

Disconnect Between Conventional Photometry and Scene Brightness Perception

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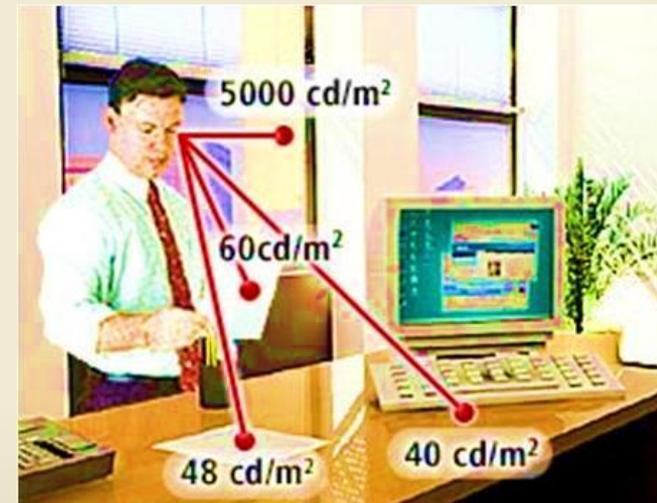
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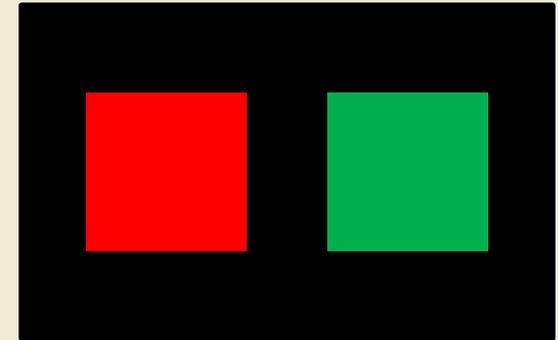
Overview

- Luminance (cd/m^2) is a photometric quantity based on radiance ($\text{W}/\text{m}^2/\text{sr}$), weighted spectrally by $V(\lambda)$
 - We often think of the luminance of a surface as a stand-in for its brightness
 - Formerly called “photometric brightness”
- Brightness can be influenced in nonlinear ways by color



Two Brightness Modes

- Aperture or signal mode: How do two isolated surfaces or lights compare in brightness?
- Scene or spatial mode: How do two illuminated scenes compare in overall brightness?

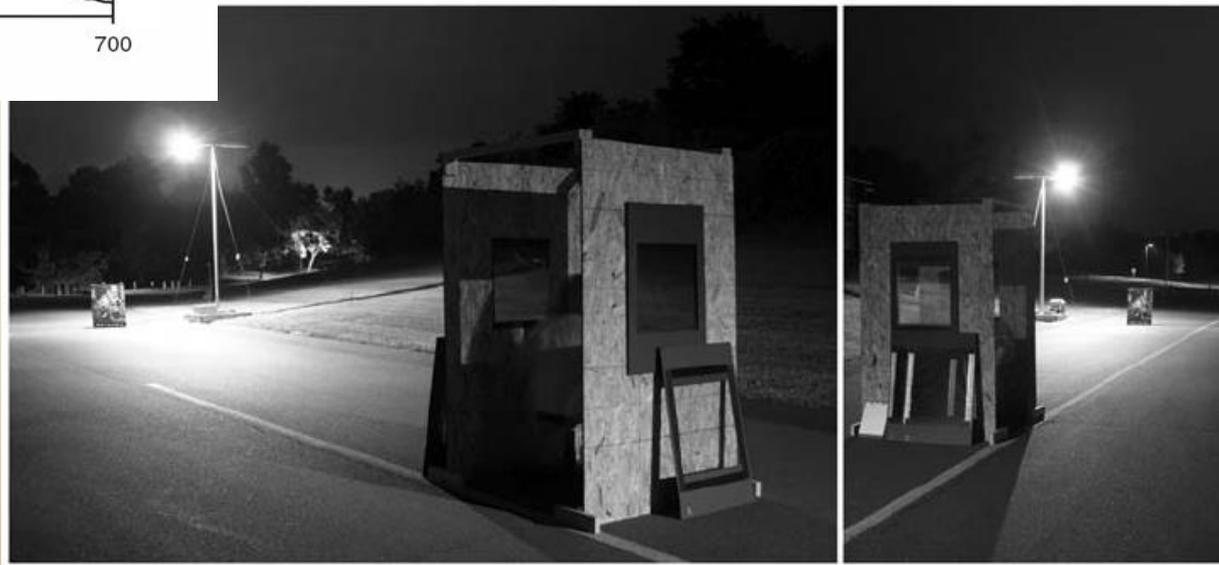
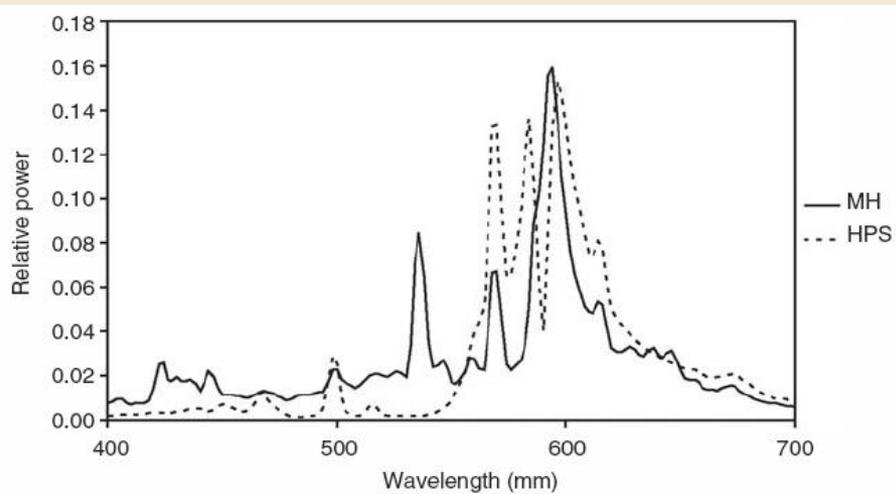


Brightness in Spatial Mode

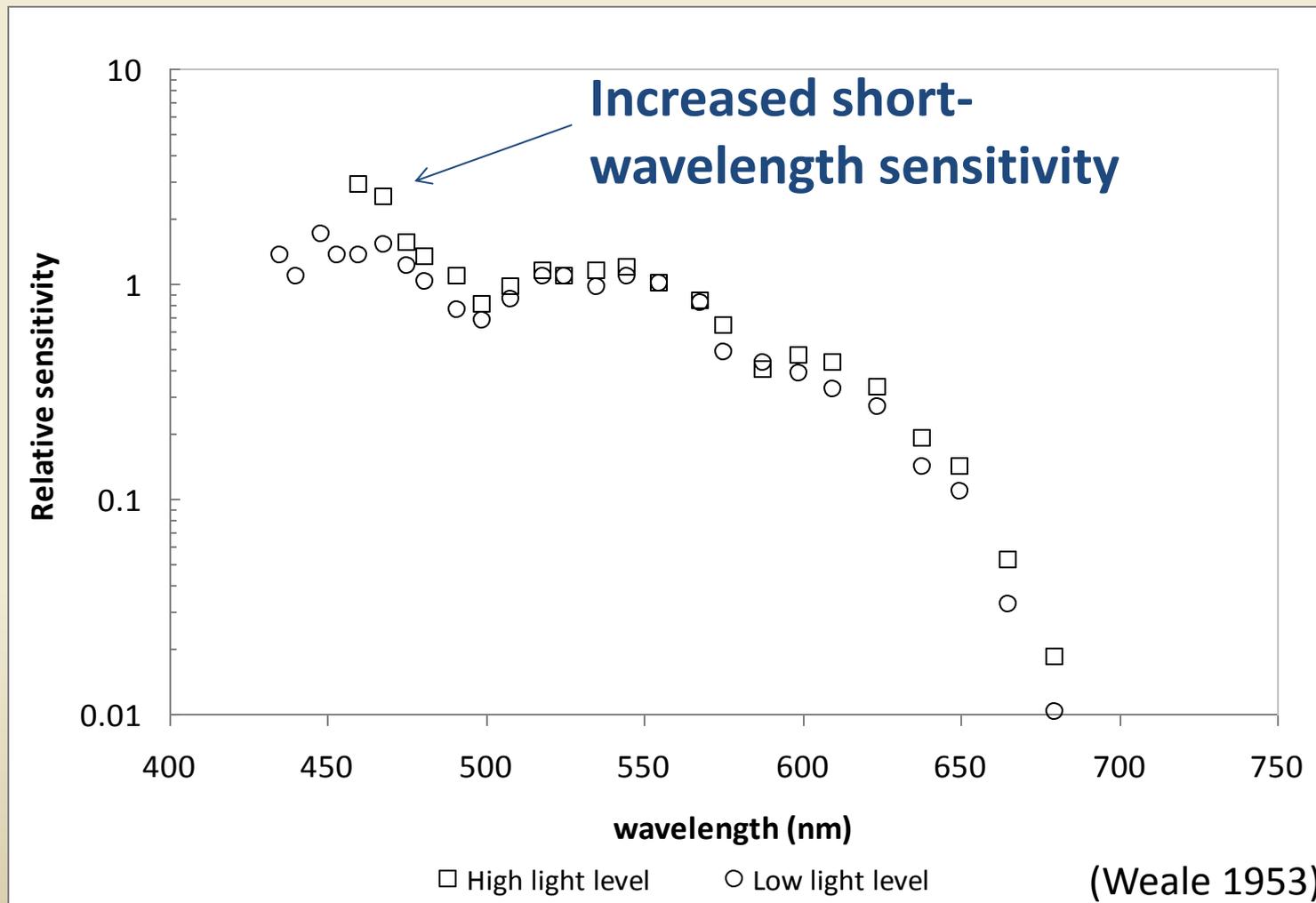
- Often, we may judge the lighting in a scene or space with respect to the overall brightness



Example: High Pressure Sodium vs. Metal Halide Street Lighting



Peripheral Brightness Data



Experimental Method



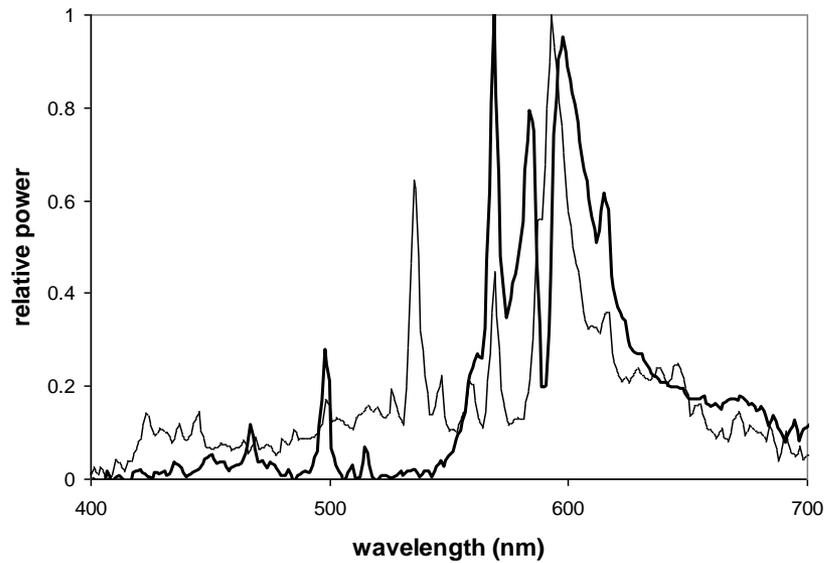
Luminance of pavement: 1 cd/m^2 ($\sim 20 \text{ lx}$)

Lower luminance simulated through dark glasses: 0.13 cd/m^2 ($\sim 2 \text{ lx}$)

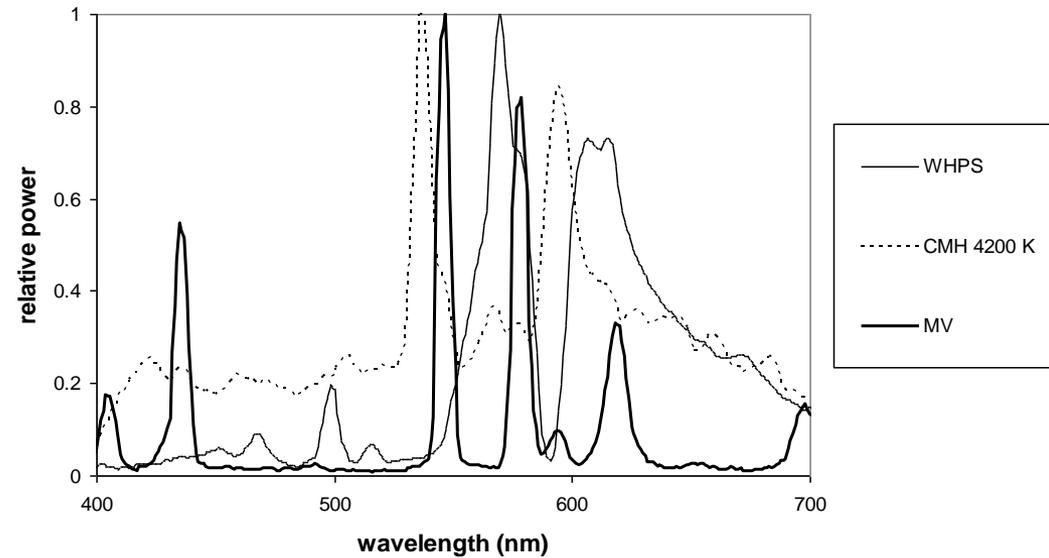
Horizontal angle subtended by each scene: 18°

(Rea et al. 2011)

Light Sources

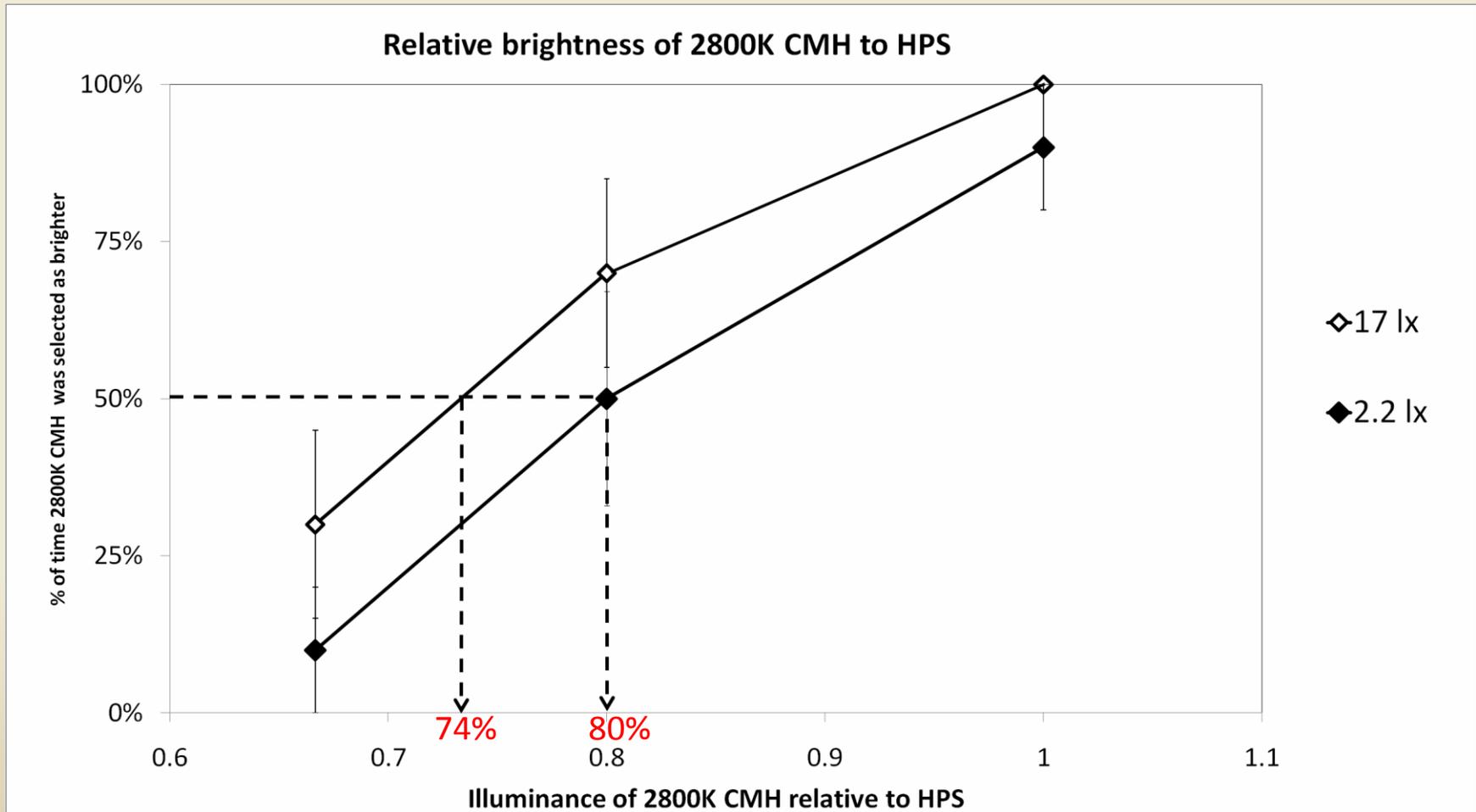


Experiment 1



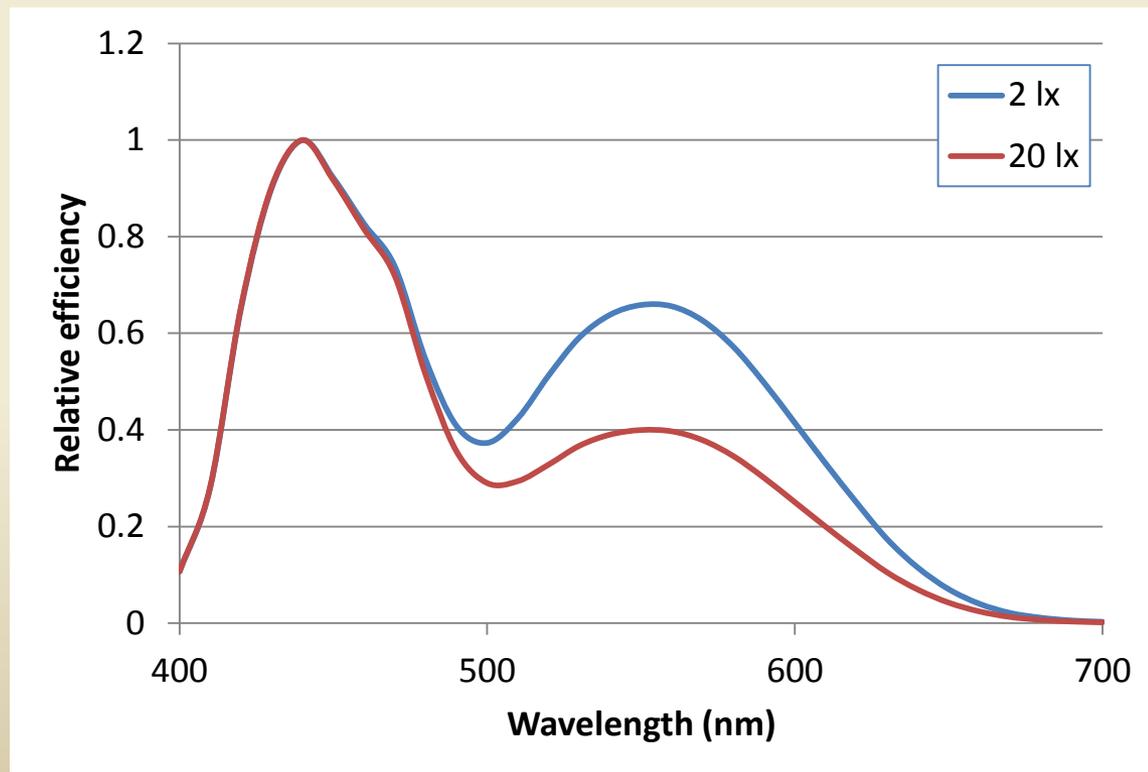
Follow-Up Experiment

Results: Experiment 1



Provisional Spectral Sensitivity Model

- $B(\lambda) = V(\lambda) + gS(\lambda)$ [$S(\lambda)$ is short wavelength cone]
- g appears to be a function of the overall light level:
 - Around 2 lx, $g=1.5$
 - Around 20 lx, $g=2.5$
- Likely role of rods?
 - Even under 2 lx, color perception is robust
 - Neither rods nor ipRGCs improved the model



Experiment 2

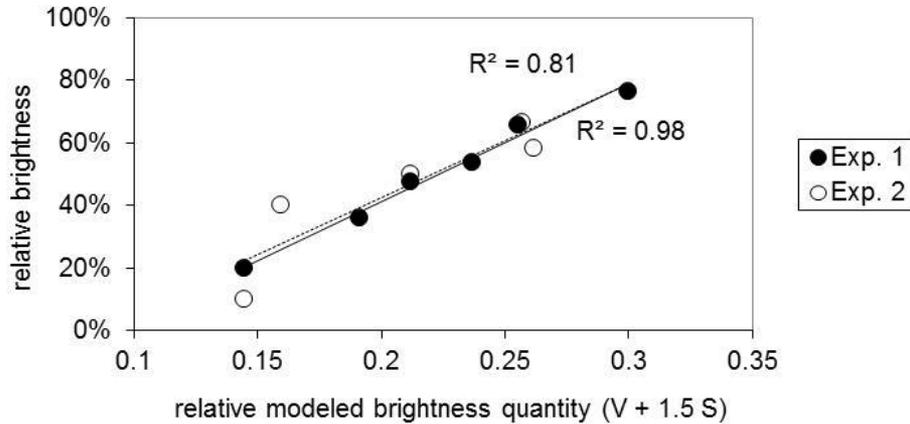
Lamp	Measured CCT	Measured CRI	S/P	C _s /P
HPS	1896	22	0.52	14.2
WHPS	2136	57	0.73	21.5
2800 K CMH	2583	65	1.12	49.9
MV	4052	41	1.12	80.8
4200 K CMH	3750	86	1.62	78.7



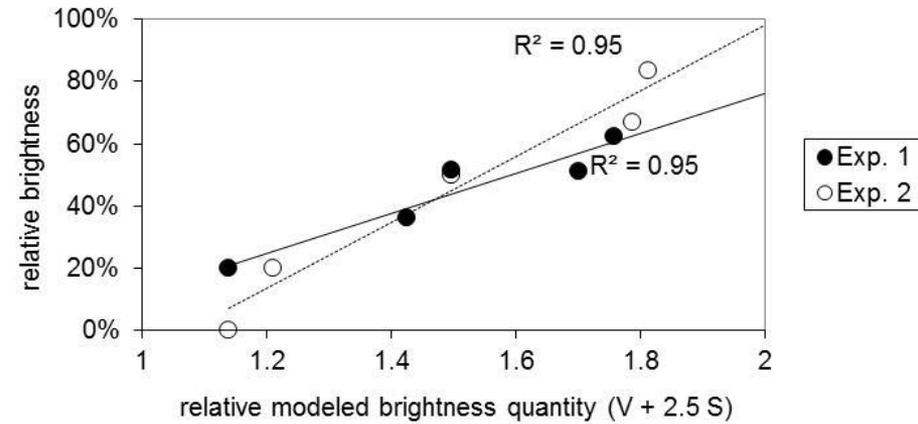
Lamp	Percentage of time overall scene was judged brighter than the CMH 2800 K condition (2.2 lx)	Percentage of time overall scene was judged brighter than the CMH 2800 K condition (17 lx)
HPS	10	0
WHPS	40	20
CMH 4200 K	58	67
MV	67	83

Brightness Data from Both Experiments

Rea et al. data (2011): 2 lx

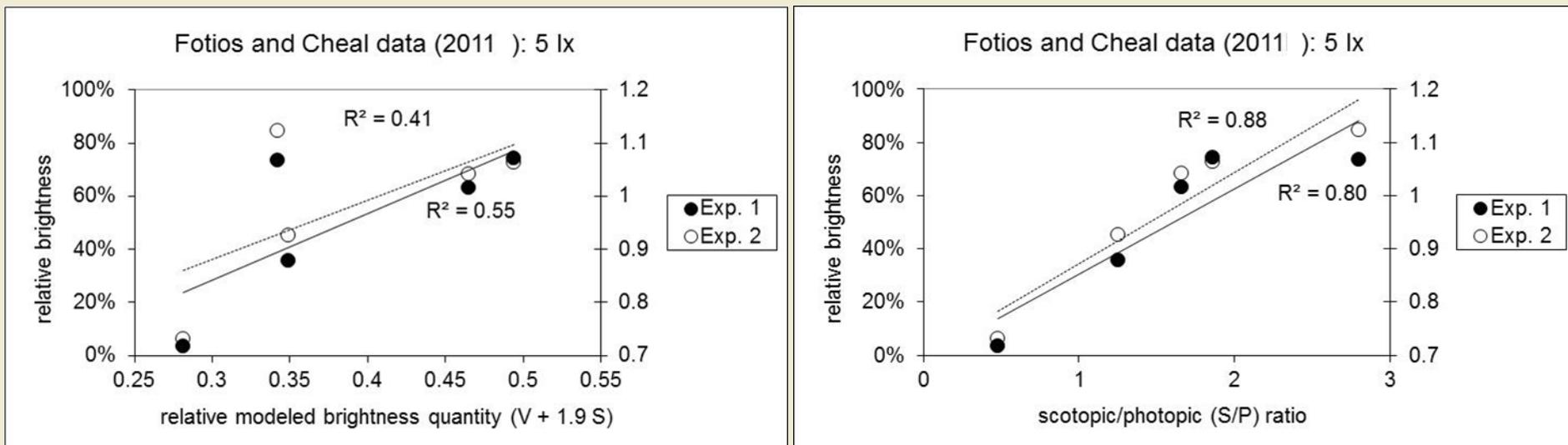


Rea et al. (2011) data: 20 lx



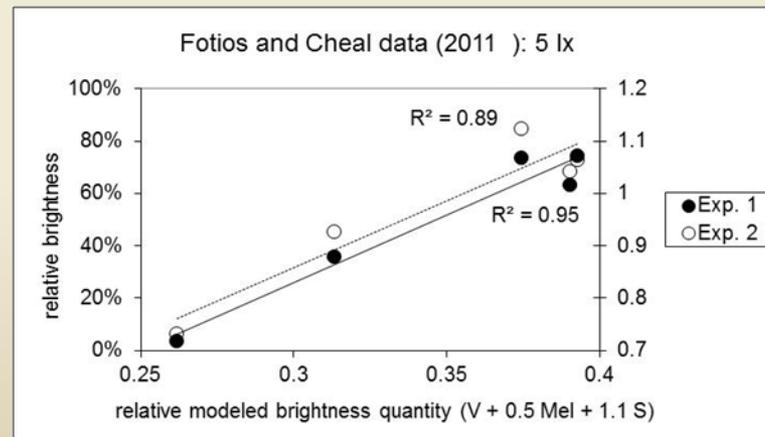
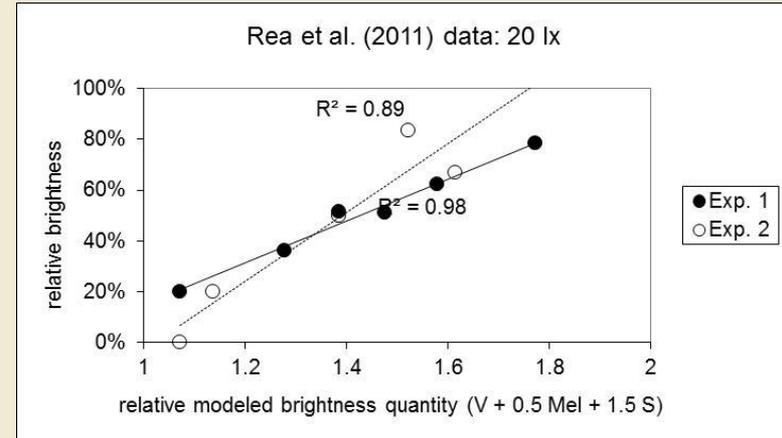
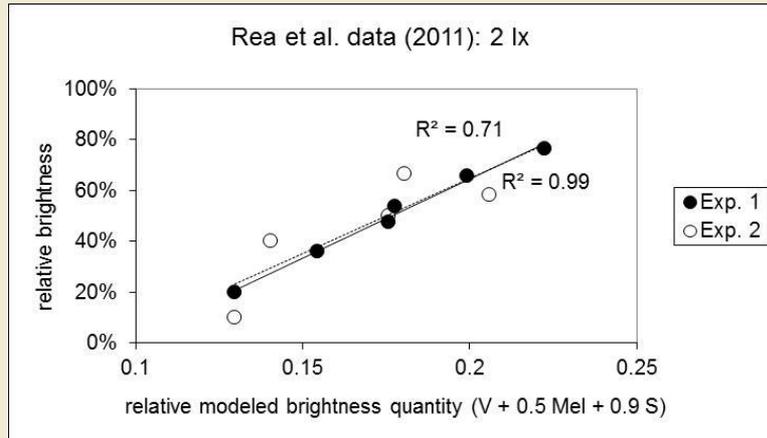
- ◆ Spectral sensitivity model based on responses to varied light sources – high pressure sodium, metal halide, mercury vapor, white high pressure sodium
- ◆ Model does not include responses from rods or melanopsin-containing, intrinsically photosensitive retinal ganglion cells (ipRGCs, peak $\lambda=480$ nm)
 - Including them did not improve goodness of fit to these data
 - Previous literature suggests rods play little role in brightness above 0.1 cd/m^2 (Rea et al. 2004) but that ipRGCs do appear to influence brightness (Brown et al. 2012)

Brightness Data from Fotios and Cheal (2011)



- ◆ Model did not fit well to brightness data from Fotios and Cheal (2011) using HPS, MH, fluorescent and an LED source with green + red LEDs
- ◆ LED source was judged as brighter than predicted by Rea et al. (2011)
- ◆ In comparison, the data from Fotios and Cheal (2011) were rectified by their scotopic/photopic (S/P) ratios underlying the CIE (2010) mesopic system
 - S/P ratio correlated with spectral content near 500 nm
 - ipRGCs are sensitive to light near this region, as well (peak ~480-490 nm)

Provisional Modified Model

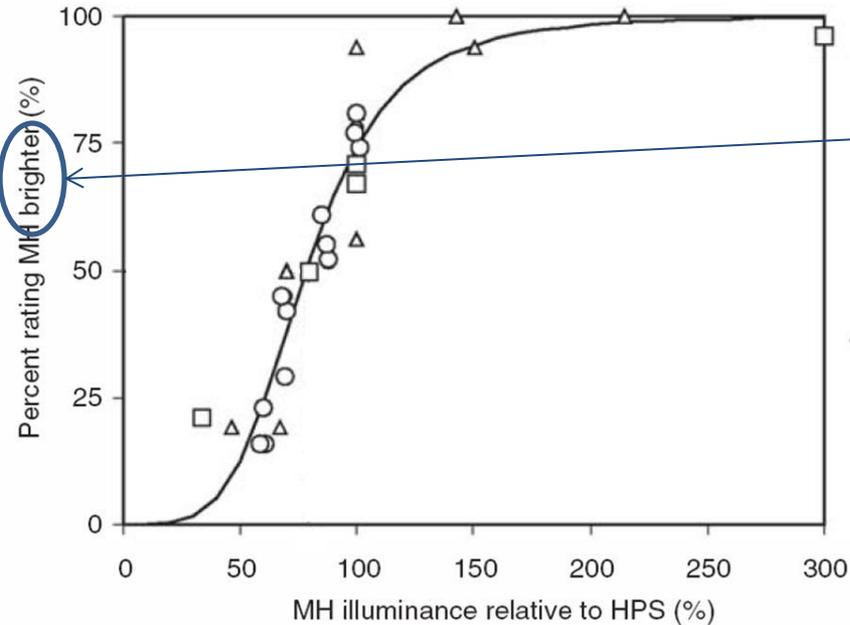


$$B_2(\lambda) = V(\lambda) + 0.5 \text{Mel}(\lambda) + g_2 S(\lambda); g_2 = 0.6g$$

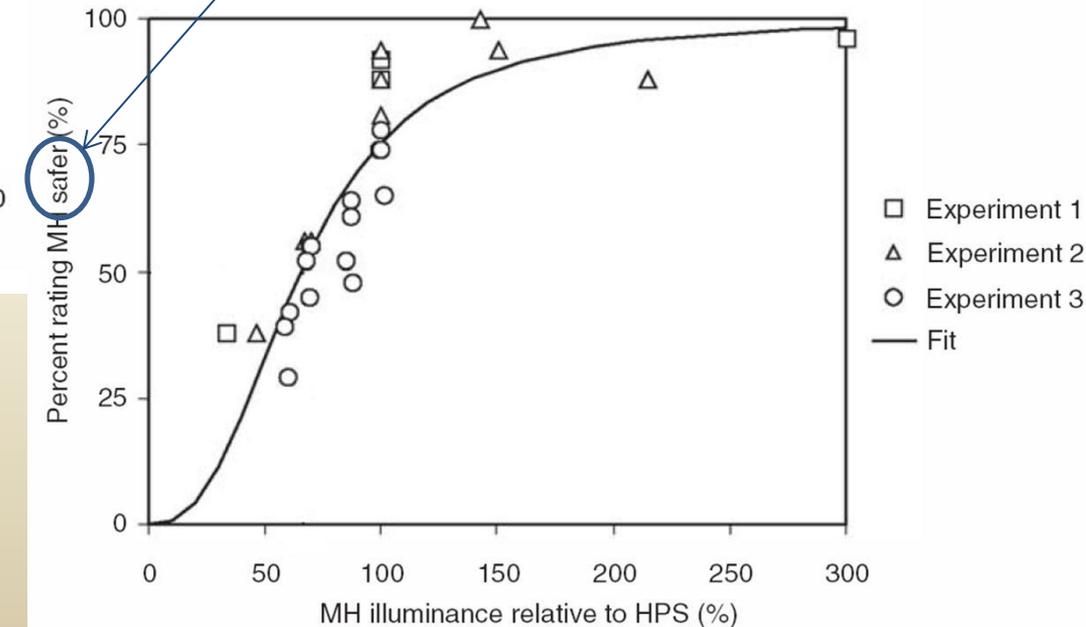
Discussion

- Scene brightness perception differs from brightness in aperture or signal mode
- At nighttime light levels (2-20 lx), brightness perception seems to have substantial short-wavelength sensitivity
 - Different mechanism from that underlying visual performance at mesopic light levels
 - Participation from ipRGCs rectifies scene brightness data from multiple studies

What is the Value of Increased Scene Brightness at Night?



Locations that look brighter, feel safer



Summary

- We use photometry to specify the stimulus in an experiment or in a lighting application
- It is important to remember that conventional photometric quantities (e.g., luminance) do not always predict how we see (e.g., brightness)
- Balancing the value of a linear, additive system of photometry to the nonlinear, nonadditive ways we respond to light will continue to challenge the lighting community

Thank You!