresponding scotopic lumens and the magnitude of the “meltoptic” effect for various sources as defined by CIE or using spectral power distribution data provided by Philips.

<table>
<thead>
<tr>
<th>Source</th>
<th>Watts</th>
<th>Pho</th>
<th>Sco</th>
<th>Mel</th>
</tr>
</thead>
<tbody>
<tr>
<td>CIE Daylight (D65)</td>
<td>0.49</td>
<td>100</td>
<td>257</td>
<td>136</td>
</tr>
<tr>
<td>CIE Incandescent (Illum. A)</td>
<td>0.61</td>
<td>100</td>
<td>147</td>
<td>59</td>
</tr>
<tr>
<td>Avg Metal Halide</td>
<td>0.31</td>
<td>100</td>
<td>166</td>
<td>76</td>
</tr>
<tr>
<td>Avg High Pressure Sodium</td>
<td>0.26</td>
<td>100</td>
<td>68</td>
<td>27</td>
</tr>
<tr>
<td>Fluorescent 3000K</td>
<td>0.28</td>
<td>100</td>
<td>131</td>
<td>53</td>
</tr>
<tr>
<td>Fluorescent 3500K</td>
<td>0.29</td>
<td>100</td>
<td>151</td>
<td>66</td>
</tr>
<tr>
<td>Fluorescent 4100K</td>
<td>0.30</td>
<td>100</td>
<td>169</td>
<td>78</td>
</tr>
<tr>
<td>Fluorescent 6500K</td>
<td>0.32</td>
<td>100</td>
<td>227</td>
<td>118</td>
</tr>
</tbody>
</table>

From this preliminary data it is clear that daylight can have the most significant effect and 6500K fluorescent is a close second. Furthermore it is evident that typical metal halide (CCT ~ 4100K) has a significantly greater effect than high pressure sodium, with incandescent and “warm” fluorescent in between. In fact the relationship between correlated color temperature and “meltopic” is a clear trend, as is the relationship between scotopic and “meltopic” – not exact but roughly consistent.

Obviously “light” from different sources could have greatly differing effects on melatonin and therefore health.

**Conclusions**

The recent research into light, melatonin and health presents challenges to the lighting industry in technical ways and furthermore shows that source selection – from daylight to night-lighting – may make a difference in the health of the people who live with the “light” produced.

**Acknowledgements**

The author wishes to thank Jan Hollan and Philips Lighting for the information they graciously provided, while retaining all responsibility for its use to himself, and Jefferey Knox for all the talks.
References

1) Pupil size regulation of threshold of light-induced melatonin suppression
Gaddy JR, Rollag MD, Brainard GC.
This article is available from: http://jcem.endojournals.org/cgi/reprint/77/5/1398

2) Human melatonin regulation is not mediated by the three cone photopic visual system
Brainard, Hanifin, Rollag, Greeson, Byrne, Glickman, Gerner and Sanford
J Clin Endocrinol Metab 2001 86:433–436
This article is available from: http://jcem.endojournals.org/cgi/reprint/86/1/433

3) Action Spectrum for Melatonin Regulation in Humans: Evidence for a Novel Circadian Photoreceptor
Brainard, Hanifin, Greeson, Byrne, Glickman, Gerner & Rollag
This article is available from: http://www.truesun.com/pdf/Jneurosci.pdf%20copy.pdf

4) Preliminary evidence for a change in spectral sensitivity of the circadian system at night
Mariana G Figueiro, John D Bullough, Robert H Parsons and Mark S Rea
This article is available from: http://www.jcircadianrhythms.com/content/3/1/14

5) Ocular Input for Human Melatonin Regulation: Relevance to Breast Cancer
Glickman, Levin and Brainard
Neuroendocrinology Letters 2002; 23(suppl 2):17–22
This article is available from: http://www.apollolight.com/pdf_files/NEL.pdf

6) Lighting for the human circadian clock: recent research indicates that lighting has become a public health issue
S. Pauley
Medical Hypotheses (2004) 63, 588–596
This article is available from: http://darksky.org/links/pauleylhh.pdf

7) Spectral Sensitivity of the Circadian System
Mariana G Figueiro, John D Bullough and Mark S Rea
This article is available from: http://www.lrc.rpi.edu/programs/lightHealth/pdf/spectralSensitivity.pdf

8) The Next Big Thing, Maybe, D. DiLaura, Leukos, v2n1 Jul 05

9) Visual, Biological, And Emotional Aspects Of Lighting: Recent New Findings And Their Meaning For Lighting Practice, W van Bommel, Leukos, v2n1 Jul 05

10) Light, Lighting, And Health: Issues For Consideration, J. Veitch, Leukos, v2n2 Oct 05

11) Lemmings, Light, And Health, P. Boyce, Leukos v2n2 Jan 2006