Communicating Light Source Color Properties for General Illumination: Class A Color

Jean Paul Freyssinier
Mark Rea, PhD
Lighting Research Center
Rensselaer Polytechnic Institute

ENERGY STAR® Lighting Webinar Series
March 31, 2016

Lighting Research Center

Rensselaer

Introduction

- **Color rendering**, the **color of illumination**, and **color consistency** are three key factors that support architectural lighting.
- However, presently accepted metrics used to describe these color properties (**CRI**, **CCT**, **ANSI quadrangles**) often are not sufficient to predict user acceptability.

photos.com

Amerlux

Amerlux

Light source color research

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

- Since 2002, ASSIST has funded research in the areas of light source color consistency, color rendering, and light source color. This research has resulted in
  - recommendations for 2- or 4-step MacAdam ellipses as tolerance zones for consistency of white illumination
  - the two-metric approach to describe good color rendering
    - *a priori* testing in the lab and in the field
  - the empirical and theoretical understanding of light sources of minimum tint
  - the concept of Class A color as a communication tool for sources used in general illumination.

Lighting Research Center

Rensselaer

Color Rendering of Illumination

CRI and GAI

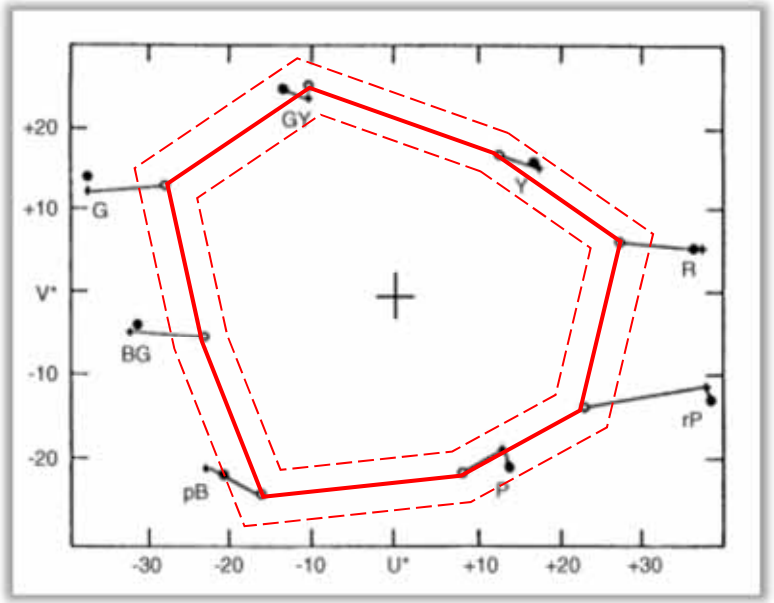
http://www.lrc.rpi.edu/programs/solidstate/colorResearch.asp

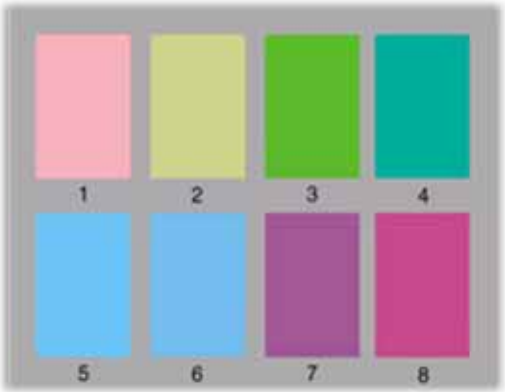
Lighting Research Center

Rensselaer

Color rendering index (CRI)

- Measure of the degree of color shift objects undergo when illuminated by the light source as compared with the color of those same objects when illuminated by a reference source of comparable color temperature

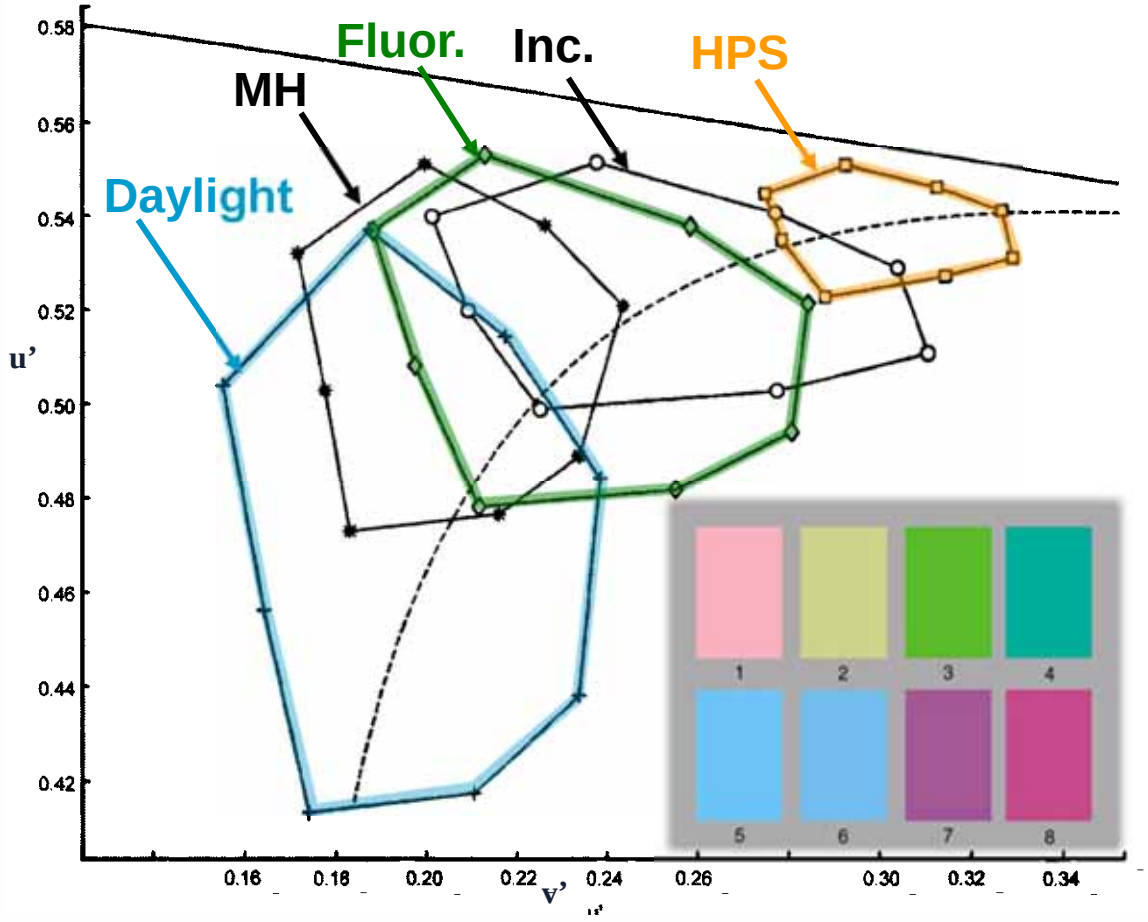




IESNA Lighting Handbook, 9th Ed. (2000)

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.

LRC color rendering experiments: *a priori* tests of two-metric approach

- Display of fresh fruits and vegetables
- Color chart

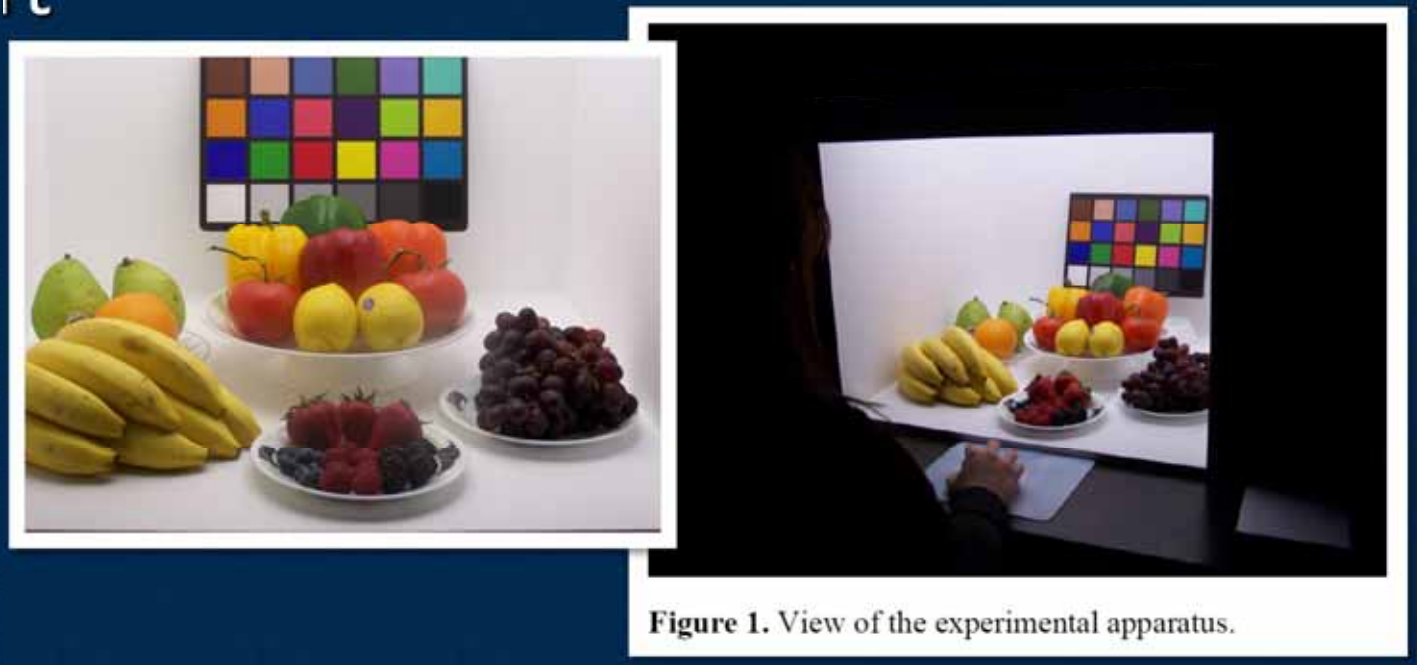


Figure 1. View of the experimental apparatus.

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.

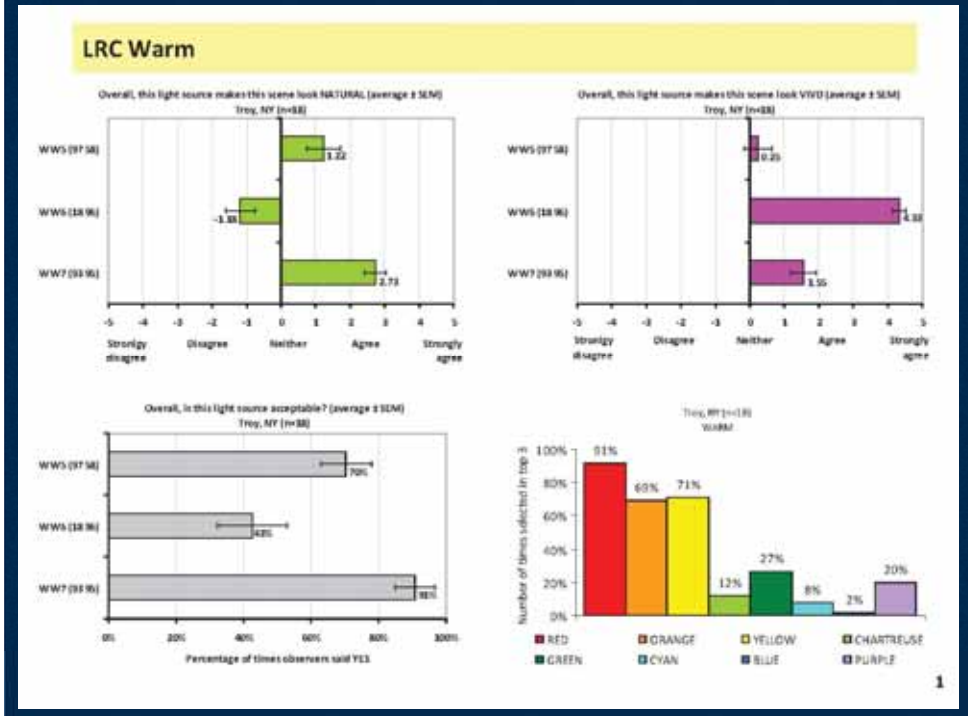
Rea, M.S. and J.P. Freyssinier-Nova. 2008. Color rendering: A tale of two metrics. *Color Research and Application* 33(3): 192-202.

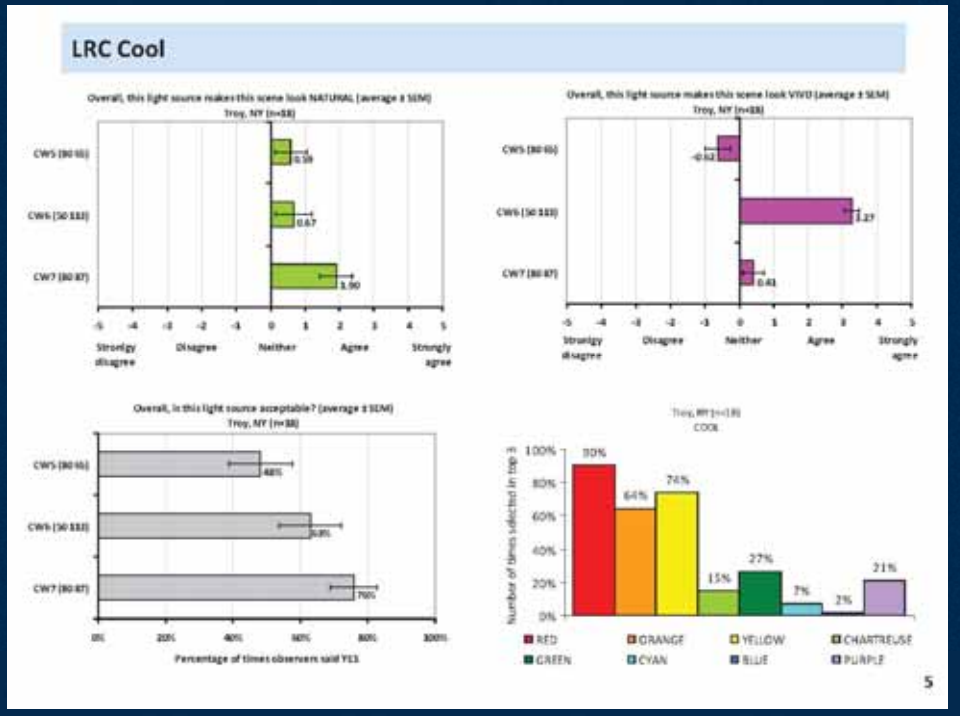
Rea, M.S., and J.P. Freyssinier. 2010. Color rendering: Beyond pride and prejudice. *Color Research and Application* 35 (6): 401-409.

Freyssinier, J.P., and M.S. Rea. 2013. Class A color designation for light sources used in general illumination. Journal of Light and Visual Environment 37(2&3): 46 –50.

Results

- A single metric of color rendering was not capable of predicting acceptability
  - Color rendering index (CRI) >80
  - Gamut area index (GAI) between 80 and 100





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

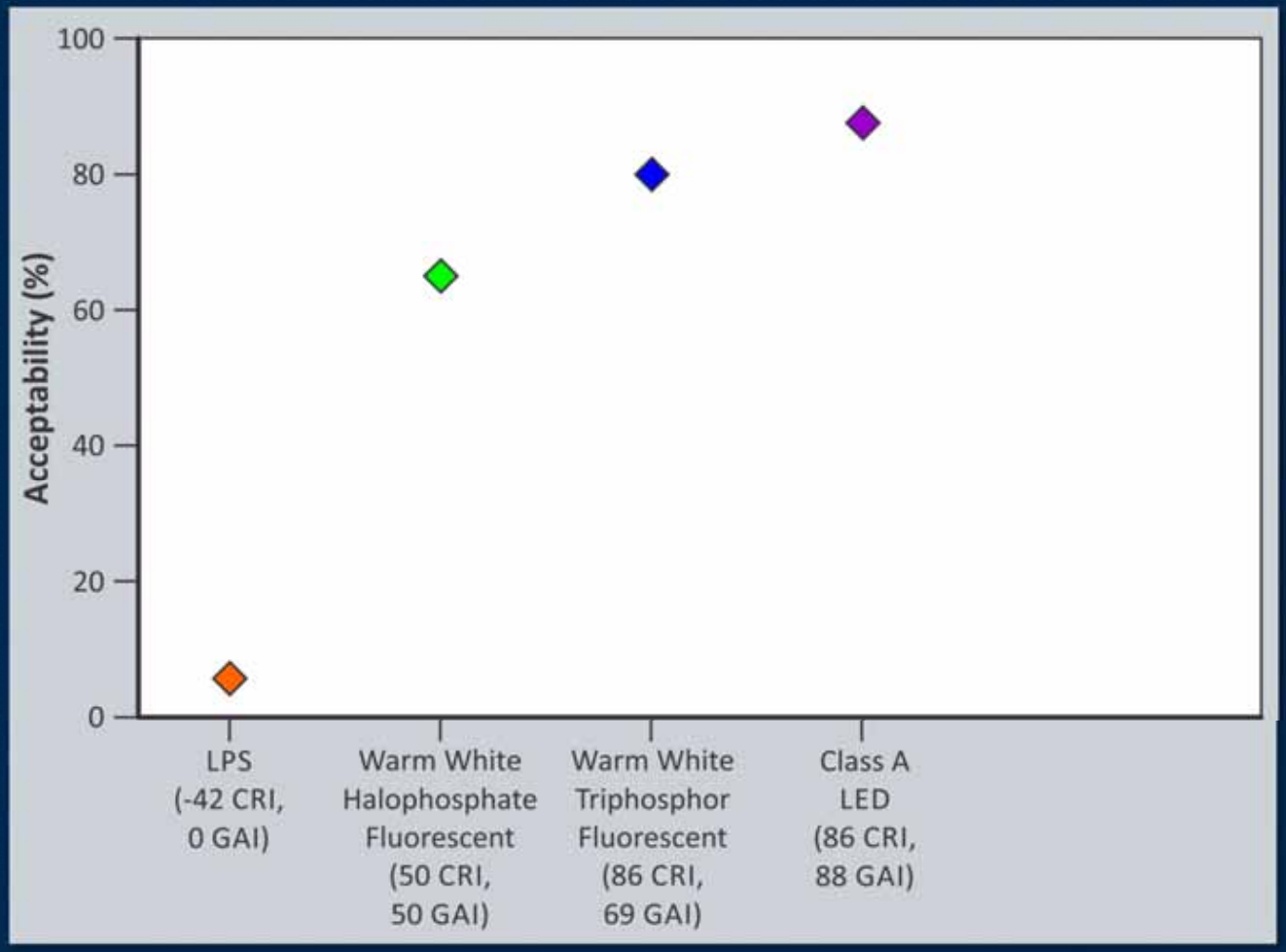
Basic considerations

- Define the stimulus — know what people are actually viewing
- Define the response — know what aspects of the stimulus are being evaluated
- Color rendering is two-dimensional — thermal comfort is both ambient temperature and wind speed, even though we use “wind chill” as a metric

Color rendering – current thinking

- No single metric can characterize color rendering
  - Good color rendering by a light source for general illumination depends on providing an optimum amount of color saturation without distortion (e.g., daylight)

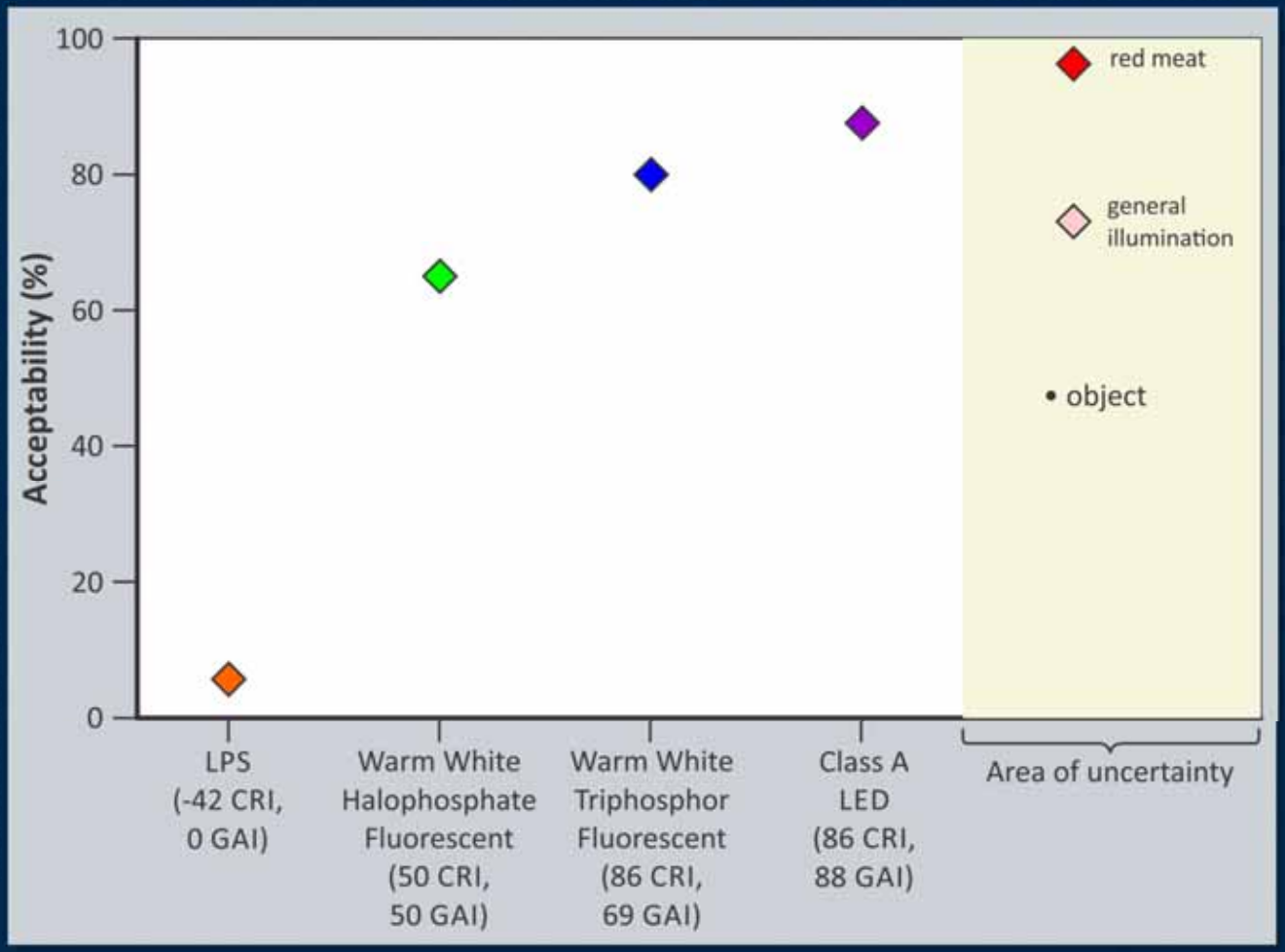
Acceptability



Color rendering

- No single metric can characterize color rendering
  - Good color rendering by a light source for general illumination depends on providing an optimum amount of color saturation without distortion (e.g., daylight)
  - Unless…

Acceptability



Butcher's case lighting

Specification of the stimulus

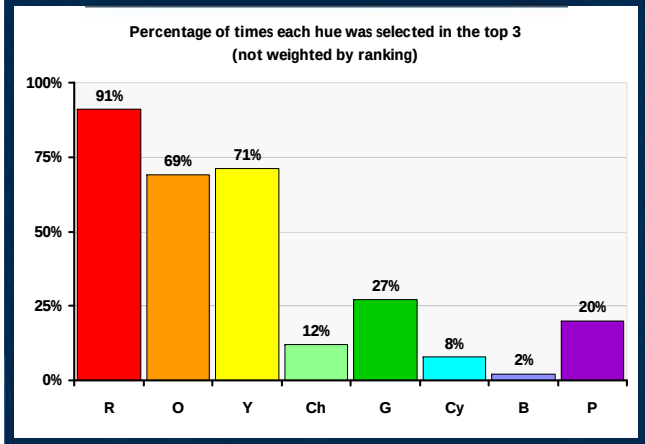
- Clarify what people should evaluate
  - Unknown stimuli can lead to results that are hard to interpret
- Point observers to specific hues or objects in a scene
  - Blues and reds

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

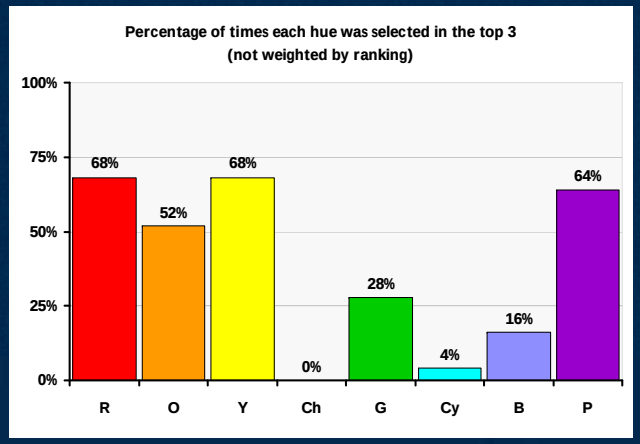
Specification of the stimulus

- Or, ask what they are observing (e.g., top three hues influencing decision)

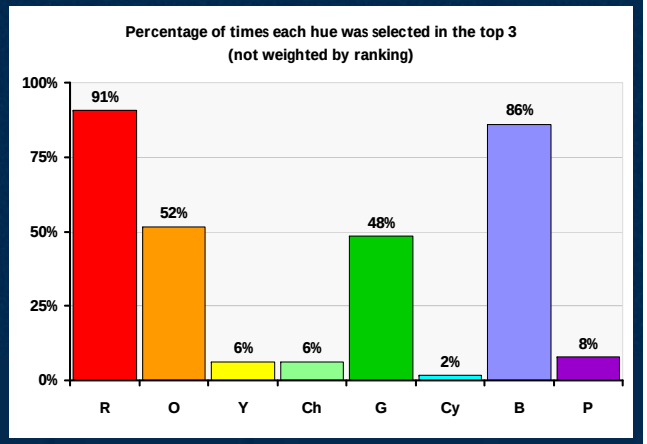
2007-2012



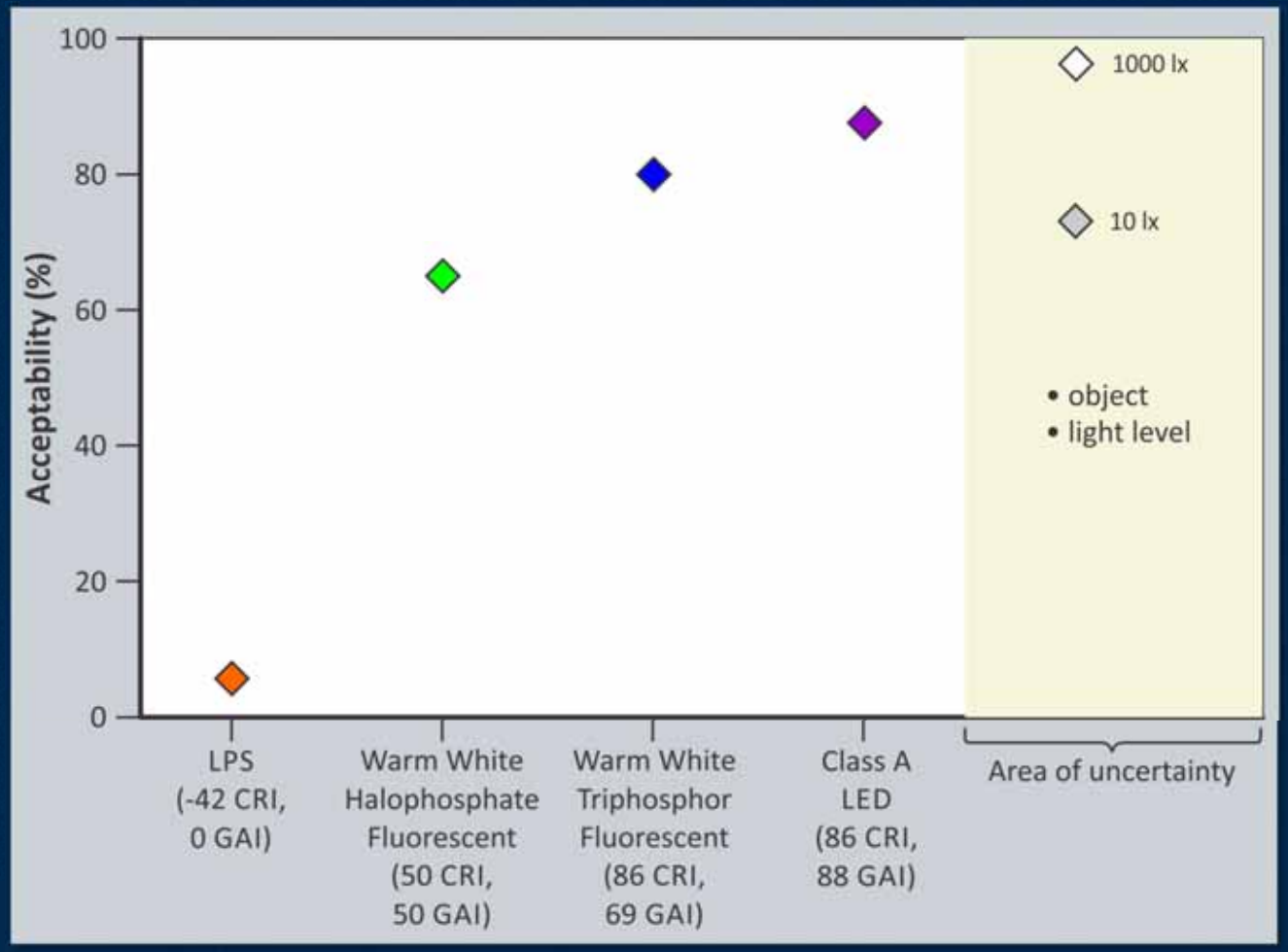
2013



2015



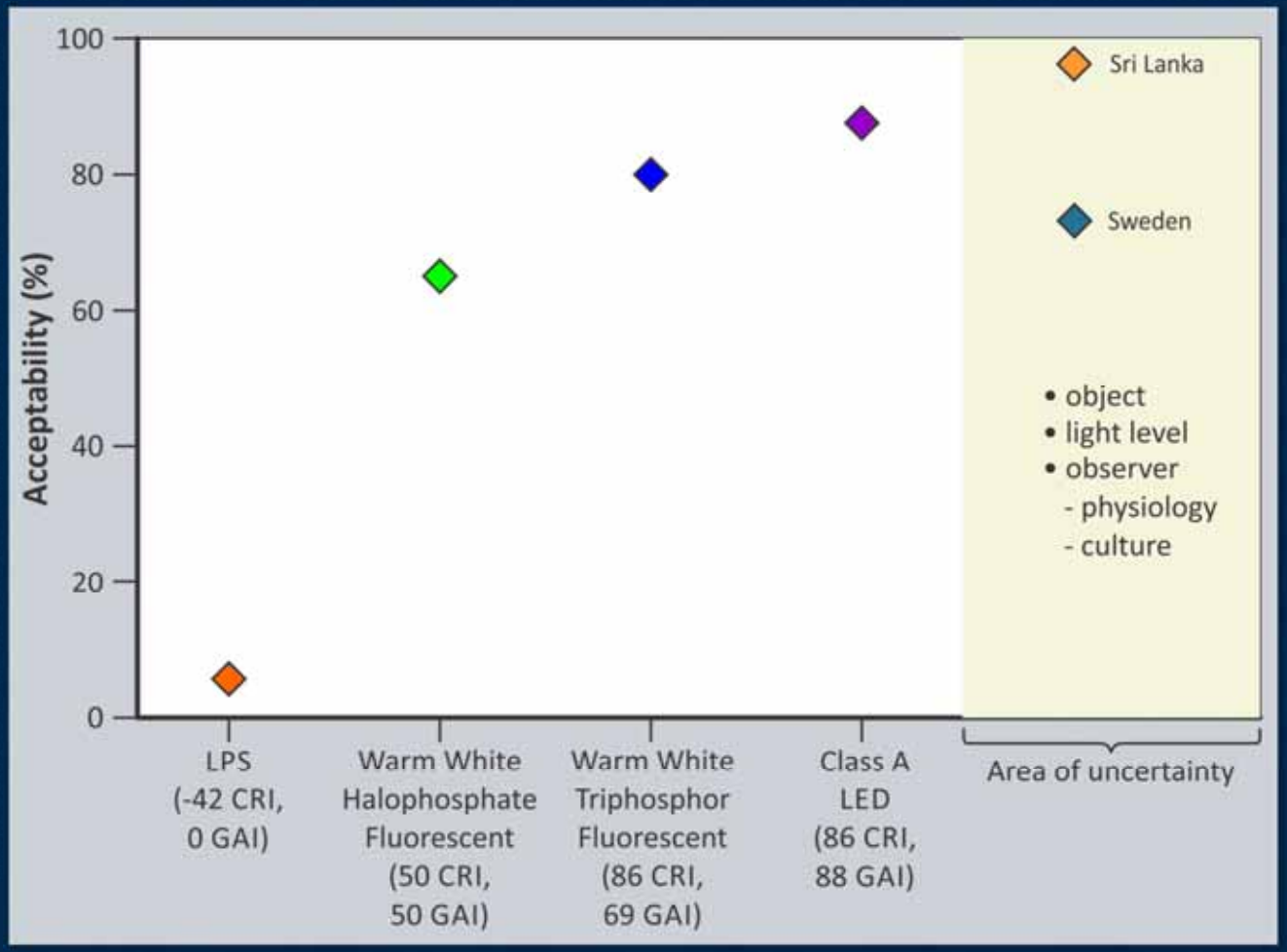
Acceptability

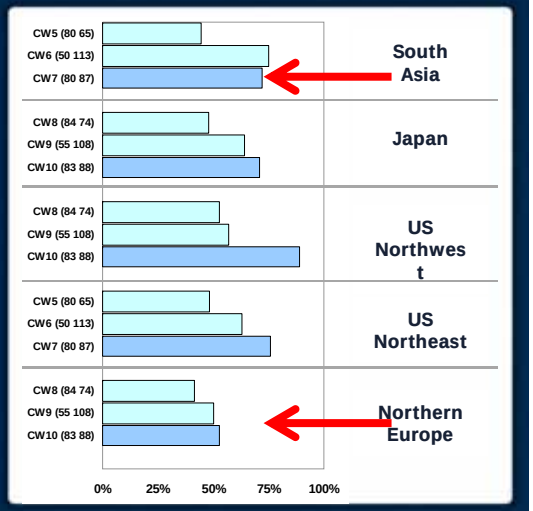


Different populations

- South Asia
- US Northwest
- US Northeast
- Japan
- Northern Europe

Acceptability





Color Appearance of Illumination

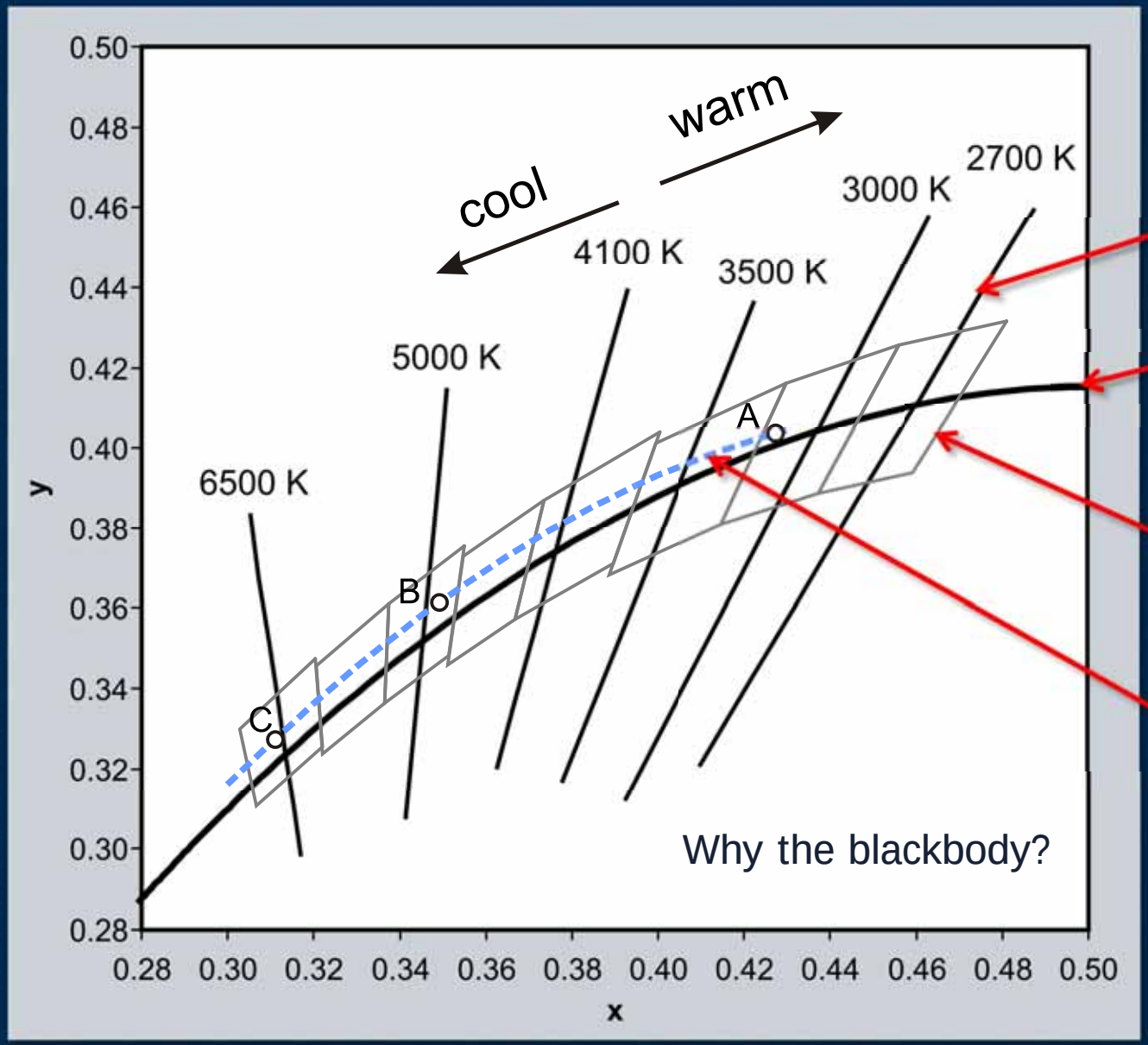
Line of minimum tint

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

Lighting Research Center

Rensselaer

Color of illumination



Iso-temperature lines

Blackbody locus

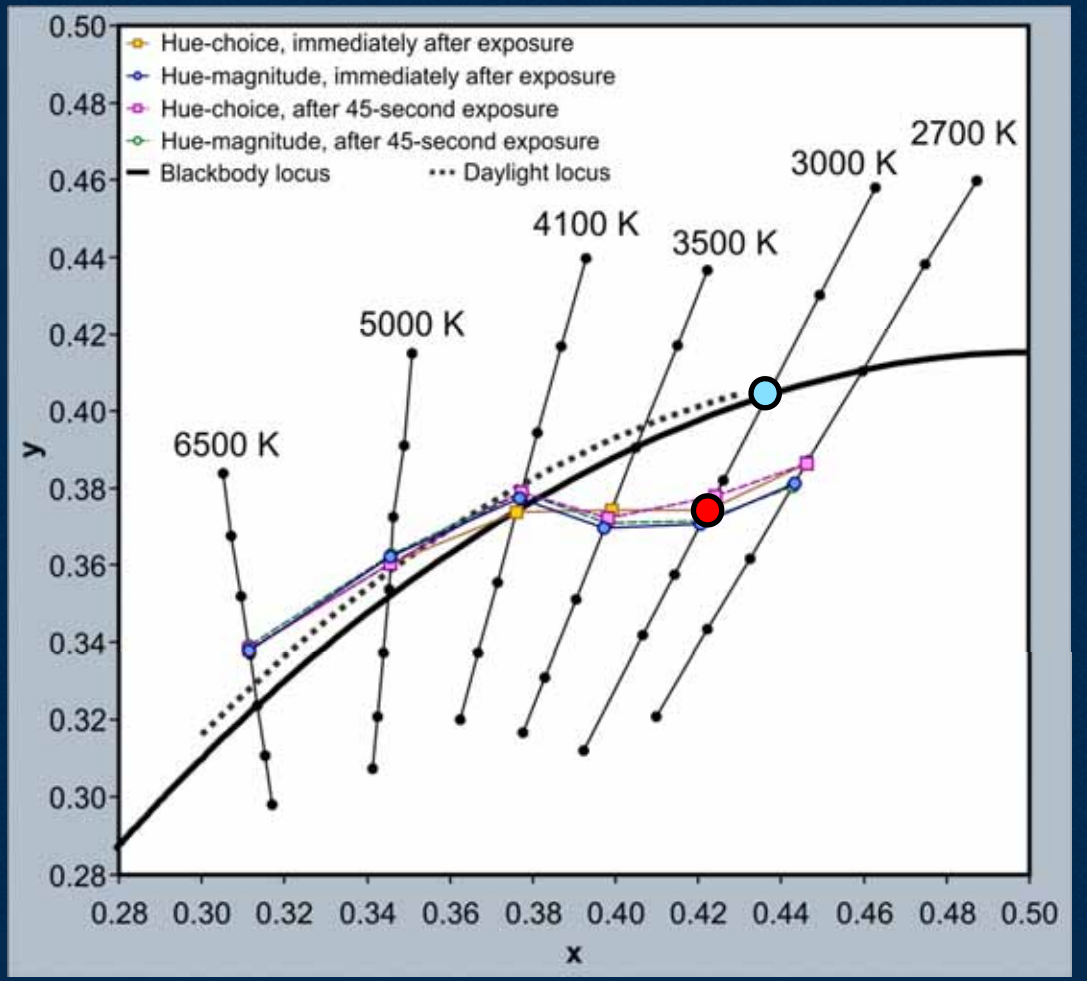
ANSI SSL tolerance zones

Daylight locus

Results

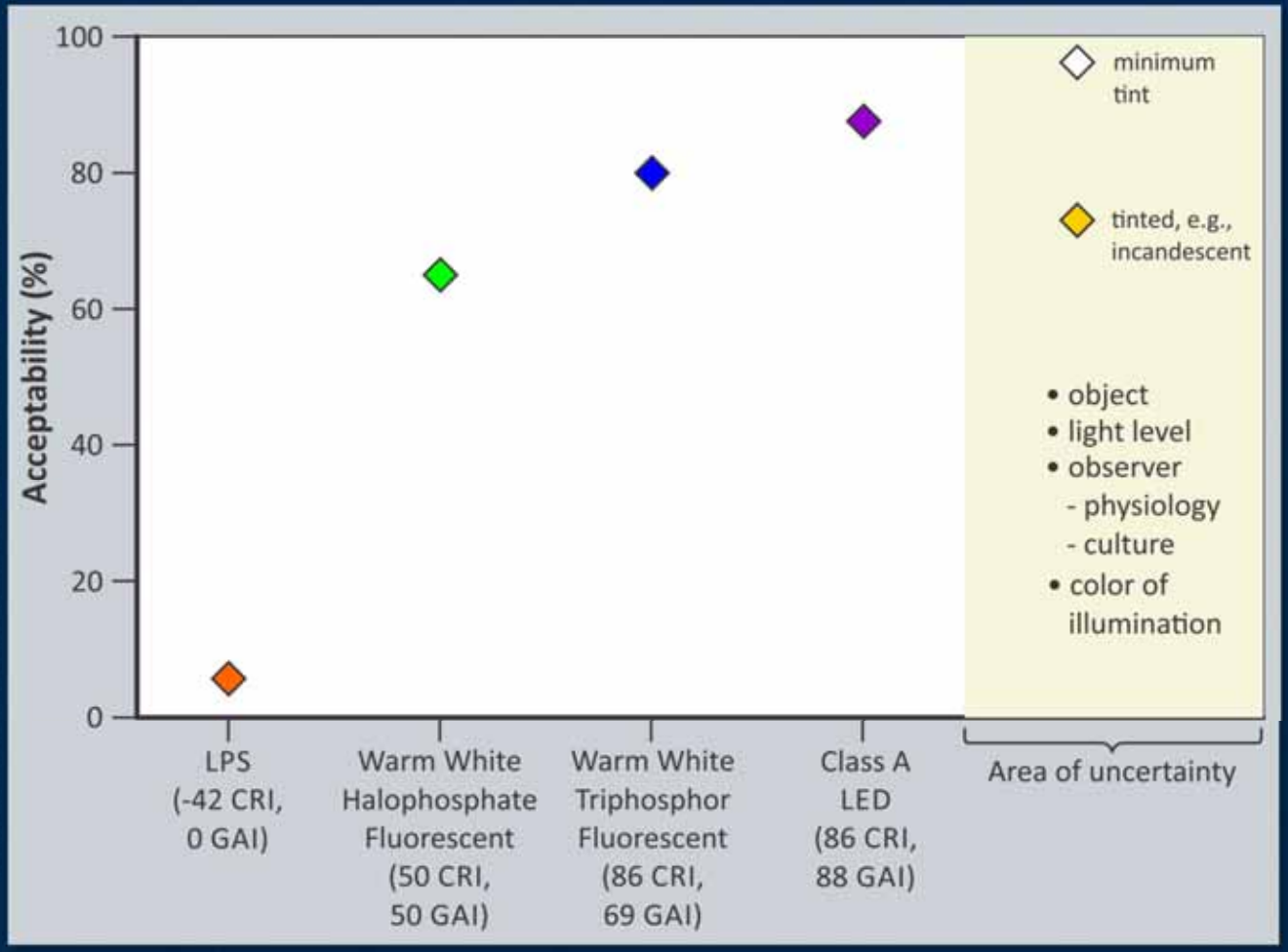
- The four “white points” are close together for each CCT
  - White is white; does not change with time
- “White points” for CCTs 3500 K and lower are below the blackbody locus
  - And above the blackbody locus for 4100 K and above

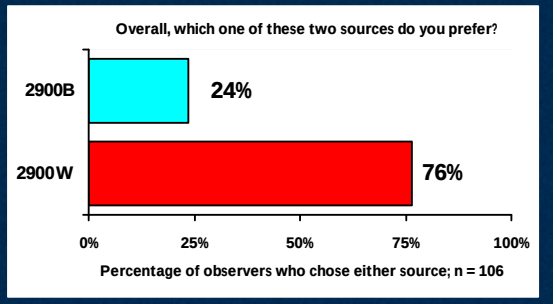
Δ time to respond	Psychophysical method: Indirect	Psychophysical method: Direct
0 s	Hue choice	Hue magnitude
45 s	Hue choice	Hue magnitude



Rea MS and JP Freyssinier. White Lighting. *Color Research and Application*, 2013.

Acceptability





Color consistency

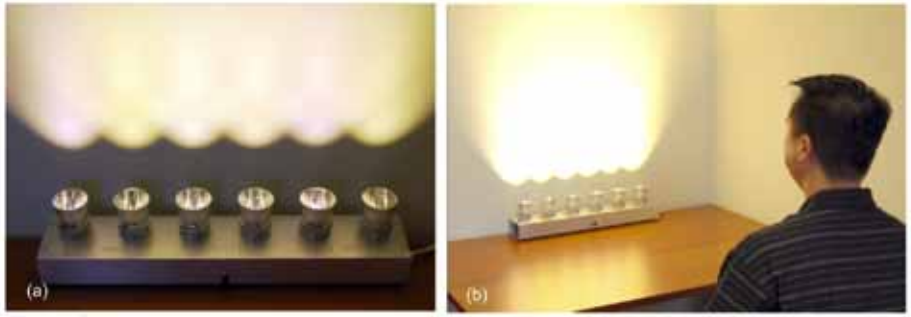


Fig 3 Portable color consistency test set-up (a) front top view with three sets of two test modules (b) typical test configuration with observer.

Xicato

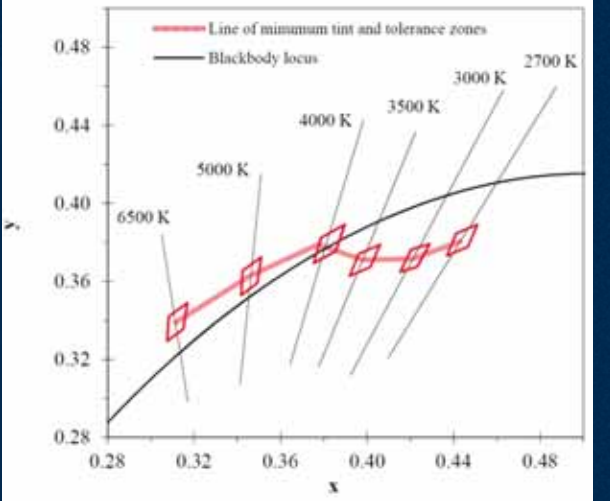
LEDs Magazine

Class A Color Designation for Light Sources Used in General Illumination

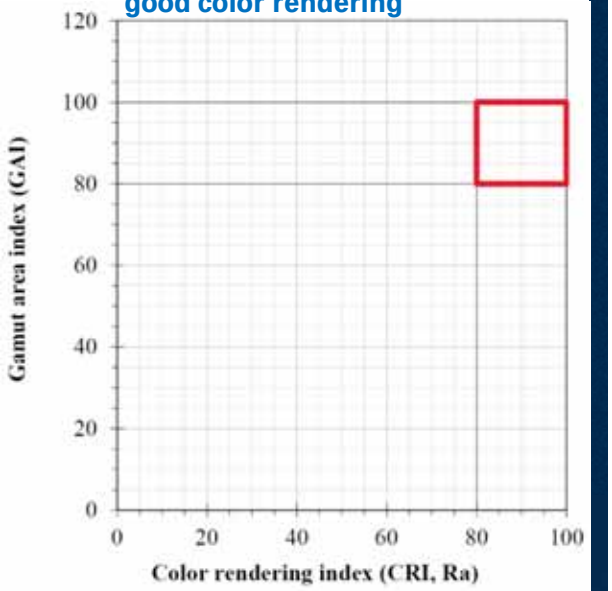
http://www.lrc.rpi.edu/programs/solidstate/colorResearch.asp

- Simple and predictive concept to communicate light source color properties to consumers
  - White light sources with good color rendering properties and consistent color appearance
    - Chromaticity on or near the line of minimum tint
    - CRI>80 and 80<GAI<100
    - Consistent in chromaticity
- Based on multiple human factors studies, including several groups of different cultural backgrounds and field evaluations.
- Manufacturers have been using this research to develop new products.

Target chromaticity zones for "white" lighting



Target CRI and GAI for good color rendering



Final thoughts

- CRI cannot be used as the sole metric to predict color preferences
- The Class A color designation is useful, simple and predictive of overall preference
  - Rendered color saturation (e.g., GAI) and tint of illumination (e.g., line of minimum tint) add meaningful dimensions to CRI
- However, more precise predictions are not possible unless we know:
  - The visual capabilities of the observer
  - The object being viewed (i.e., the stimulus)
  - The light level
- We also need to define the response: What aspects of the stimulus are being evaluated?

Thank you!

Acknowledgements

- US Environmental Protection Agency
  - Taylor Jantz-Sell, Daniel Rogers
- Alliance for Solid-State Illumination Systems and Technologies
- Lighting Research Center
  - Mark Rea, N. Narendran

freysj@rpi.edu

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

Lighting Research Center

Rensselaer