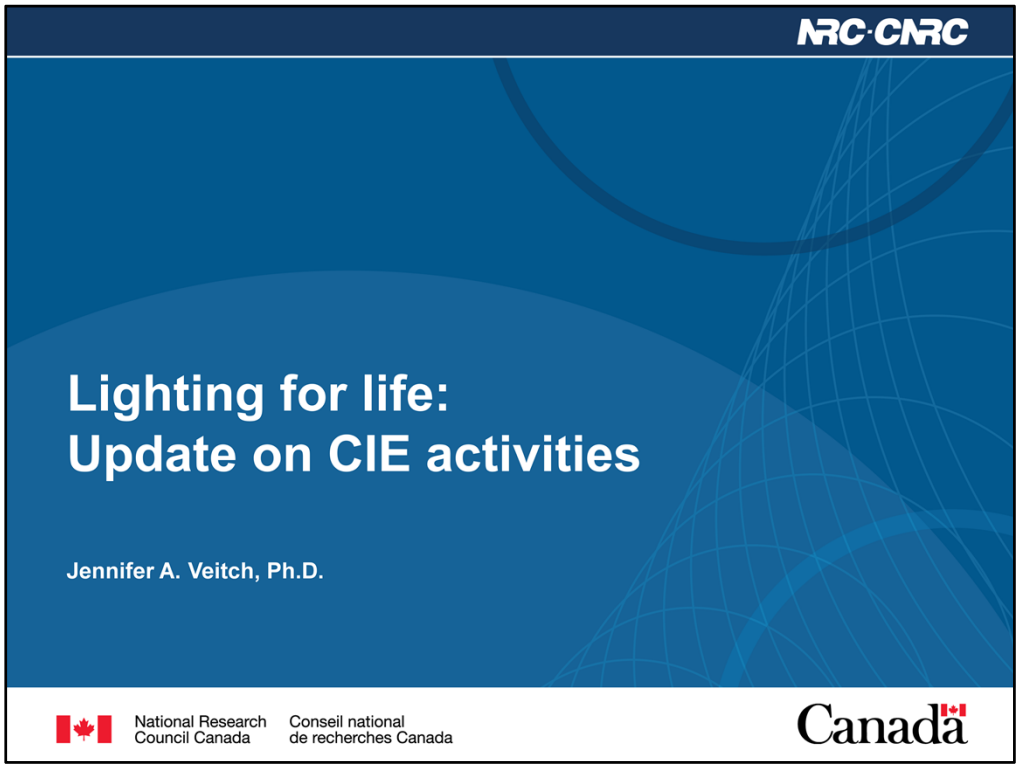
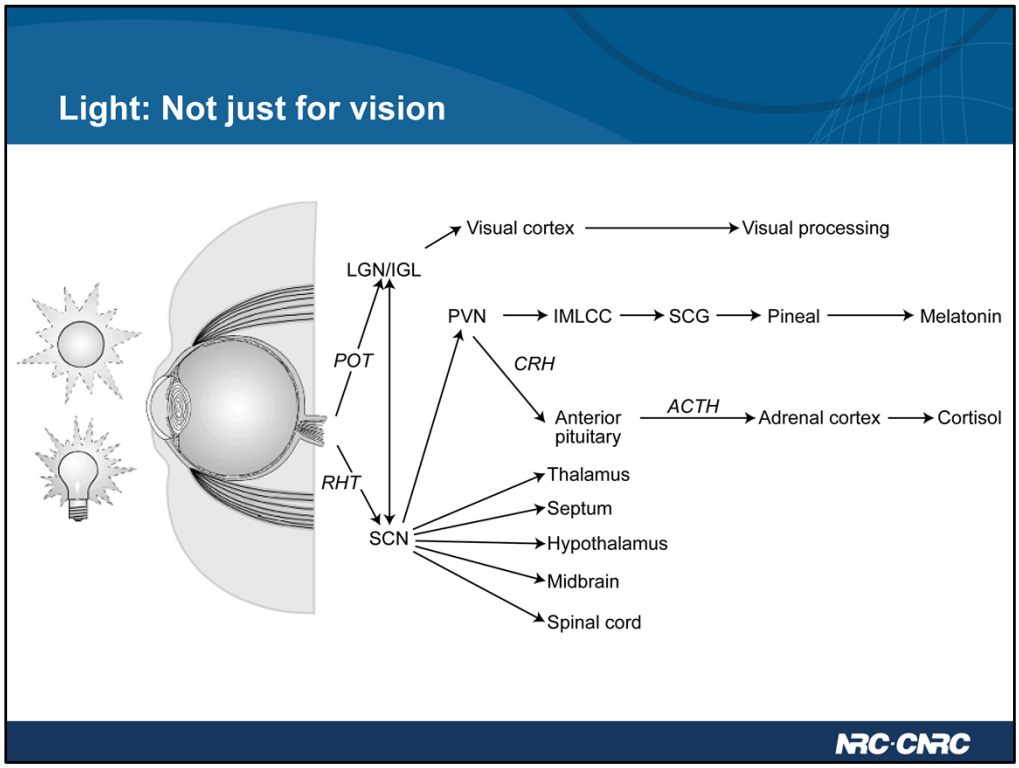


Recent years have revolutionized not only lighting technologies, but also our understanding of the complexity of ocular light detection and the physiological and behavioural responses that follow: light enables vision, but also affects quality of life in myriad other ways. There has been, and continues to be, widespread interest in applying this fundamental knowledge – and countervailing opinions from those who argue that our understanding is not yet adequate to support responsible applications. As the international body responsible for scientifically founded, consensus-based guidance and standards related to light and lighting, CIE has taken several actions to foster understanding of this important topic. Most recently, CIE took an important step in publishing an official statement titled “Proper Light at the Proper Time”, outlining its evaluation of the state of knowledge and its plans for sound guidance in the use of light and lighting to support health and well-being in an integrated way. Taking the official statement as the starting point, this presentation will summarize CIE’s activities in this domain, including the state of knowledge concerning photoreceptor action spectra, research priorities to support applications, and new technical committees that currently seek expert members.

This is a PDF copy of a presentation given at the 10th Biennial Joint Meeting of the CNC/CIE and CIE/USA in Toronto, Ontario, on Oct. 19, 2015.

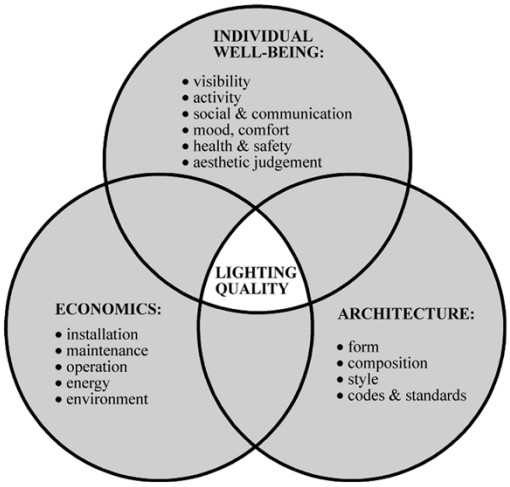


The signals from these photoreceptors travel a complex route to various brain structures. This figure is from CIE 158:2004, and © CIE, 2009.

Schematic diagram of eye-brain pathways. Light received by the eye is converted to neural signals that pass via the optic nerve to two pathways, one visual and one non-visual. POT = Primary optic tract. RHT = Retino-hypothalamic tract. LGN/IGL = Intergeniculate leaflet of the lateral geniculate nucleus of the hypothalamus. SCN = Suprachiasmatic nucleus of the hypothalamus. PVN = Paraventricular nucleus of the hypothalamus. IMLCC = Intermediolateral cell column. SCG = Superior cervical ganglion. CRH = Corticotropic releasing hormone. ACTH = adrenocorticotropic hormone

Melatonin is the hormone that has received the greatest amount of attention. It's a key molecule in keeping physiological systems on schedule - it seems to start some things up, and slow others down - and it's released in darkness. Because of the dominance of research on this hormone, some people talk about "circadian effects of light", but really there is more to it than this.

Lighting Quality



NRC Lighting Quality model.

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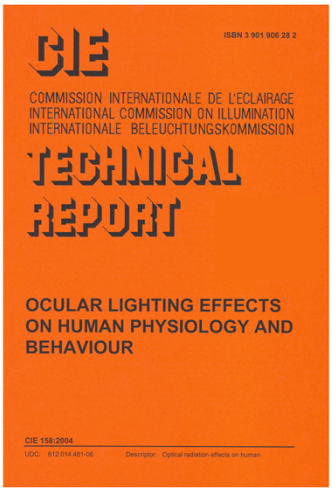
CIE Responses

- Proper Light at the Proper Time – official statement, June 2015
  - CIE 158:2004/2009
  - 2 expert symposia
- First International Workshop on Circadian and Neurophysiological Photometry, 2013
  - CIE TN 003:2015
- CIE TC 3-46: Research Roadmap for Healthful Interior Lighting Applications
- JTC 4: Visual, Health, and Environmental Benefits of Windows in Buildings during Daylight Hours
- New JTC

CIE 158:2004

- First consensus publication on neuroendocrine effects of light exposure on human physiology and behaviour
- Published January 2004



This was the report produced by CIE TC 6-11. The committee existed for many years, having been formed not long after the reorganization of CIE in the mid-1980s (when the Division and TC structure was created). There were several chairmen, but I was the last.

Much of the structure and the beginnings of the content were based on a keynote address given by Dr. Brainard at the CIE session in New Delhi in 1995 (and of course greatly update in the intervening years).

CIE 158:2004, Principles of Healthy Lighting

1. The daily light dose received by people in Western countries might be too low.
2. Healthy light is inextricably linked to healthy darkness.
3. Light for biological action should be rich in the regions of the spectrum to which the non-visual system is most sensitive.
4. The important consideration in determining light dose is the light received at the eye, both directly from the light source and reflected off surrounding surfaces.
5. The timing of light exposure influences the effects of the dose.

These five principles were articulated in the report CIE 158:2004, based on our review of the literature at that time. (If I could change just one thing, I would say "industrialized" instead of "Western" countries.) I will come back to these later in the talk.

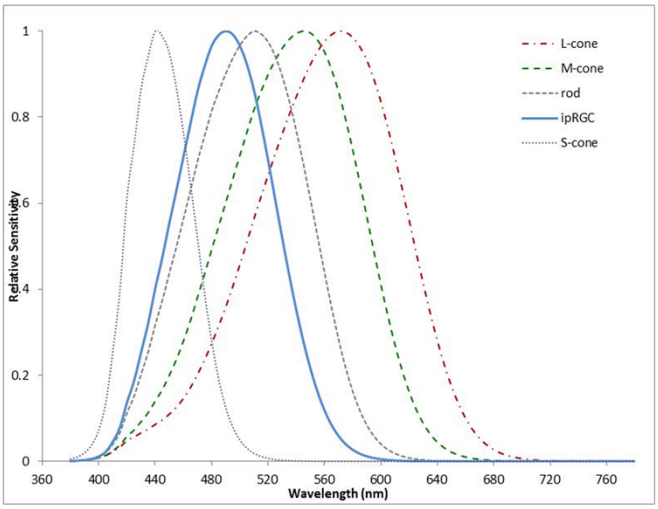
The first comprehensive CIE meeting on this topic was held in Vienna in 2004 with ~ 75 attendees. Sponsored by Division 6 it included extensive coverage of UVR exposure and other hazards (e.g., blue light hazard) as well as neuroendocine effects. There was less emphasis on lighting application, and more on fundamentals of physiology.

Two years later in Ottawa, the focus broadened to encompass applications, and the name change reflects that. The 2006 event was approximately twice the size of the 2004 event (~ 160), reflecting the increasing interest in the topic.

In 2007, Dr. Brainard with Dr. Veitch chaired a workshop at the CIE session in Beijing at which over 200 people attended during the end of the last conference day.The summary of the workshop is available from the authors.

International Workshop on Circadian and Neurophysiological Photometry, 2013

- 13 researchers invited to 3-day workshop to develop consensus
- Consensus is that the system is more complex than had been thought:



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Quoted from CIE TN 003:2015, the workshop consensus was:

- A novel photopigment, melanopsin, has recently been discovered in a sub-class of retinal ganglion cells, and there is a good understanding of its action spectrum.
- Neither this photopigment nor any classical photopigment, present in rod and cone cells, is sufficient alone to fully explain individual systemic responses to light.
- Calibrated spectral measurements should be recorded in published research to enable experimental conditions to be accurately replicated and lighting conditions between studies to be compared, by evaluating the stimulus intensities for all five photopigments.
- As scientific work in the field is ongoing to establish the relationships between light stimuli and non-visual effects, the Workshop should reconvene in five years, or earlier, when it will be appropriate to update the current information.

Workshop Accomplishments

- Consensus on the melanopsin action spectrum (ipRGC)
- Development of toolkit for calculations
- Publication to point to better photometric practice for photobiologists (Lucas et al., 2014, *Trends in Neuroscience*)
- 2015, CIE added SI-compliant units (irradiances, in W/m^2) and re-issued the toolkit with TN 003.

TC 3-46,
Research Roadmap for Healthful Interior Lighting

This TC will review relevant CIE publications (CIE 158:2004 and the two CIE expert symposia on light and lighting and health in 2004 and 2006) and the more recent scientific literature to identify the information that is needed before such lighting application may take place. The output will be a technical report which will describe a research roadmap intended to stimulate fundamental research into questions relevant to lighting applications.

Formed 2007, Beijing

Research Agenda

NRC·CNRC

Research Agenda Categories / Design Issues

Fundamentals ○ Acute effects ○ Retinal sensitivity ○ Neurophysiology	Pattern ○ Daily ○ Amplitude ○ Exposure ○ Application ○ Light sources ○ Illuminances ○ Reflectances ○ Design ○ Duration ○ Daylighting
Application – specific ○ Shift work	
Individual Differences ○ Age ○ Disorders ○ Visual impairment ○ Stressors ○ Other	

Design
- Daylight integration
- Controls
- Surface characteristics
- Special populations
- Conflicting requirements between simultaneous users

Example question

- What pattern of light exposure by day and darkness at night provides an adequately strong stimulus for both circadian rhythm entrainment and immediate, acute effects?
  - Note that this question contains within it a need for a body of specific evidence for both circadian rhythm effects and effects on underlying processes including alertness, attention, cognition, mood, social behaviour, and metabolism.

TC 3-46 Summary

- A few areas seem to have sufficient understanding to support applications – shift work being an example
  - Caution on a rush to action
  - Natural experiments taking place now
- Some areas are the topic of existing TCs: TC 1-82, JTC 7
  - Or proposed activities: JTC on action spectra
- Research agenda will identify priorities
  - To focus labs' attention
  - To support funding applications

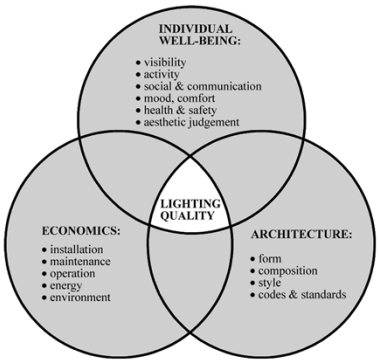
Proposed new Joint TC

- *JTC x (D2/D3/D6): Quantifying ocular radiation input for non-visual photoreceptor stimulation*
- Goal is to write a standard
  - To define action spectra and metrics in order to quantify the ocular radiation input to all photoreceptors possibly involved in non-visual responses.
  - To provide a method to calculate from a measured spectral irradiance, ideally at the cornea surface, the stimulation of each photoreceptor that can potentially contribute to non-visual responses.
  - To demonstrate the validity of such metrics for predicting physiological responses based on existing data in the literature.

Summary

- Progress may seem slow...

...but we need to get this right



Thank you

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