

# Research Needs to Support Standards and Recommendations for Healthful Lighting

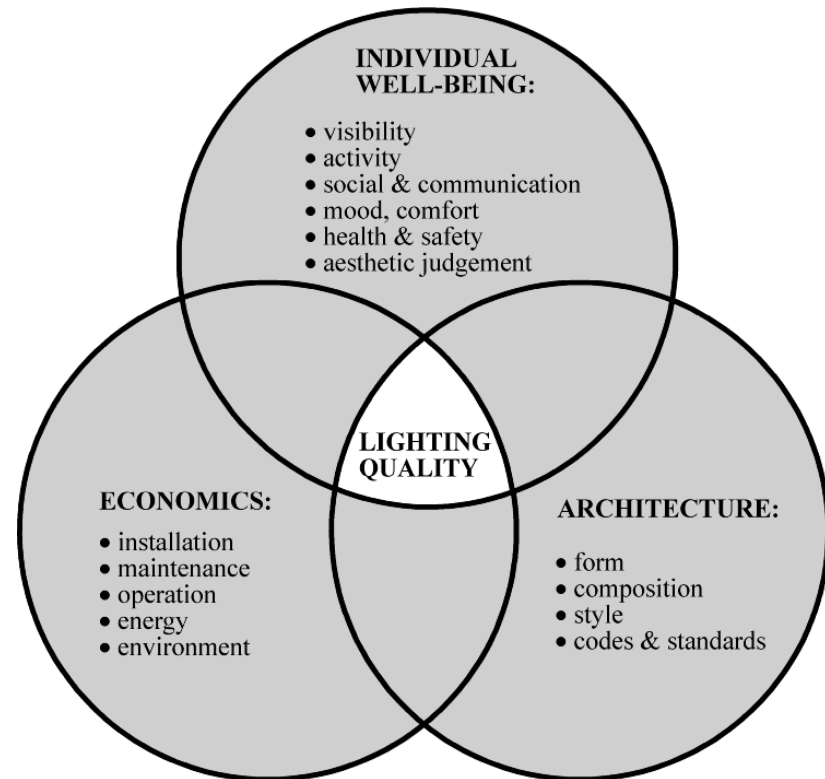
Jennifer A. Veitch, Ph.D.  
2018-01-29, Nashville, TN – DOE SSL R&D Workshop

# Introduction: Definitions

- **lighting quality** [CIE DIS 017:2016]

- degree of excellence to which the totality of lighting characteristics fulfils user needs and expectations or other applicable requirements

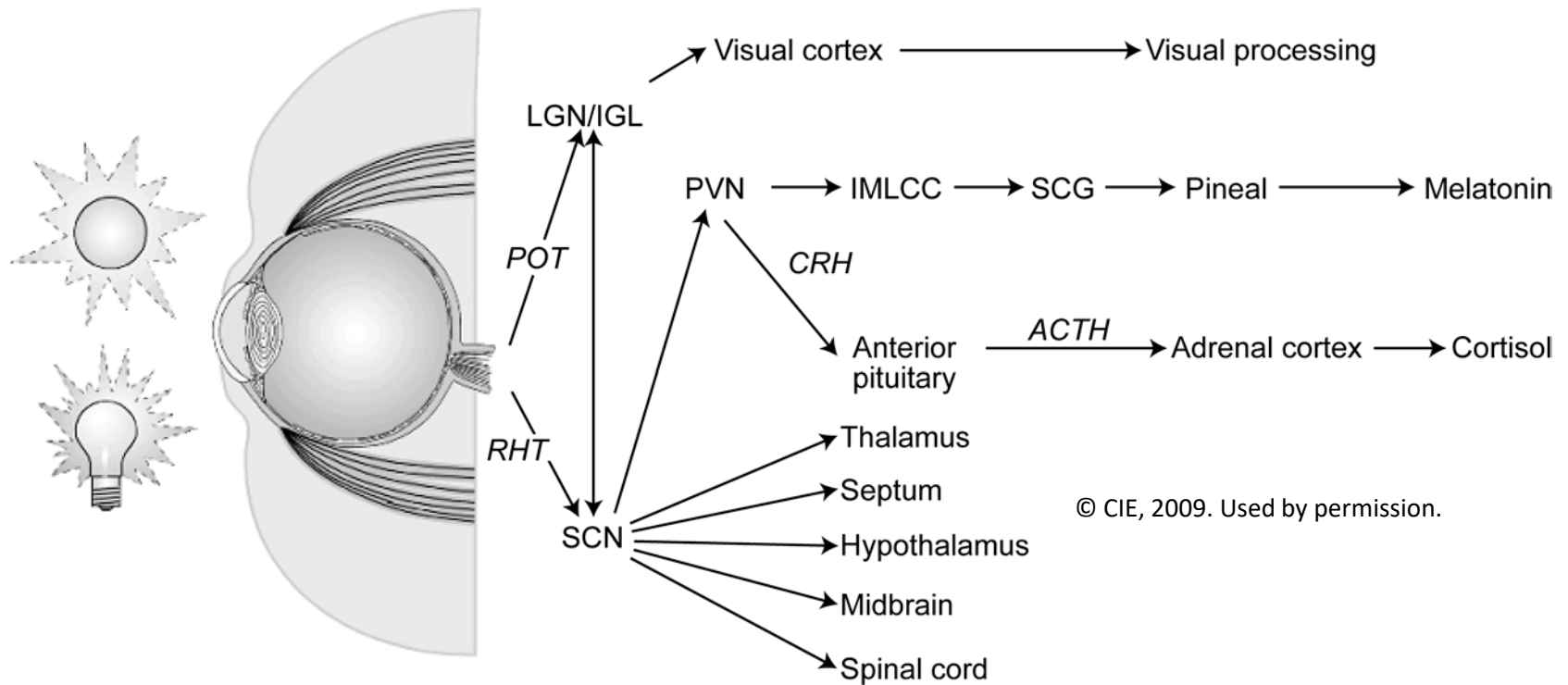
- Note 1 to entry: The degree of excellence depends on the application area and covers individual end user well-being, safety and public security, architecture and lit environment



# Introduction: Definitions

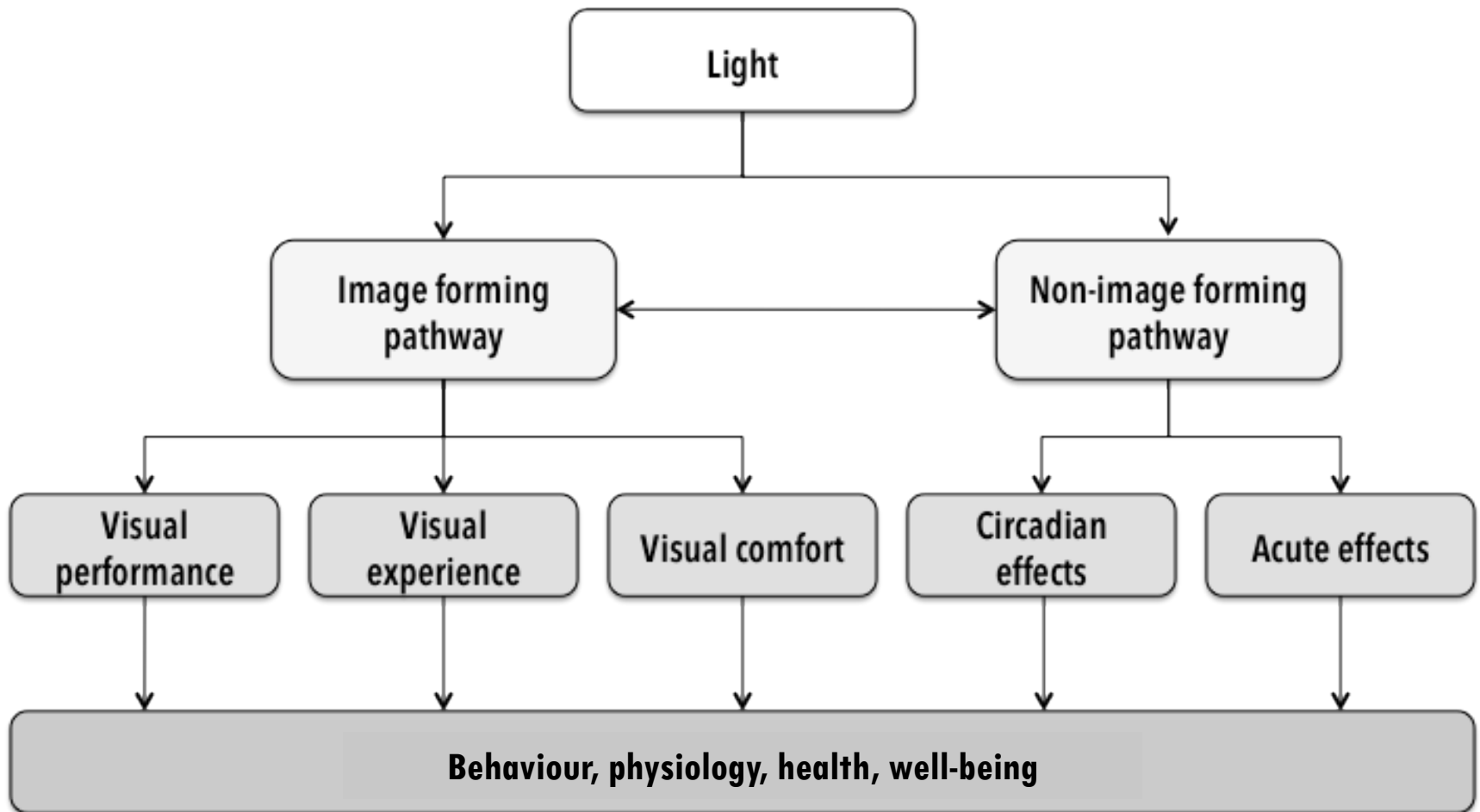
- **integrative lighting** [CIE DIS 017:2016, 17-29-030]
  - Lighting specifically designed to produce a beneficial physiological and/or psychological effect upon humans
    - Note 1 to entry: This includes both visual and non-visual effects.
    - Note 2 to entry: The term human centric lighting is used with a similar meaning.
- SO -- glare, color, sparkle, visual performance, flicker, and appearance all matter
- Good integrative lighting has many effects on viewers
- When we talk about “healthful lighting” we need to keep ALL of these effects in mind

# Introduction: Knowledge revolution



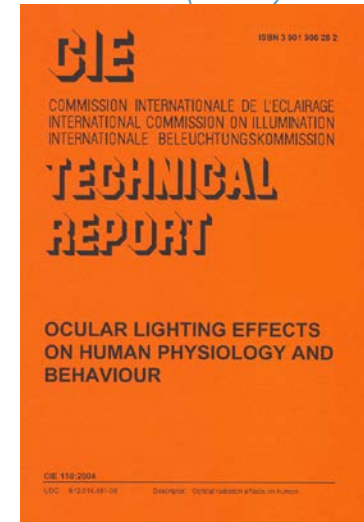
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# Conceptual model of effects



## 5 Principles of Healthy Lighting

1. The daily light dose received by people in industrialized 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.



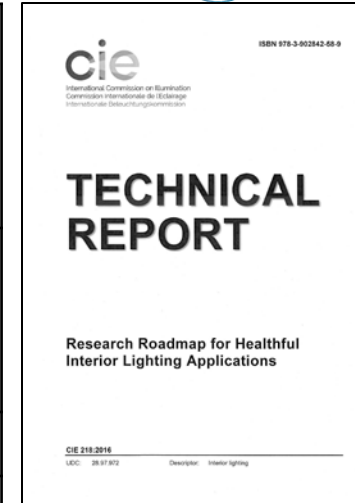
# Research needs: Lighting for well-being

- [CIE 218:2016](#): Research Roadmap for Healthful Interior Lighting Applications
- Research Strategy:
  - [Recommendations for Healthful Lighting and Non-Visual Effects of Light](#)
  - [Support for Tailored Lighting Recommendations](#)
  - [Adaptive, Intelligent and Dynamic Lighting](#)

# CIE Research Roadmap

- 28 detailed questions, rated by importance and difficulty
- Classified as influencing
  - light sources
  - luminaires
  - recommendations /standards/regulations
  - design practice
  - light hygiene
  - applied research

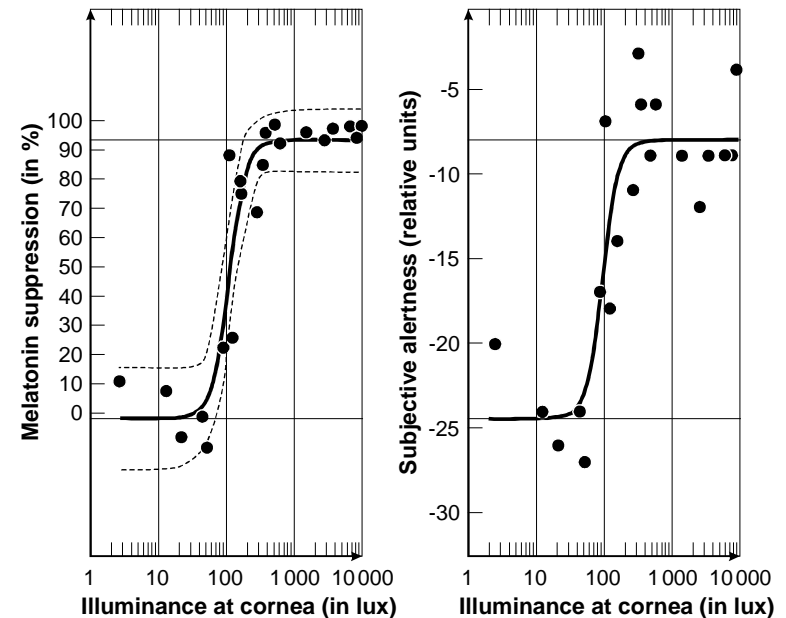
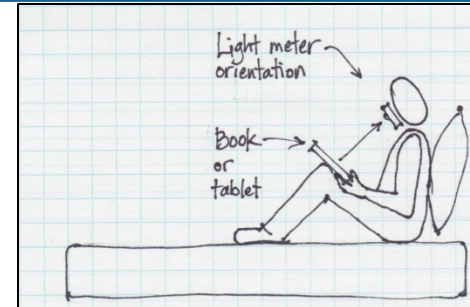
<ul style="list-style-type: none"><li>• <b>Processes</b><ul style="list-style-type: none"><li>• Acute effects (inc., glare, TLM)</li><li>• Neurophysiology</li><li>• Retinal sensitivity</li><li>• Other (e.g., what about skin?)</li></ul></li></ul>
<ul style="list-style-type: none"><li>• <b>Daily Pattern</b><ul style="list-style-type: none"><li>• Amplitude</li><li>• Frequency</li><li>• Integrated (see next slide)</li></ul></li></ul>
<ul style="list-style-type: none"><li>• <b>Longer Patterns</b></li></ul>
<ul style="list-style-type: none"><li>• <b>Application</b><ul style="list-style-type: none"><li>• Light sources (e.g., uniformity)</li><li>• Design (e.g., general vs localized delivery)</li></ul></li></ul>
<ul style="list-style-type: none"><li>• <b>Application-Specific</b><ul style="list-style-type: none"><li>• Shift work</li></ul></li></ul>
<ul style="list-style-type: none"><li>• <b>Individual differences</b><ul style="list-style-type: none"><li>• Age</li><li>• Disorders</li><li>• Visual impairment</li><li>• Stressors</li><li>• Other</li></ul></li></ul>





# How much light?

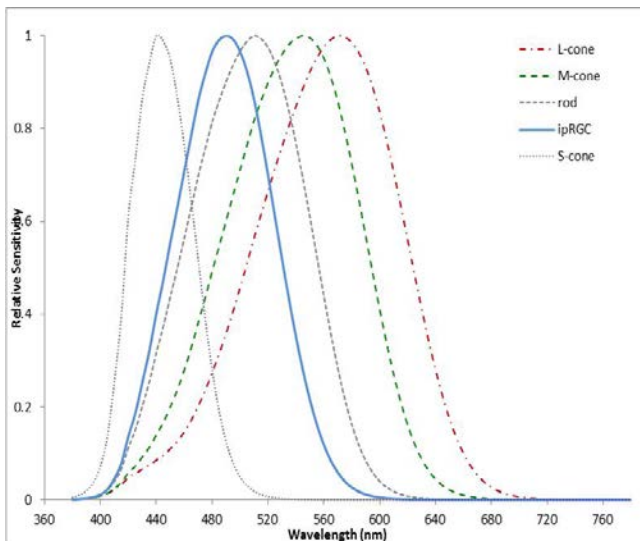
- First, light at the eye matters:
- Relationships seem to saturate, at least when measured at night (as at right).
- We still don't know what total daily dose (of light or dark) would be desirable
  - For good circadian function
  - For acute effects



The left graph is re-drawn from Zeitzer et al. (2000).  
The right is redrawn from Cajochen et al. (2000). Both are © CIE, 2016 and used by permission.

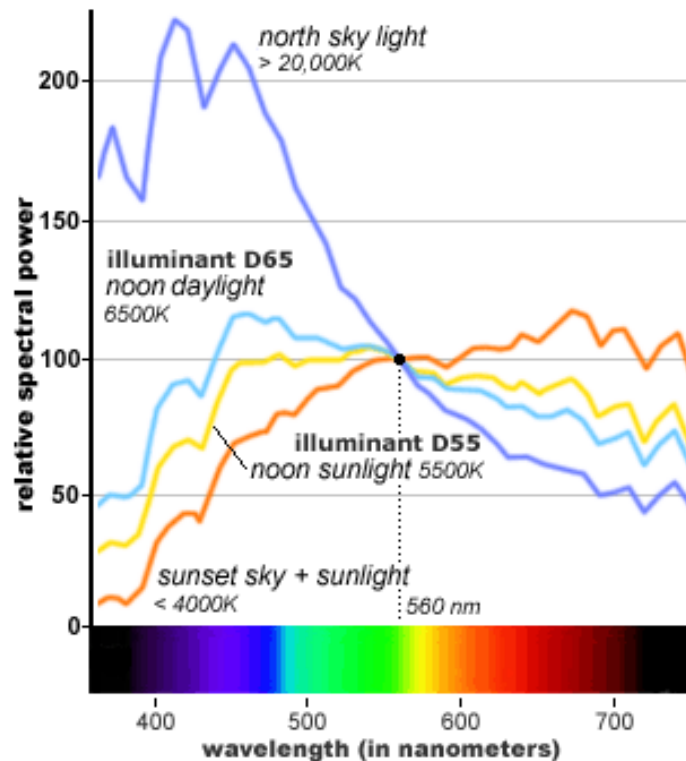
# CIE JTC 9: CIE system for metrology of ipRGC influenced light response

- International Standard expected spring 2018 -- will define spectral sensitivity functions, quantities and metrics to describe radiation for its ability to stimulate each of the five photoreceptor types...
- Definition of new quantities in SI units:



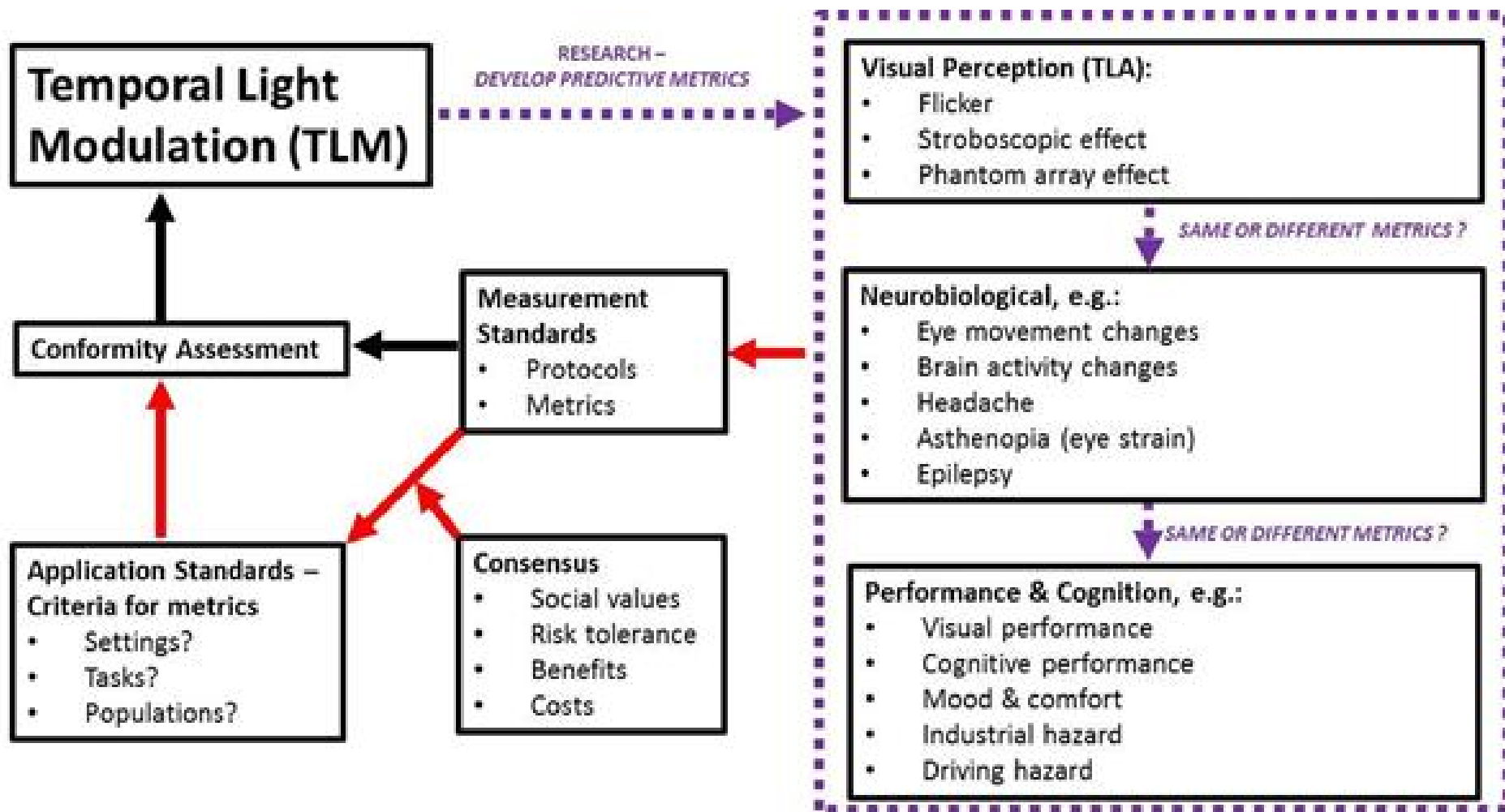
Response, $\alpha$	$\alpha$ -opic spectral efficiency functions	$\alpha$ -opic irradiance, $E_{\alpha}$ (units)	$\alpha$ -opic equivalent illuminance (units)
S-cone-opic, sc	$s_{sc}(\lambda)$	$E_{sc} (W \times m^{-2})$	$E_{v,sc} (lx)$
M-cone-opic, mc	$s_{mc}(\lambda)$	$E_{mc} (W \times m^{-2})$	$E_{v,mc} (lx)$
L-cone-opic, lc	$s_{lc}(\lambda)$	$E_{lc} (W \times m^{-2})$	$E_{v,lc} (lx)$
Melanopic, mel	$s_{mel}(\lambda)$	$E_{mel} (W \times m^{-2})$	$E_{v,mel} (lx)$
Rhodopic, rh	$s_{rh}(\lambda)$	$E_{rh} (W \times m^{-2})$	$E_{v,rh} (lx)$

# Dynamic light?



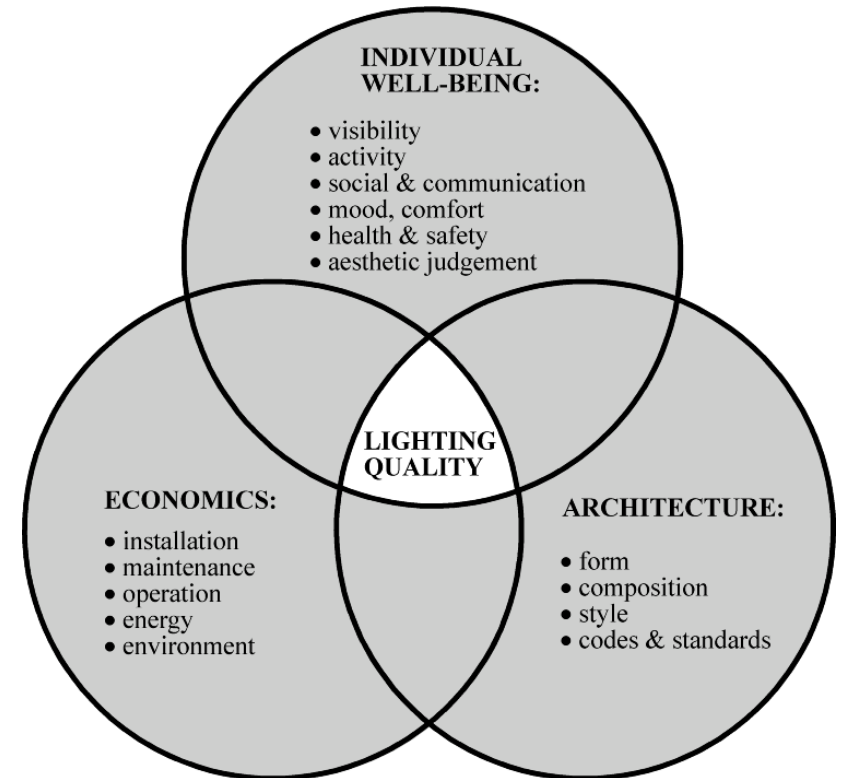
- New technologies allow lots of cool effects!
- Should people follow a daily pattern that might be typical of millenia past?
- But...
  - Our lives don't follow the same patterns
  - People are adaptive
  - Need to understand ALL of the parameters (not just spectrum)
  - Individual differences in preference matter too

# Summary of what's needed for TLM standards (CIE [TN 008:2017](#))



# Application considerations in recommendations

- Daylight integration
- Energy regulations
- Controls
- Surface characteristics
- Special populations
- Conflicting needs of simultaneous users



# Well-designed and well-conducted research

- Fundamental → applied
- Interdisciplinary:
  - architecture, psychology, physiology, medicine, physics...
- Multi-party:
  - industry, designers, regulators, scientists
- Peer-reviewed
- **Replicated**, preferably independently



# Thank you!

## CONTACT

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# Rate-Limiting Factors

- Not enough science – not enough scientists study light and lighting
- Knowledge transfer gap from science to practice
  - Misaligned reward structures
  - Skill gap for scientists
- Lighting is ubiquitous, therefore invisible
  - Science funding agencies don't prioritize us
  
- (\$\$\$, of course)



# What can industry do?

- Actively build consensus about fundamentals:
  - Use evidence in your standards and recommendations work
  - Bring together groups of scientists to address important questions to form consensus (\$)
    - e.g., First International Workshop on Circadian and Neurophysiological Photometry, 2013 ([CIE TN 003:2015](#))
  - Support experts to participate in standards/recommendations committees (\$)
- Actively participate in human factors R&D:
  - Letters of endorsement to support scientists' funding applications (confirming importance of topic)
  - In-kind support (equipment, design, photometric expertise) (\$)
  - Participate in research consortia to develop evidence (\$-\$\$)
  - Sponsor independent research to develop evidence (\$\$-\$\$\$)