The Class A Color Designation for Light Sources

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Introduction

- **Color rendering** and the **color of illumination** are two key factors that support architectural lighting (e.g., retail lighting).
- However, presently accepted metrics used to describe color properties (CRI and CCT) often are not perfectly predictive of people's assessments of illumination from a light source.

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Color Rendering of Illumination

CRI and GAI

http://www.lrc.rpi.edu/programs/solidstate/colorResearch.asp

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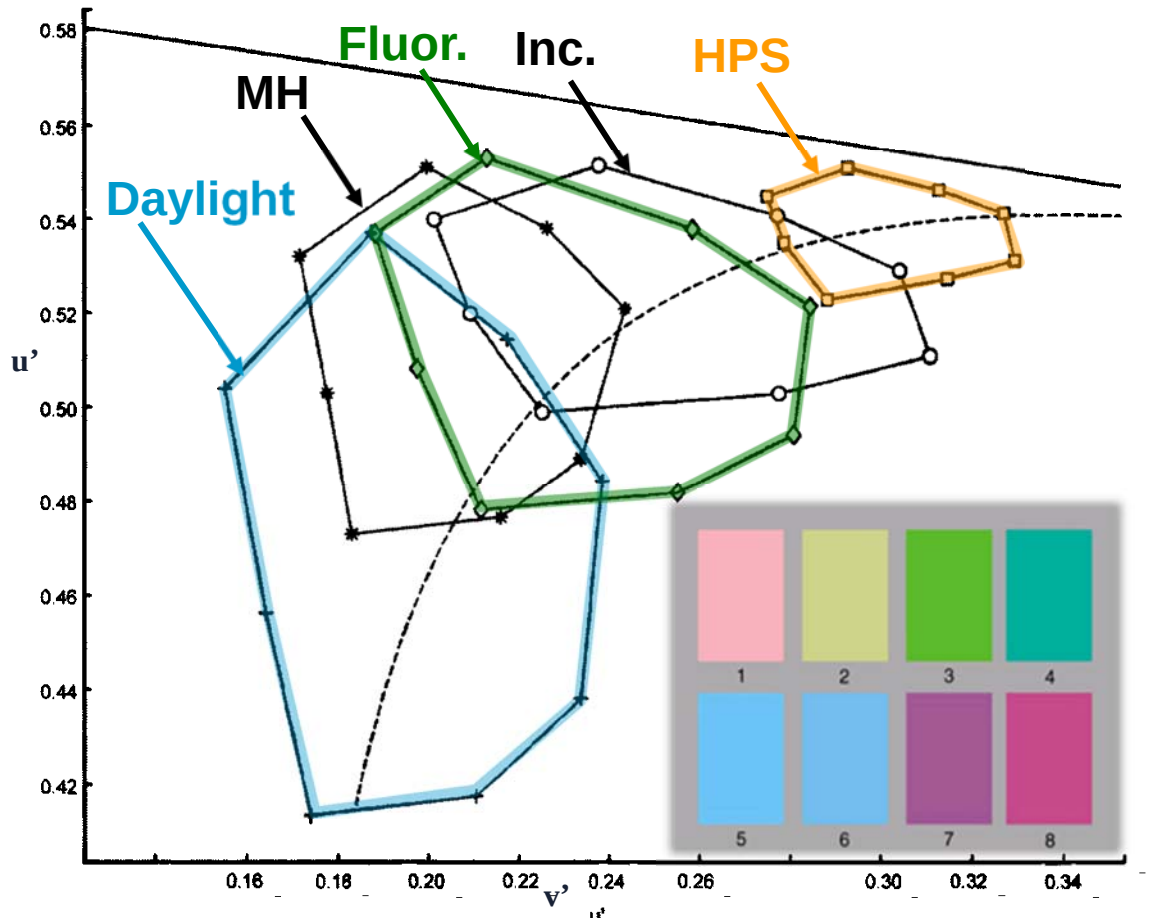
Color rendering: CRI+GAI approach

- No single metric can characterize color rendering, period.
  - e.g., Dangol et al. 2013, Quintero et al. 2012, DOE 2012, Smet et al. 2011, Zukauskas et al. 2010-12, Davis and Ohno 2010, Hashimoto 2007, Gu and Houser 2004, Rea et al. 2003-12, Schanda 1985, Thornton 1972, Judd 1967, Bouma 1947
  - Good color rendering by a light source depends on providing an optimum amount of color saturation (but without distortion; e.g., objects look like under daylight.)
- ASSIST's two-metric strategy with well established CRI plus GAI as adjunct is practical, predictive, and has been validated by several human factors studies.

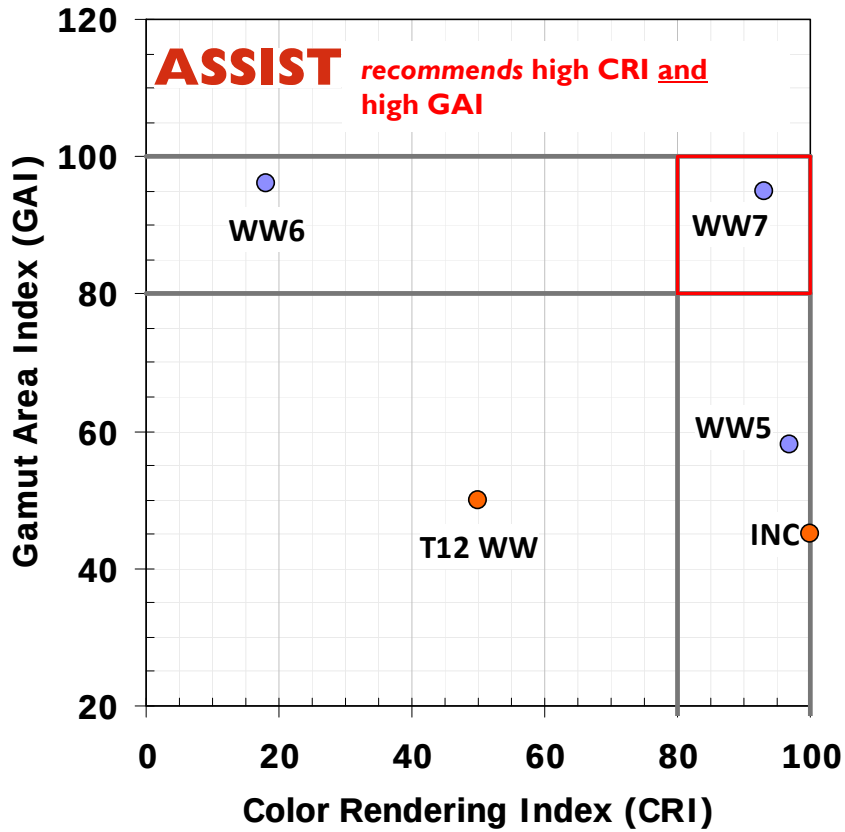
Color gamut area

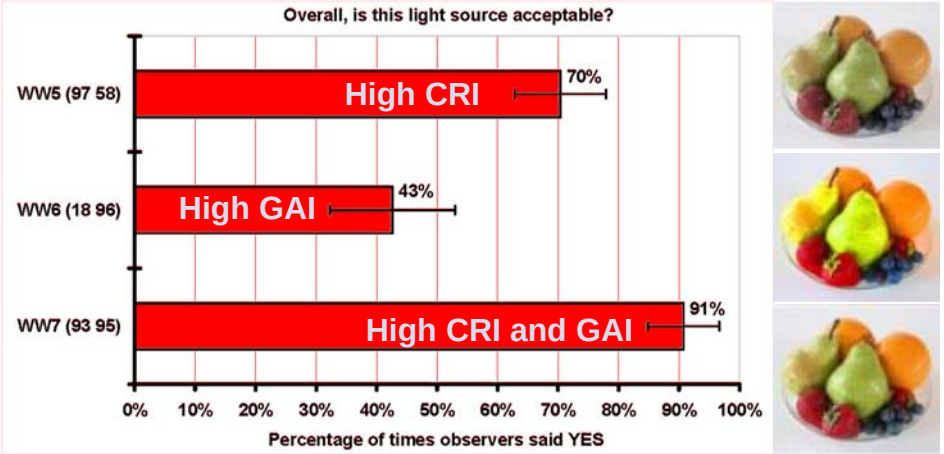
- In general, the larger the gamut area, the more saturated the color samples are and the easier it is to discriminate between them.



Adapted from ***Human Factors in Lighting*** **- 2nd Edition**
Boyce, P. R. 2003. London; New York: Taylor & Francis.

Color rendering: CRI+GAI approach





Results are representative of observers of different geographical origins and for sources of warm and cool CCTs, different spectral makeup, and light level.

ASSIST. 2010. *ASSIST recommends: Guide to Light and Color in Retail Merchandising.* Vol. 8, Iss. 1. Troy, NY: Lighting Research Center.

ASSIST. 2010. *ASSIST recommends: Recommendations for Specifying Color Properties of Light Sources for Retail Merchandising.* Vol. 8, Iss. 2. Troy, NY: Lighting Research Center.

Rea, M.S. and J.P. Freyssinier-Nova. 2008. Color rendering: A tale of two metrics. *Color Research and Application* 33(3): 192-202.

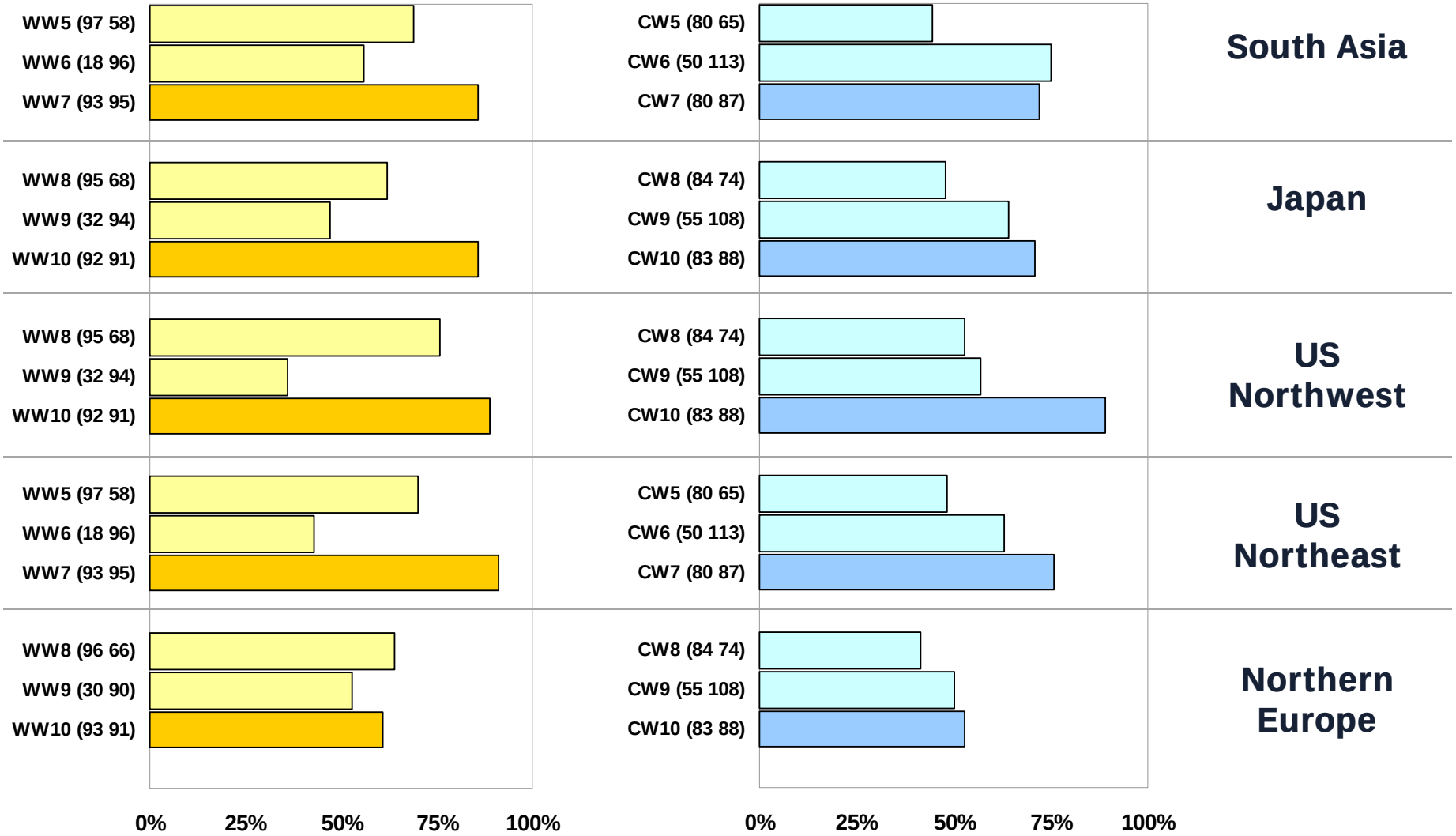
Rea, M.S., and J.P. Freyssinier. 2010. Color rendering: Beyond pride and prejudice. *Color Research and Application* 35 (6): 401-409.

Four follow-up studies:
A priori test of two-metric hypothesis

- South Asia
- US Northwest
- Japan
- Northern Europe

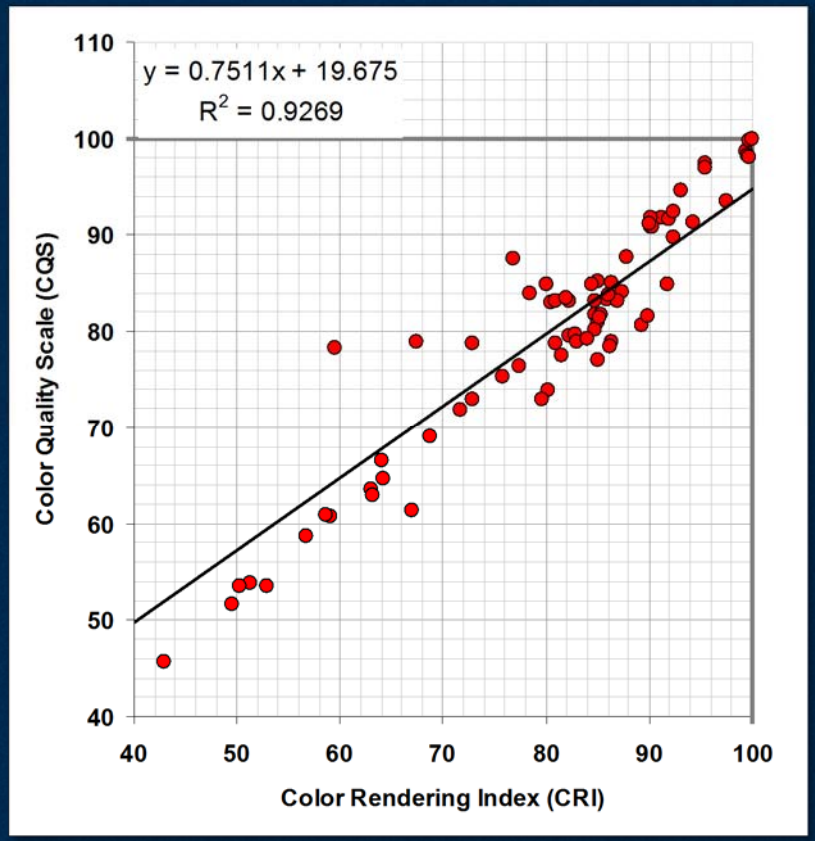
Overall acceptability

Rea, M.S. and J.P. Freyssinier. 2012. The Class A color designation for light sources.
In: *Proceedings of Experiencing Light 2012:* International Conference on the Effects of Light on Wellbeing
(Eds. Y.A.W. de Kort, W.A. IJsselsteijn, M.Aarts, A. Haans, D. Lakens, K.C.H.J. Smolders, F. Beute, L. van Rijswijk).



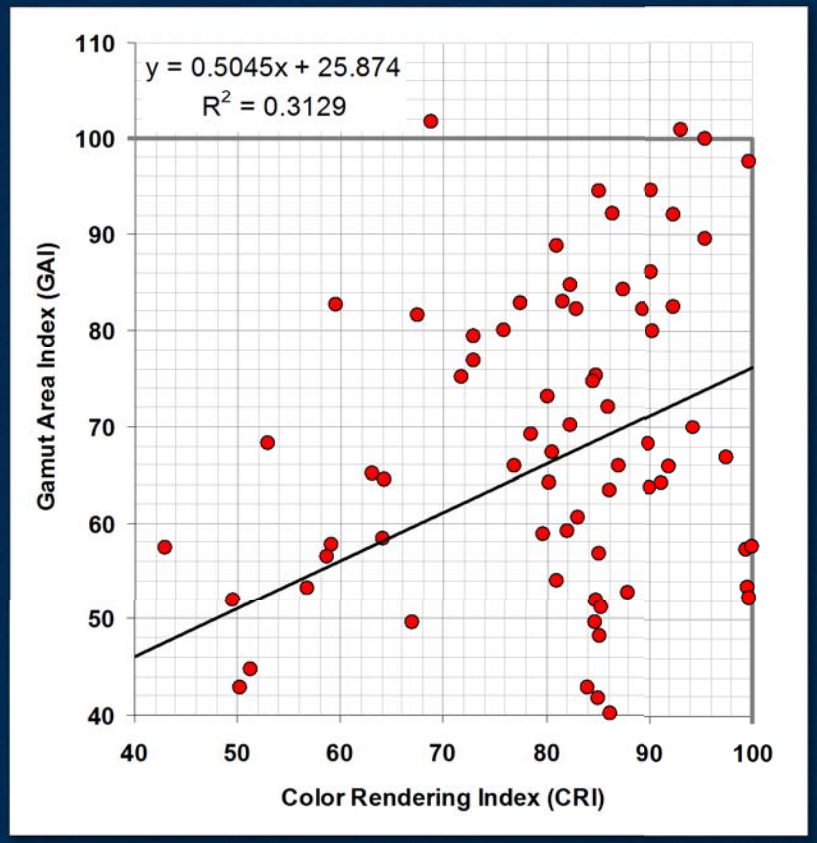
Discussion

- Two metrics needed for "acceptability" and "naturalness"
  - CRI and GAI work
- CQS and R9 could replace CRI
  - But why bother?
- CRI is well established
  - Keep it



Discussion

- Two metrics needed for "acceptability" and "naturalness"
  - CRI and GAI work
- CQS and R9 could replace CRI
  - But why bother?
- CRI is well established
  - Keep it
- GAI is a simple add-on, and measures a different aspect of color rendering
  - So, why not add predictive power <u>and</u> keep it simple?



Color Appearance of Illumination

"White Body" Line

http://www.lrc.rpi.edu/programs/solidstate/colorResearch.asp

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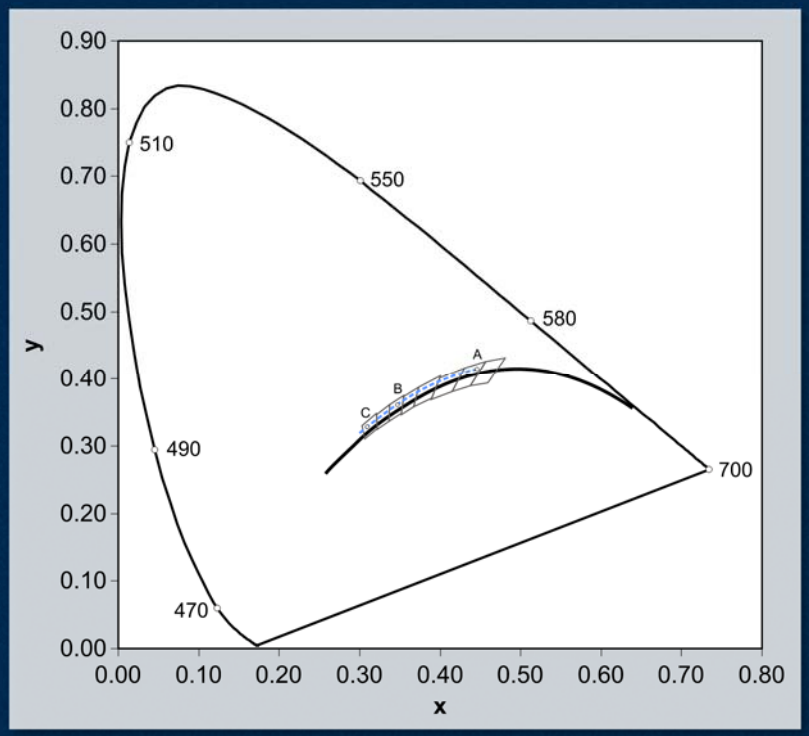
Light source color specification

- Correlated color temperature is the most used metric to specify light source color appearance
  - Based on light source chromaticity

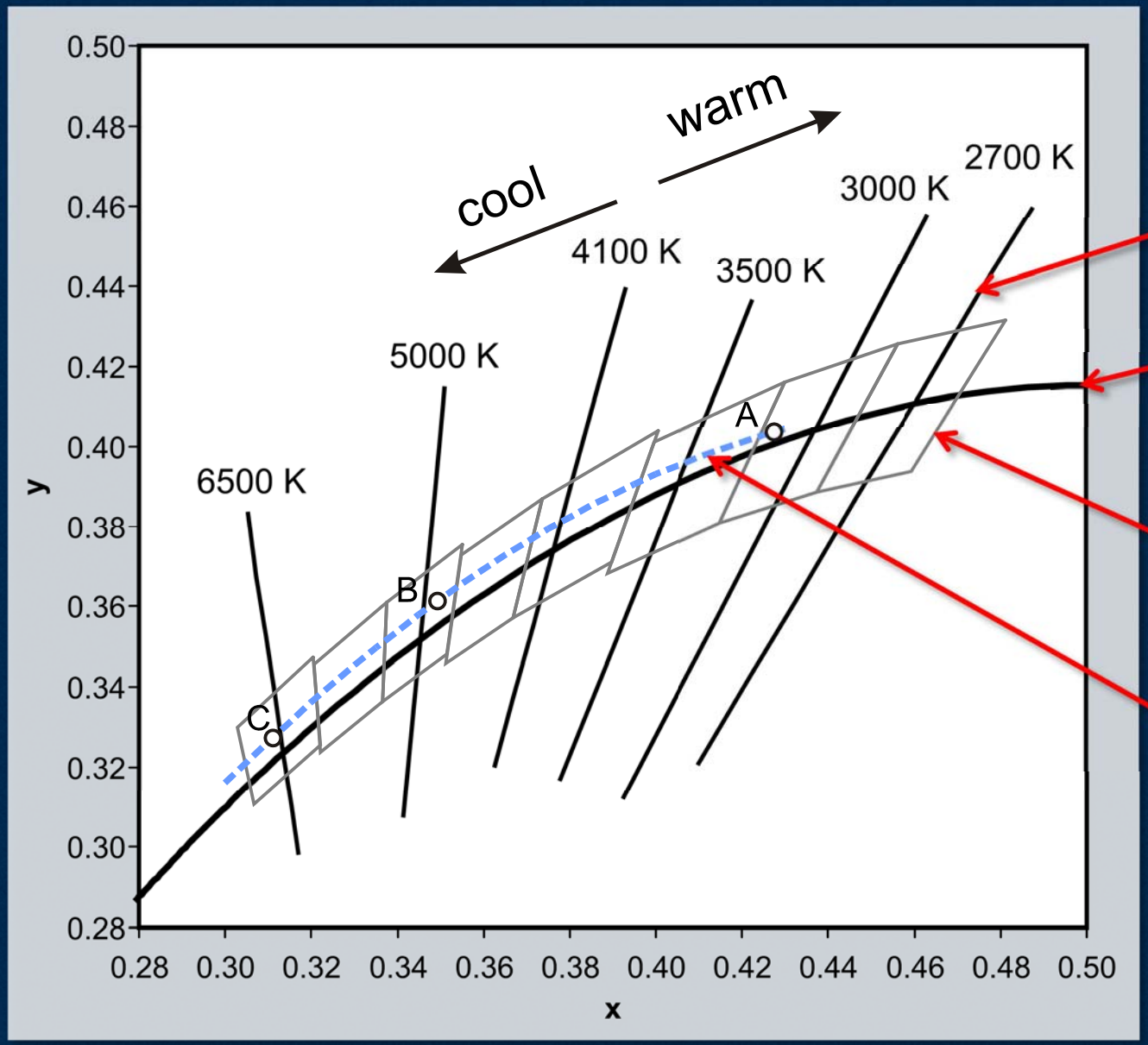


NLPIP
NATIONAL LIGHTING PRODUCT INFORMATION PROGRAM

Table 1. Most useful light source color characteristics.

Characteristic	Average Usefulness Rating	Standard Deviation	Number of Responses
Color Rendering Index (CRI)	3.5	0.7	237
Correlated Color Temperature (CCT)	3.2	1.0	233
Color Stability	3.2	1.0	232
Lamp Type	3.1	1.0	235
Color Consistency	3.1	1.0	228
Spectral Power Distribution (SPD)	2.4	1.2	226
Full-Spectrum Index (FSI)	2.0	1.3	204
Brand Name	1.9	1.2	226
Gamut Area	1.5	1.2	189

(Rating Key: 0 = Not useful; 4 = Very useful)



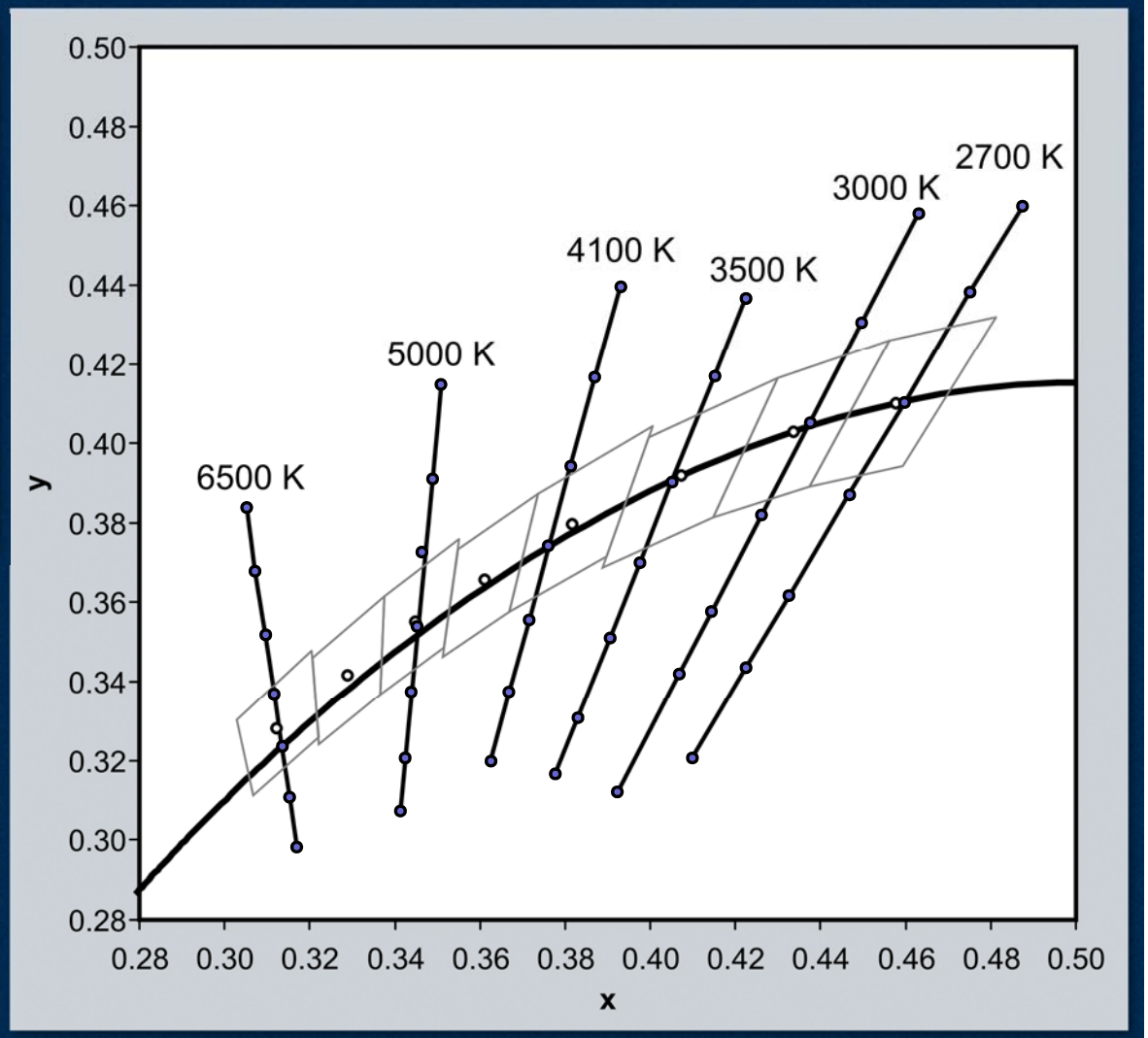
Iso-temperature lines

Blackbody locus

ANSI SSL tolerance zones

Daylight locus

What is white illumination?



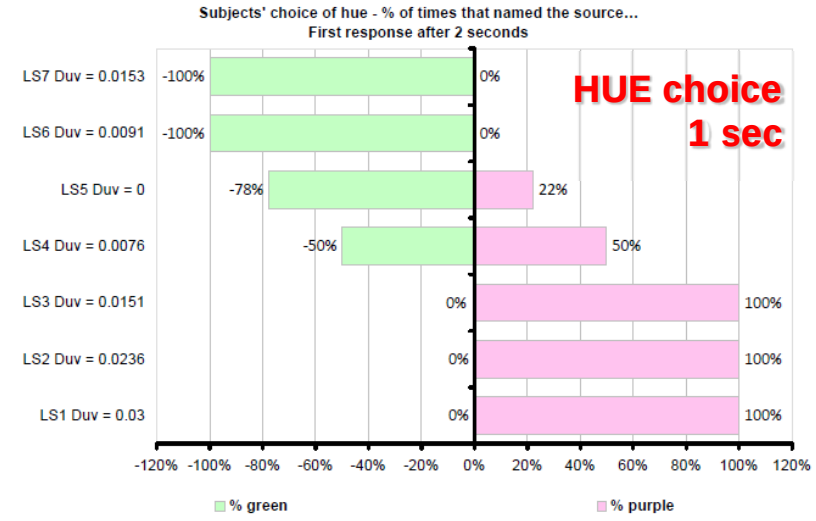
Questions:

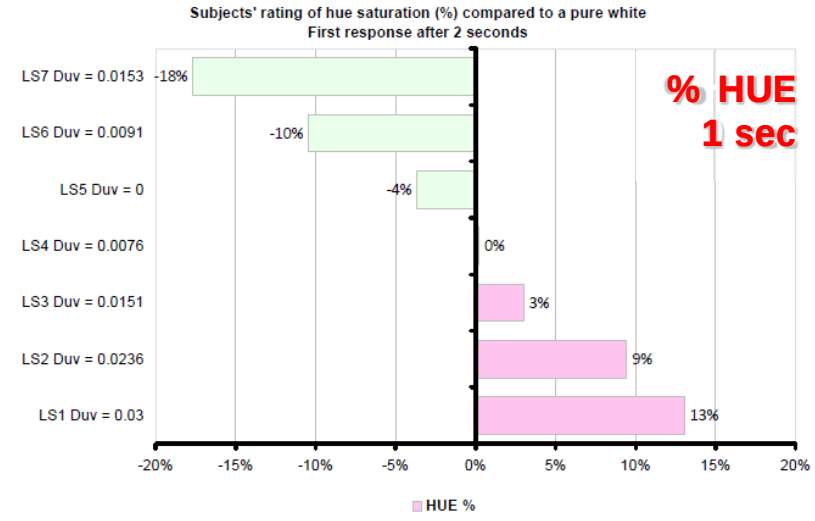
- Hue choice
- Hue percent tint

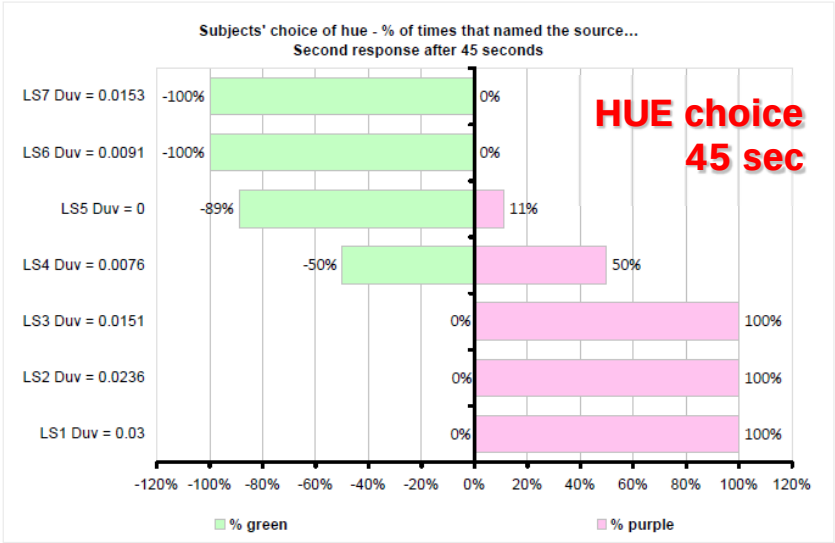
Immediately and after 45 s adaptation

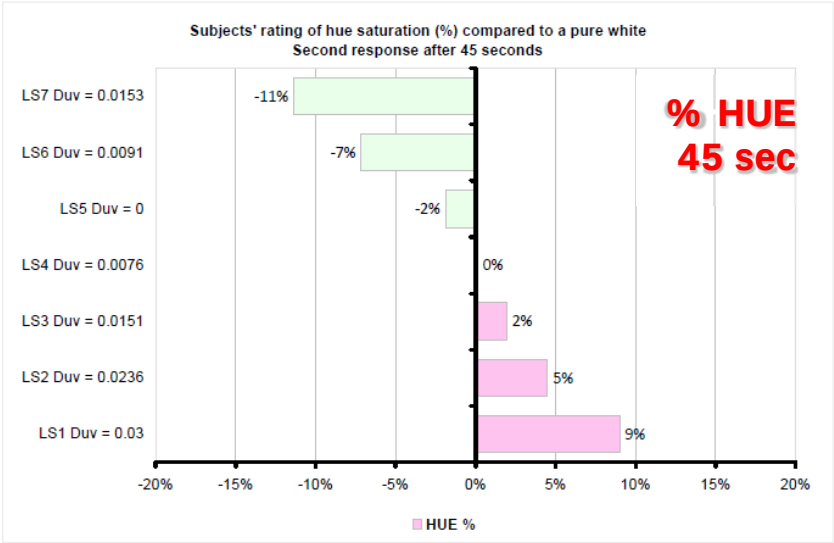
Results

CCT = 3500 K



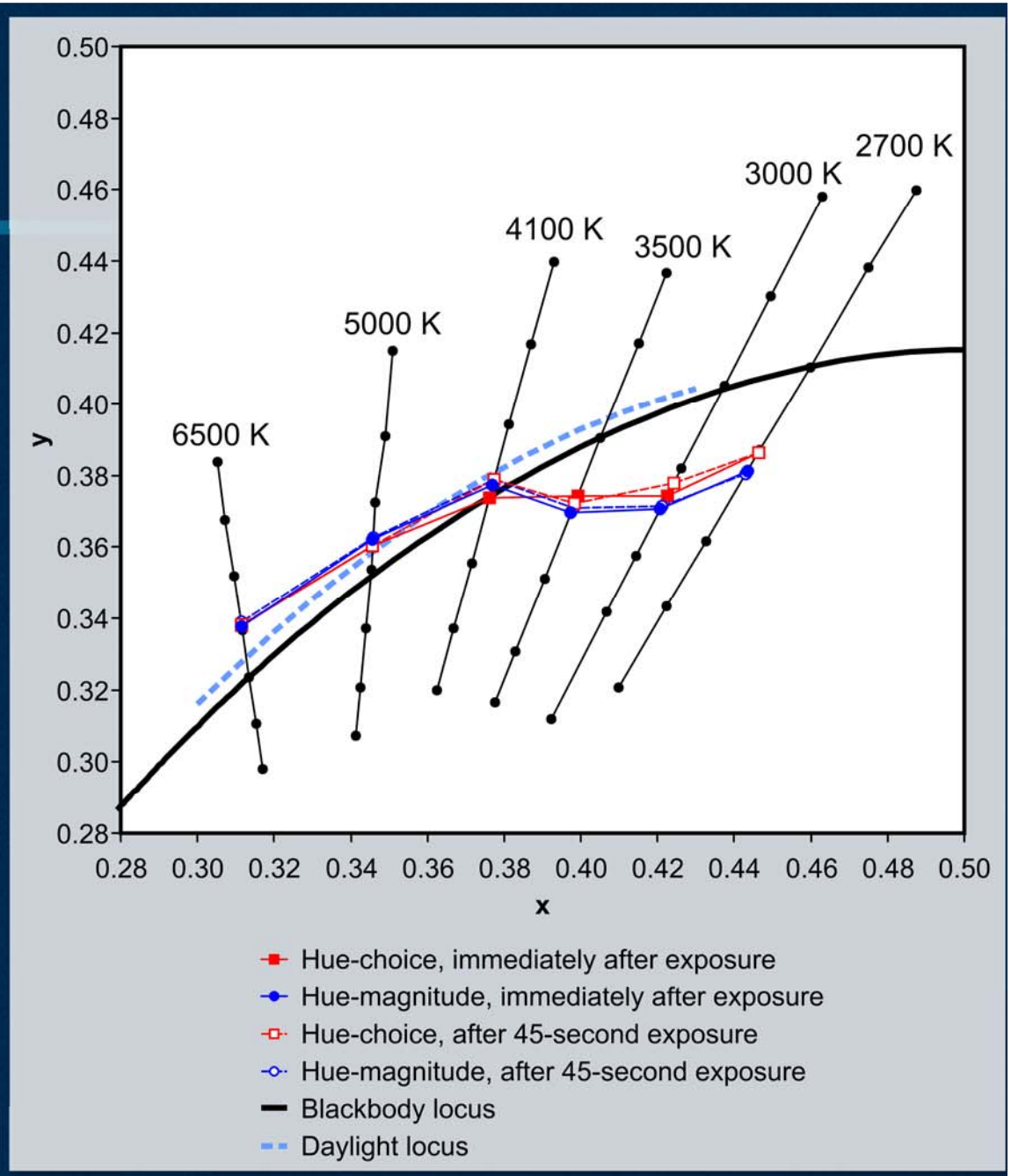






Combined results

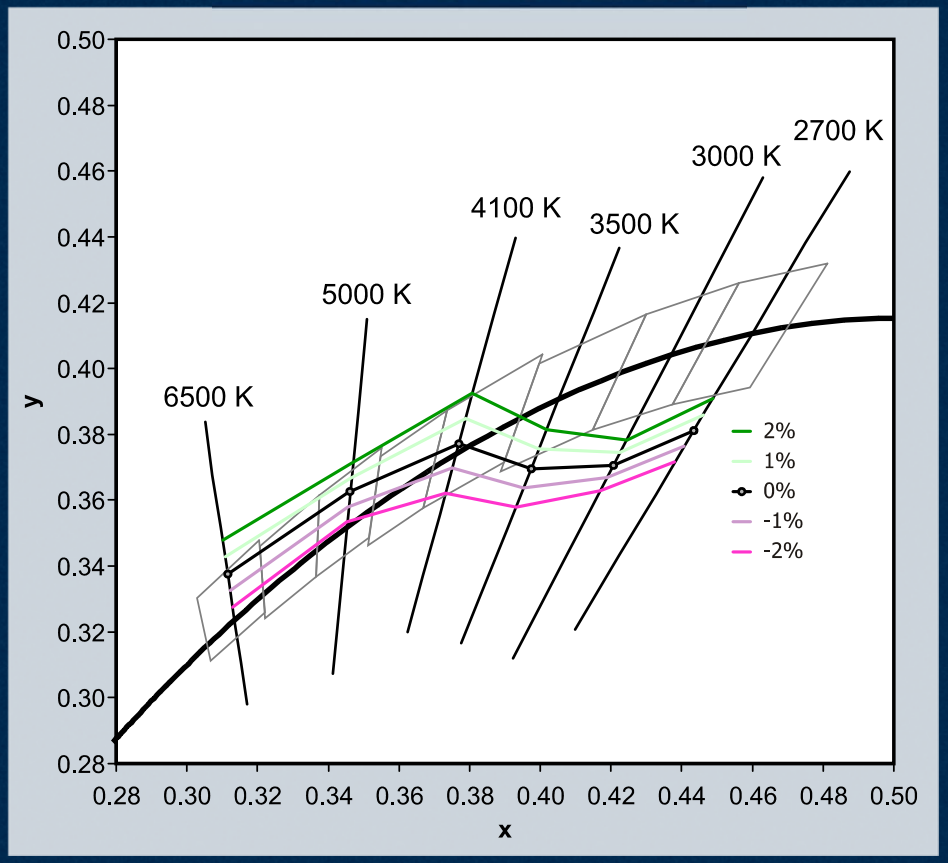
- The four "white points" are close together for each CCT
  - White is white; does not change with time
- White points for CCTs 3500 K and lower are below the blackbody locus
  - And above the blackbody locus for 4100 K and above



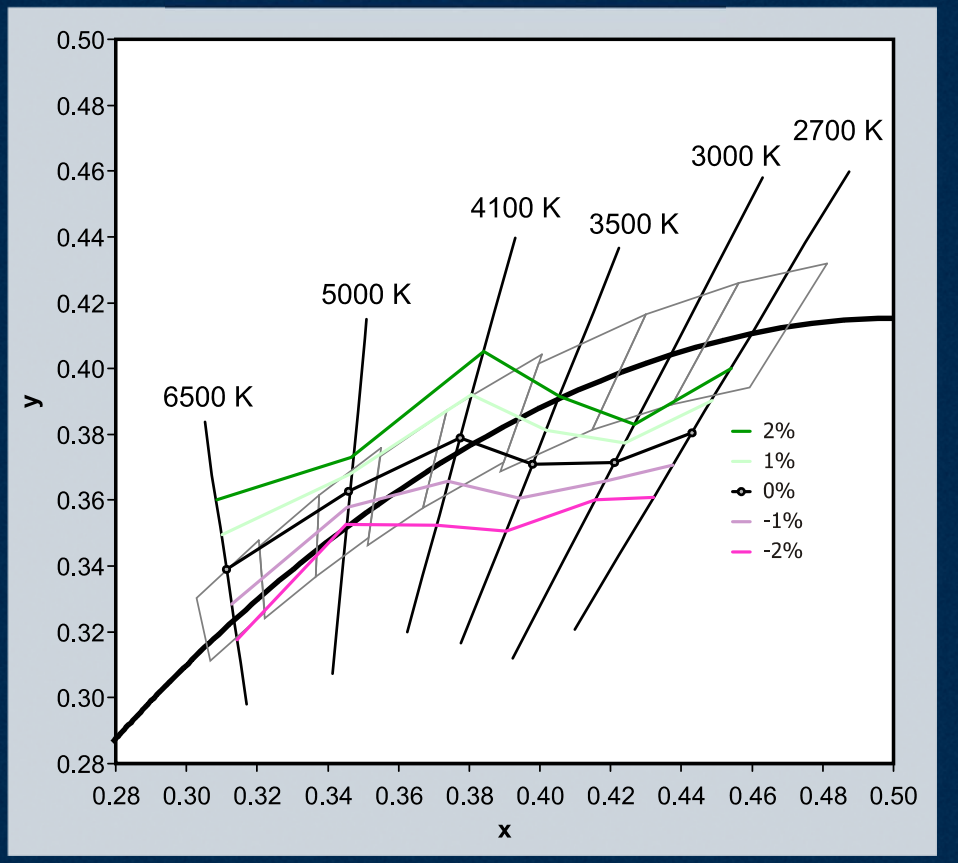
Rea, M. S. and Freyssinier-Nova, J. P. (2011), White lighting. Color Research & Application.

Discussion

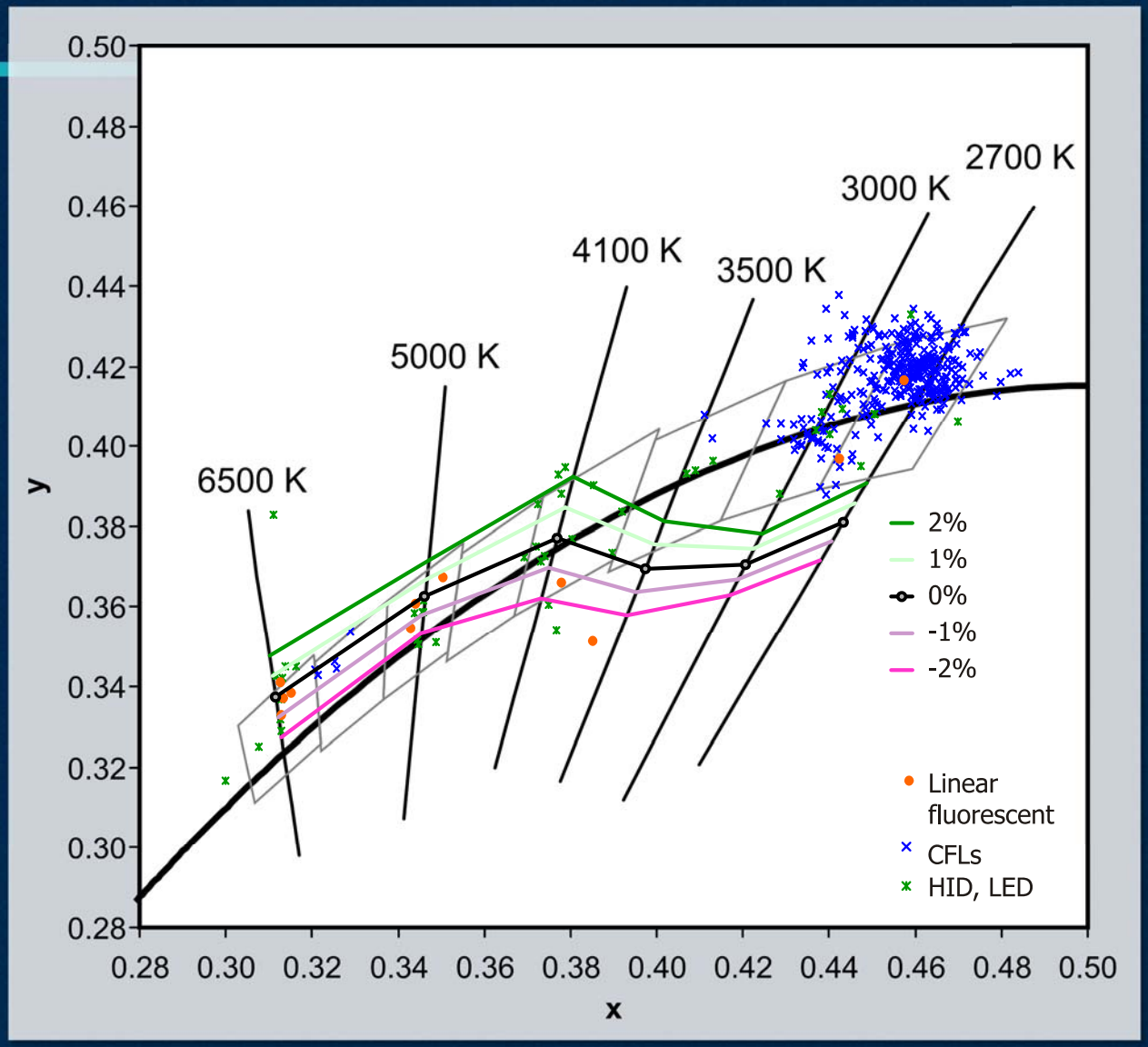
Judgment: Immediate



Judgment: After 45 sec



Chromaticity of various light sources



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Class A Color Light Sources

http://www.lrc.rpi.edu/programs/solidstate/colorResearch.asp

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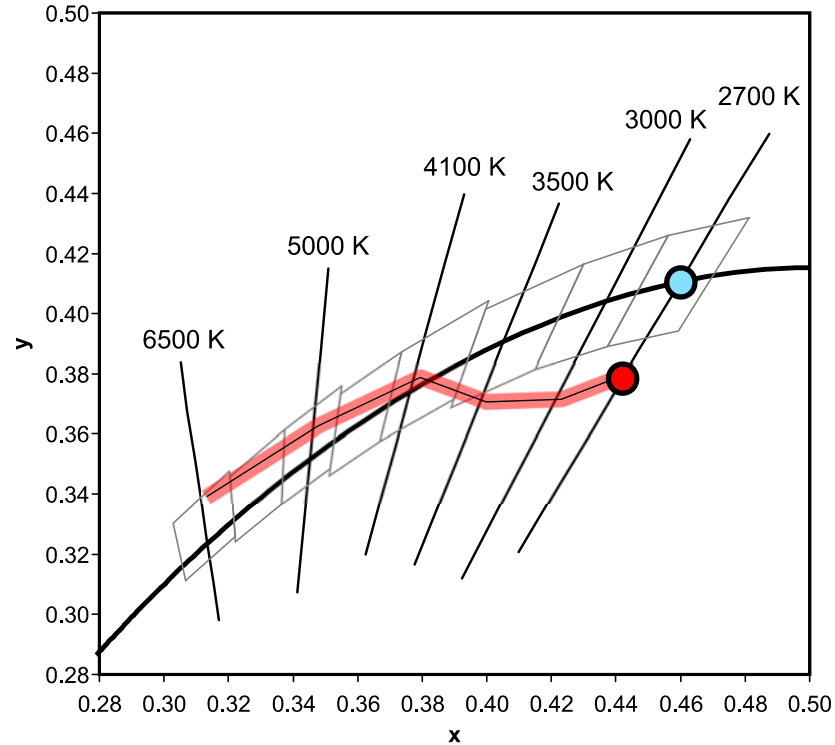
A priori test in a simulated residential application

Would you purchase this light source? (Y or N):

How much do you like this light source?

Strongly dislike it			Dislike it		Like it			Strongly like it
-5	-4	-3	-2	-1	1	2	3	4	5

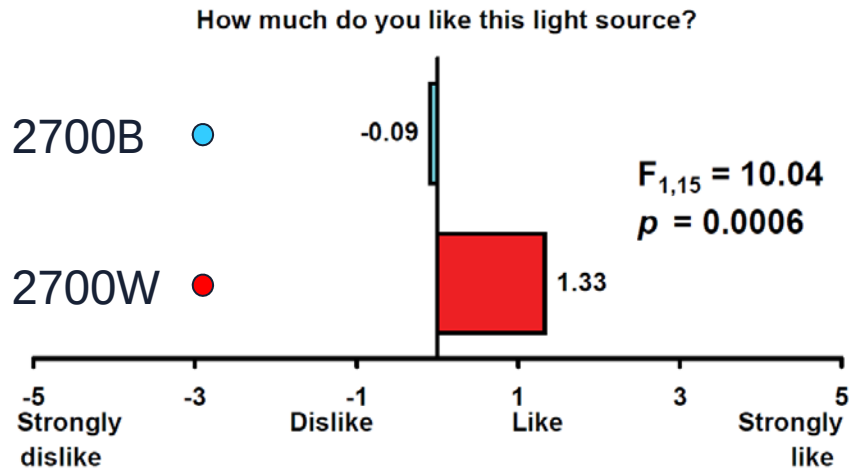


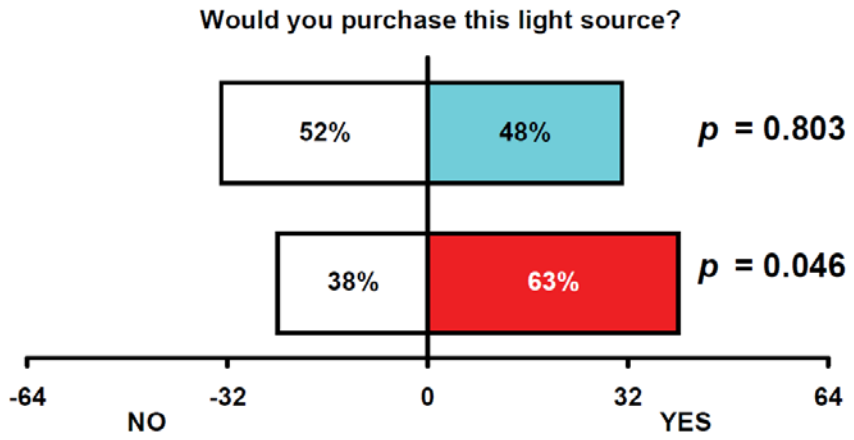
	2700B	2700W
1931 CIE x,y	0.4628, 0.4157	0.4433, 0.3813
CCT	2699 K	2704 K
CRI (Ra)	98	89
GAI	51	77

Rea, M. S. and Freyssinier-Nova, J. P. (2012), White lighting for residential applications. Lighting Research & Technology.

Results

- Class A light sources have been shown consistently to be more favorably rated than light sources of the same CCT but on the blackbody line.





Rea, M. S. and Freyssinier-Nova, J. P. (2012), White lighting for residential applications. Lighting Research & Technology.

Discussion

- Examples of when Class A color is not necessarily what is needed
  - Meat lamps
  - Candlelight dinner
  - Parking lots
  - Plant growth

- Reminder: Light level is important for good color rendering; higher light levels give better color rendering

Proposed industry recommendations for general illumination

Class A color light sources

a) have a chromaticity on or near the "white" body line

b) have CRI > 80 <u>and</u> 80 ≤ GAI ≤ 100

c) are consistent in chromaticity

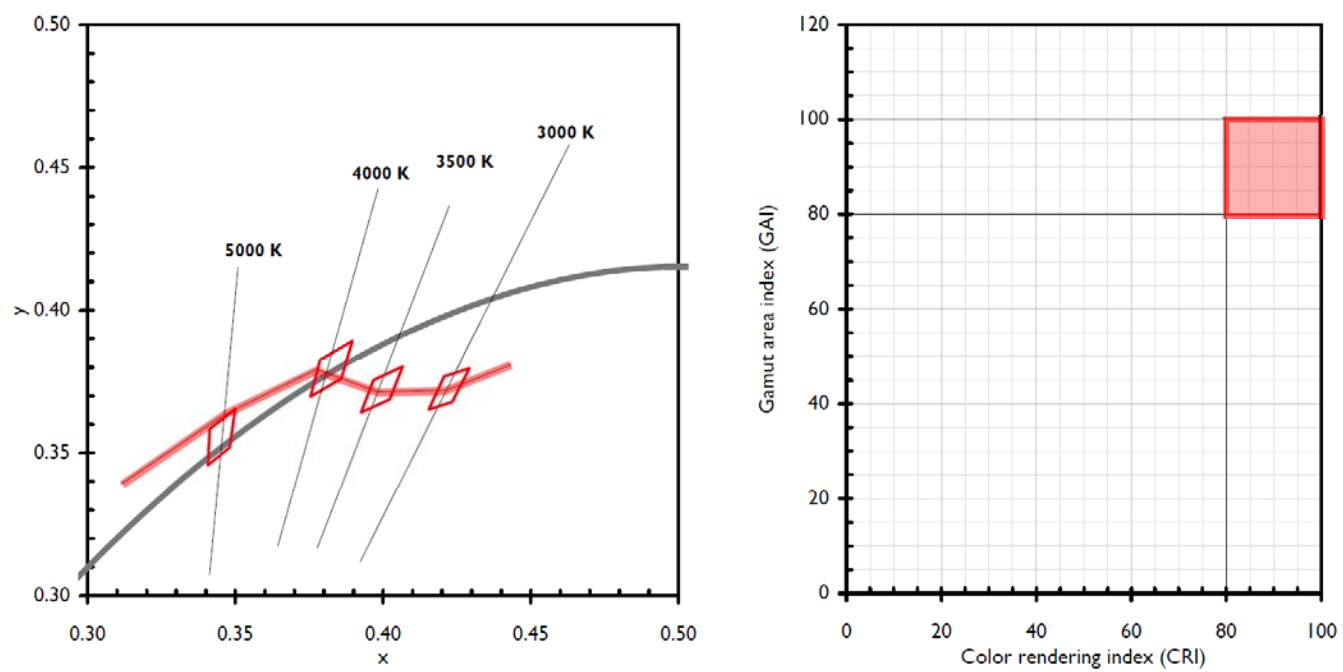


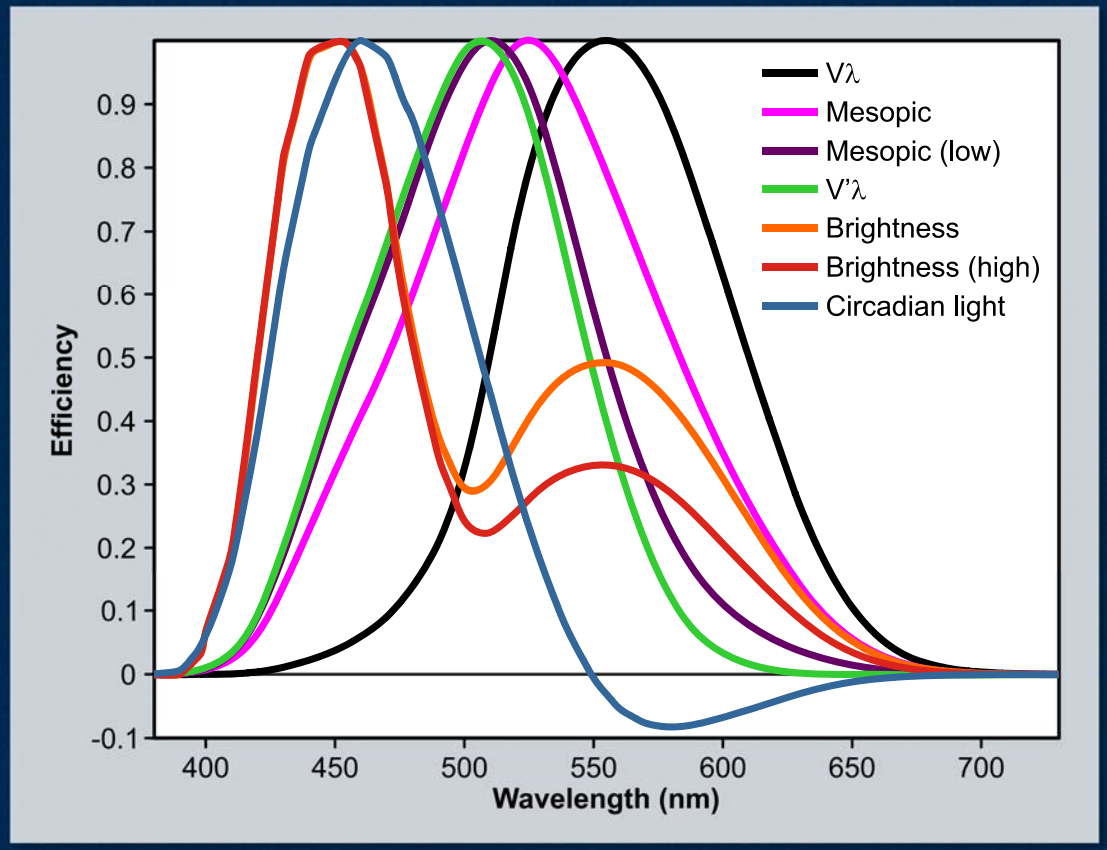
Figure 3. Class A target zones for "white" illumination (left panel) and good color rendering properties (CRI≥80 and 80≤GAI≤100; right panel).

http://www.lrc.rpi.edu/programs/solidstate/colorResearch.asp

Final thoughts

- Lighting should be a value proposition – increasing benefits is just as important as reducing costs.
  - Efficacy is more than lumens per watt
- Measurement drives what we do – measure the right benefits for an application.
  - New metrics are needed to evaluate applications, not products
  - Lighting metrics for applications should be based on <u>measurable</u> benefits
  - These include different ways to assess spectral power distributions (SPDs) based upon color rendering, mesopic (nighttime) vision, circadian light, perceived brightness

Luminous efficiency functions



Rea M. 2012. *Value Metrics for Better Lighting* . SPIE Press Monograph PM228.

http://www.lrc.rpi.edu/programs/solidstate/colorResearch.asp

Thank you!

Acknowledgements

- Alliance for Solid-State Illumination Systems and Technologies:

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