Color Preference: What Light Source Spectra are Less Likely to Disappoint?

ENERGY STAR Lighting Webinar Series
Evaluating Color Quality
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To have a preference is to like something more than something else.

In applied lighting, color preference means having a preference for the rendition of object colors; it is a property we attribute to sources.

Buck GB. 1950. Color preference studies with fluorescent lamps. Illuminating Engineering. 45:165-167.

Color preference is just one component of color rendering.

- **Color Fidelity**
- **Color Discrimination**
- **Color Preference**

Tend to be related to saturation, and can be evaluated with gamut

Sidebar for Further Reading:

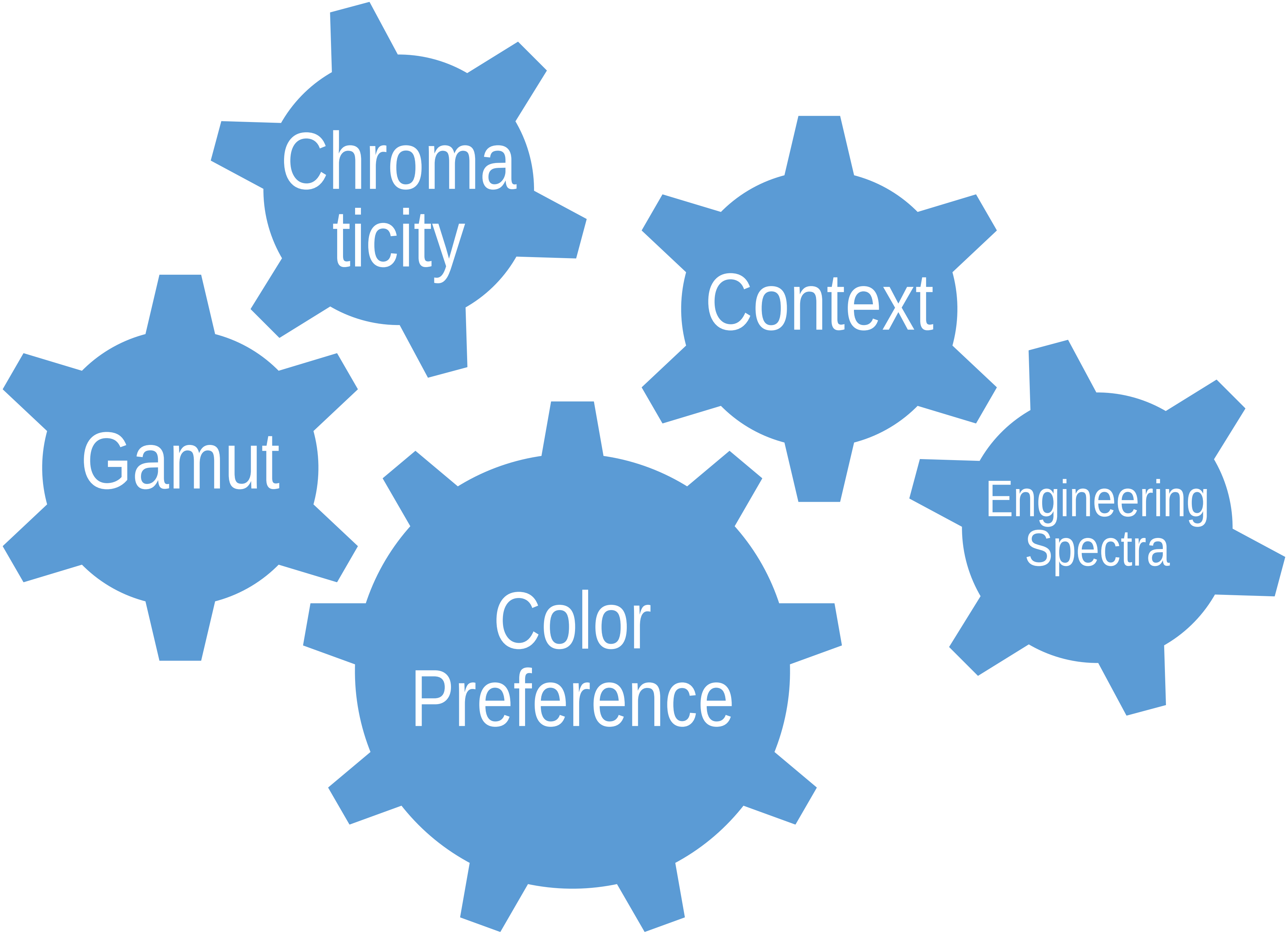
The more than 25 indices of color rendering that appear in the scientific literature tend to cluster into two categories, those based on comparison to a reference illuminant (i.e., to quantify fidelity), and those related to gamut area (i.e., to quantify increase or decrease in saturation).*

* Houser KW, Wei M, David A, Krames MR, Shen XS. Review of Measures for Light-Source Color Rendition and Considerations for a Two-Measure System for Characterizing Color Rendition. Optics Express. 2013; 21(8);10393-10411. http://dx.doi.org/10.1364/OE.21.010393

Color preference is sometimes the most important color-rendition consideration. Other times it’s not.

A typical application is for what Judd[9] calls “appreciative viewing,” in which not true, but preferred or remembered, colors are most appropriate.

Haft HH, Thornton WA. 1972. High performance fluorescent lamps. J Illum Eng Soc. 2(1):29-35.


Chroma
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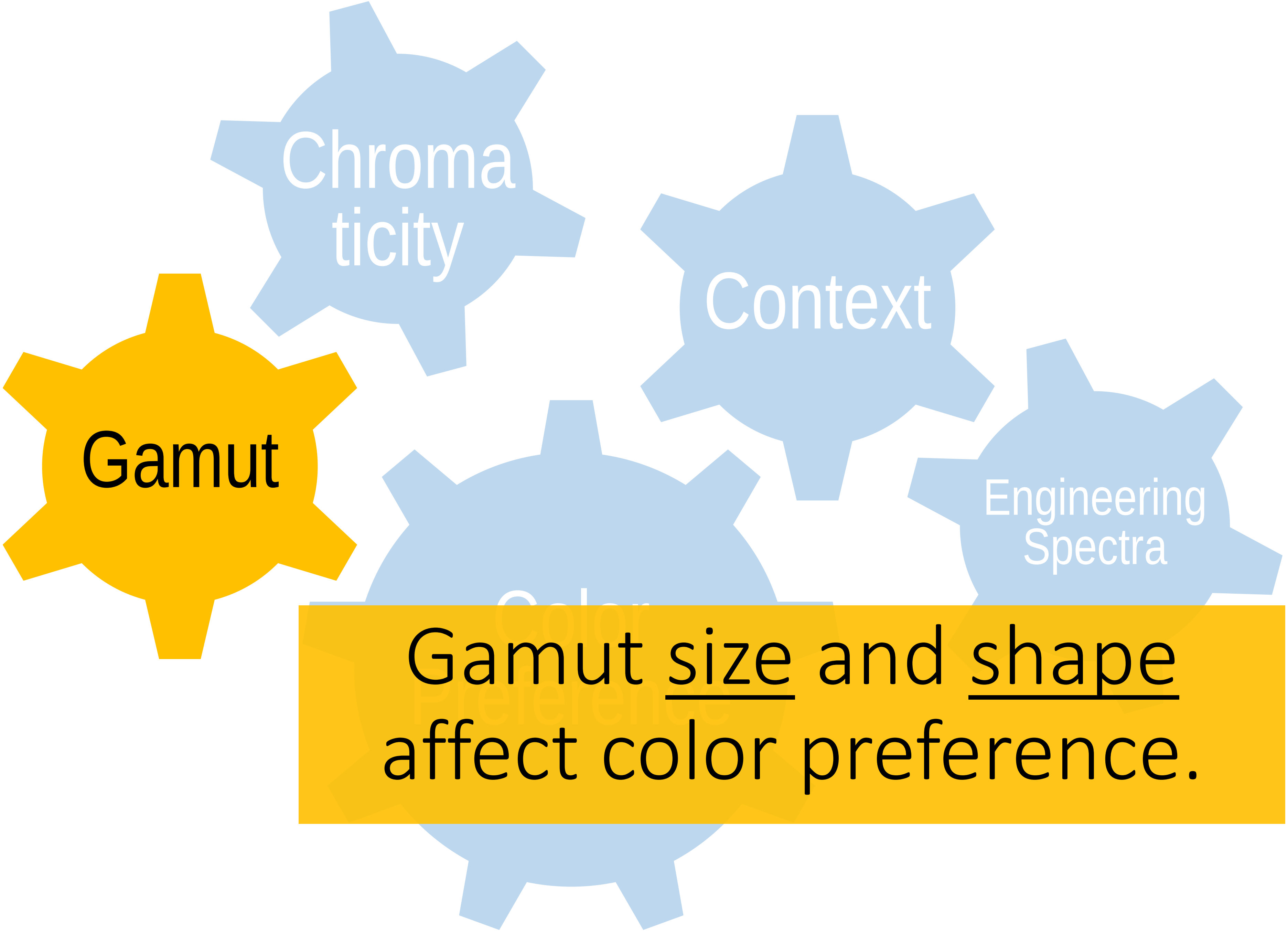
Color
Preference



Gamut size and shape affect color preference.

Figure 1. Booth illuminated by both cool white and W-13 for color preference survey.

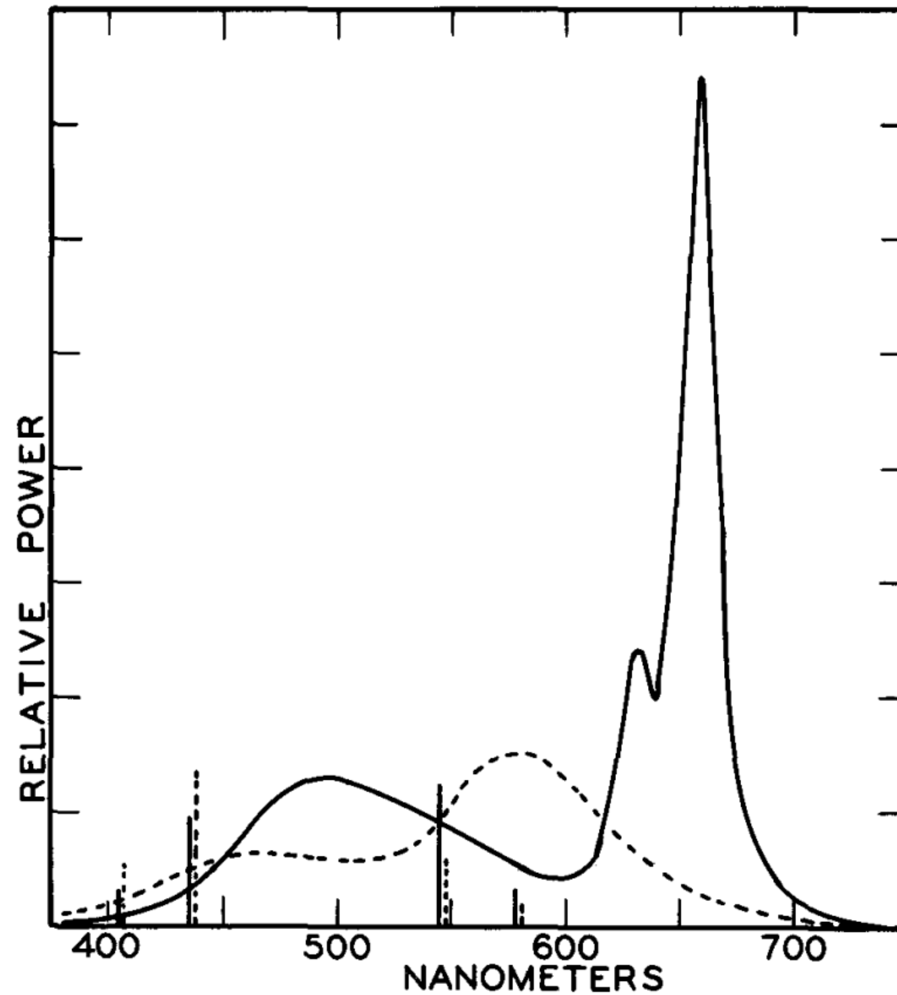


Figure 2. Spectral power distributions. Solid line—W-13. Dashed line—cool white. (Mercury lines shown separately.)

Jerome CW. 1972. Flattery vs color rendition. J Illum Eng Soc. 1(3):208-211.

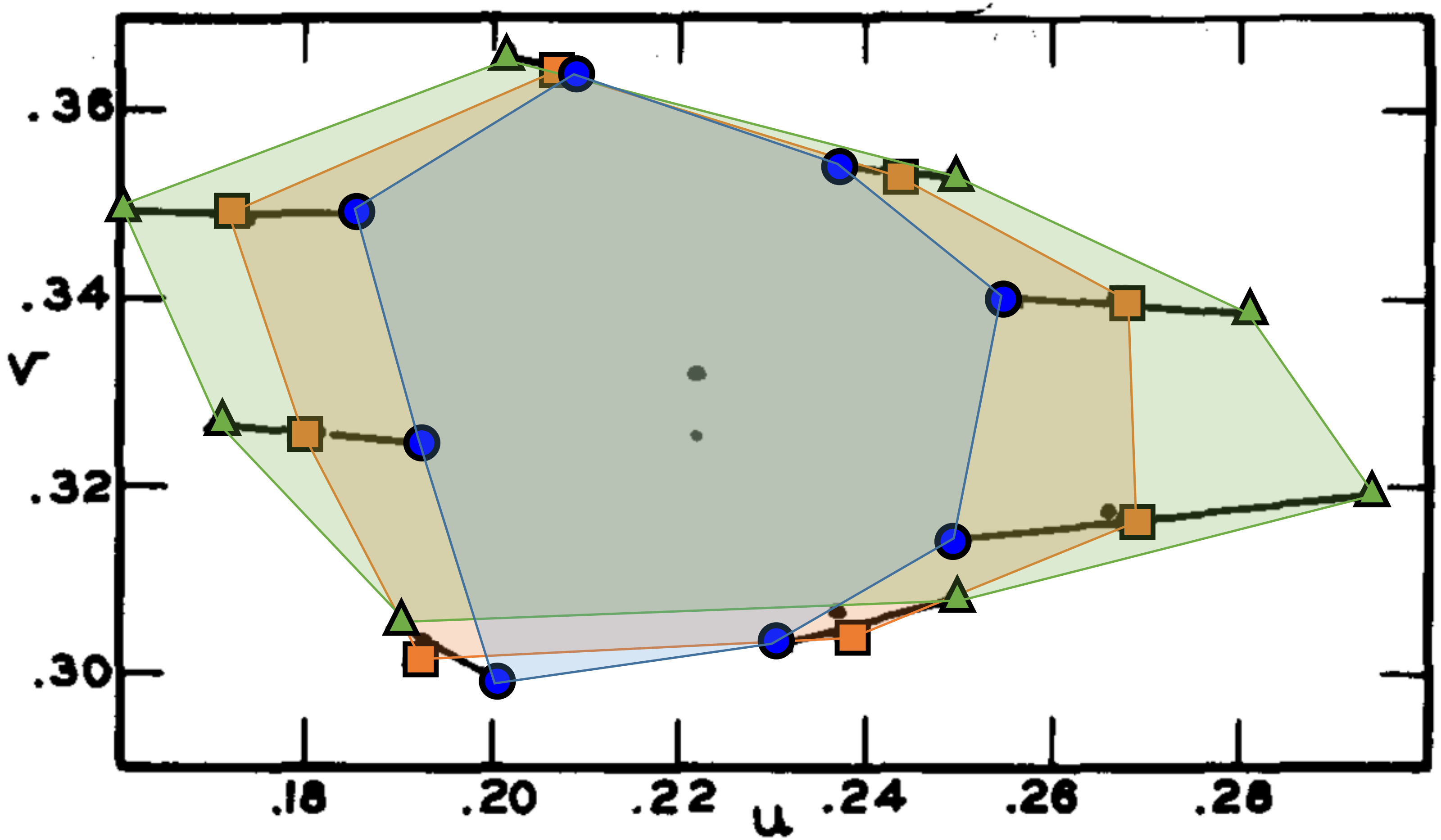


Figure 3. Eight test colors on uv diagram (dot). Illuminated by P4200; ● = illuminated by cool white; ▲ = illuminated by W-13; ■ = preferred (by Judd).

Jerome CW. 1972. Flattery vs color rendition. J Illum Eng Soc. 1(3):208-211.

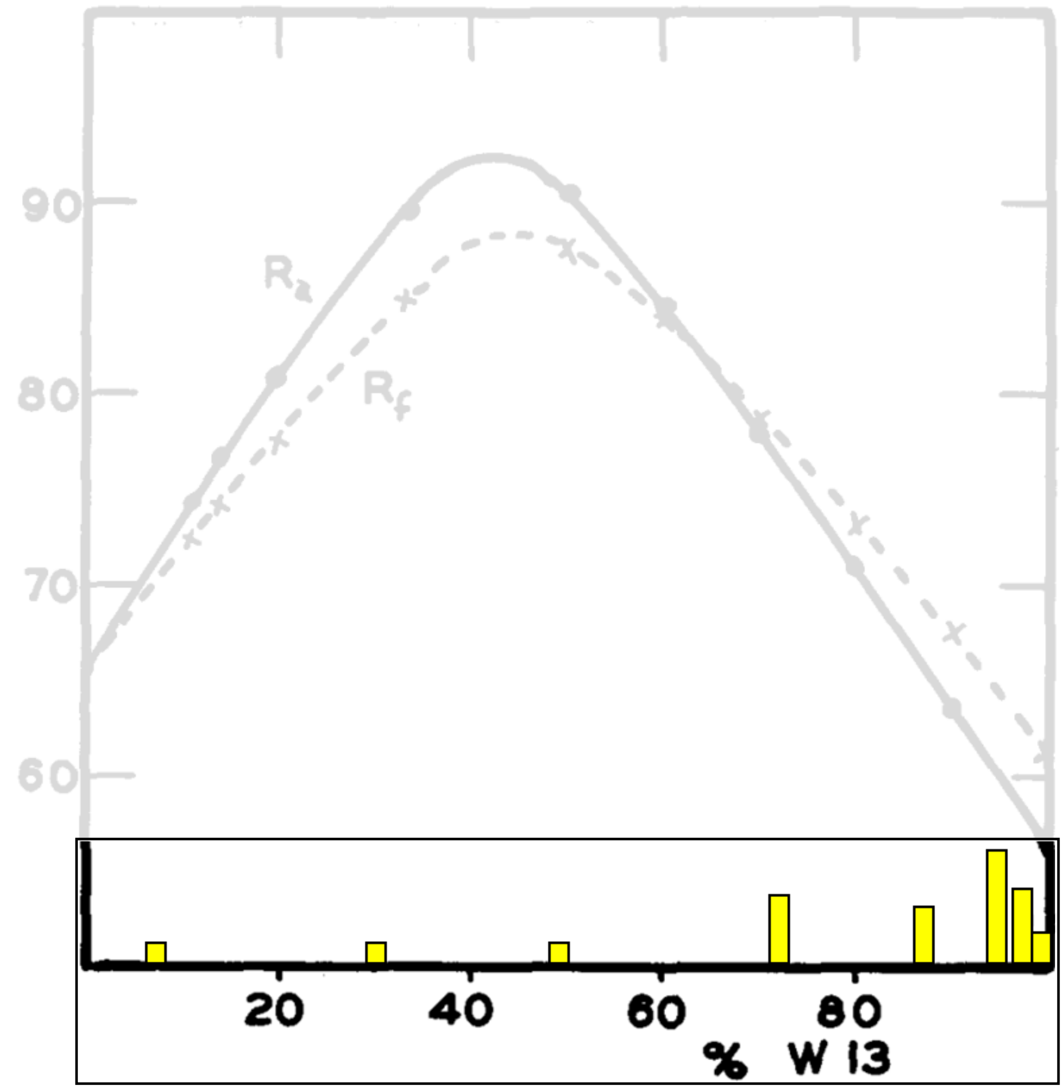
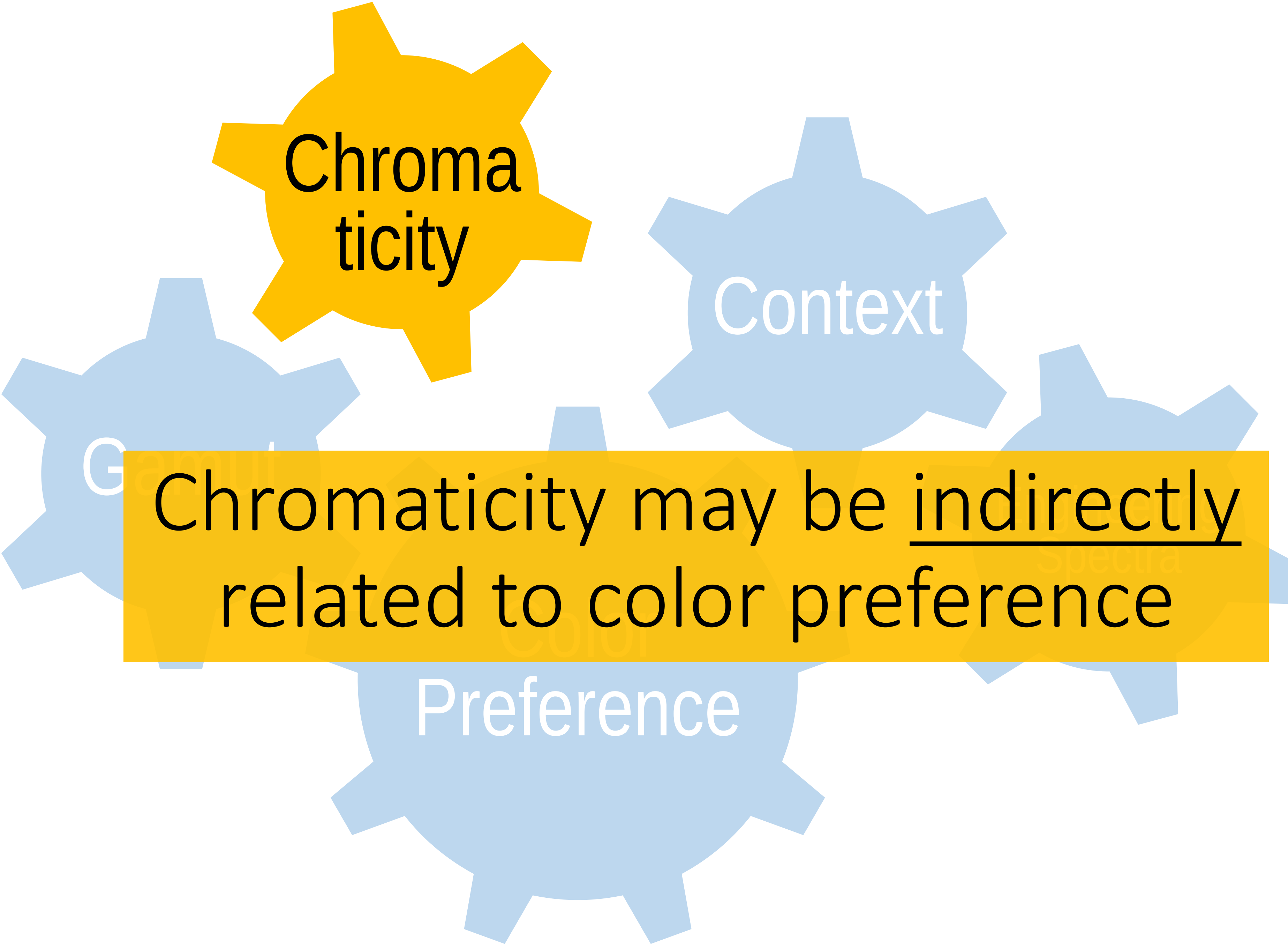


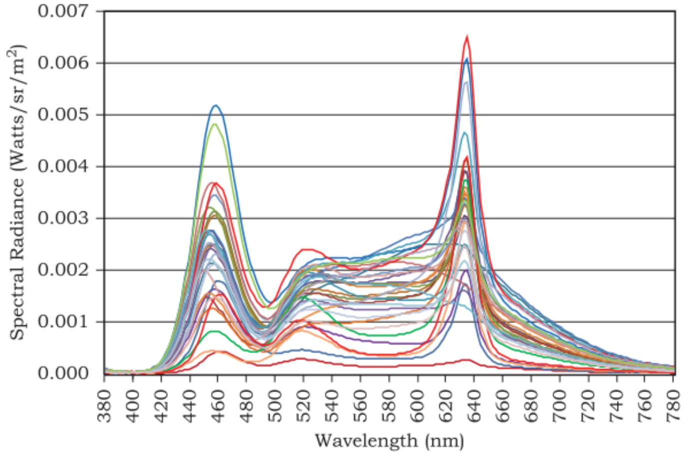
Figure 4. Color rendering index, R_a and flattery index, R_f, as a function of per cent W-13 in combination with cool white. Bars along lower edge indicate number of people preferring that percentage.

Jerome CW. 1972. Flattery vs color rendition. J Illum Eng Soc. 1(3):208-211.

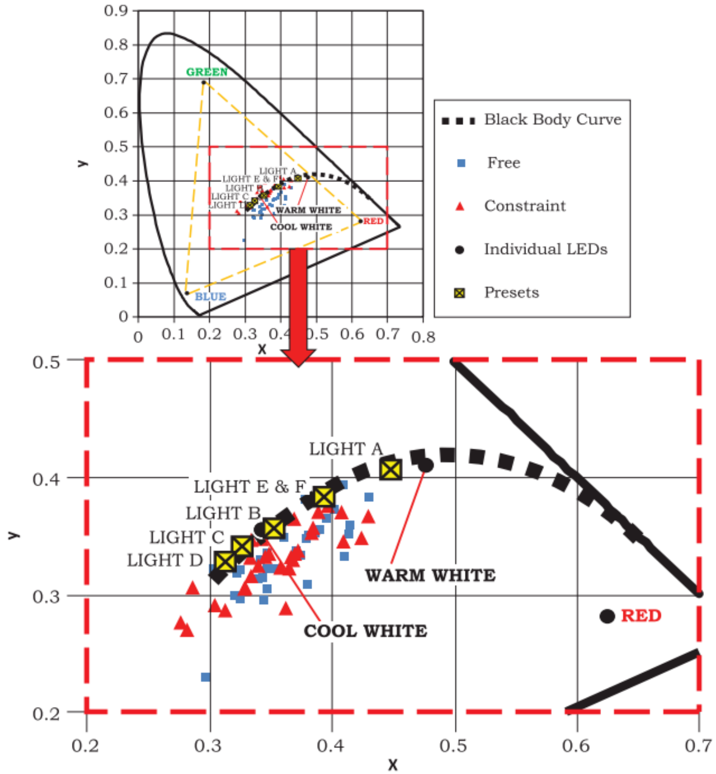


Chromaticity may be <u>indirectly</u> related to color preference

Dikel and others



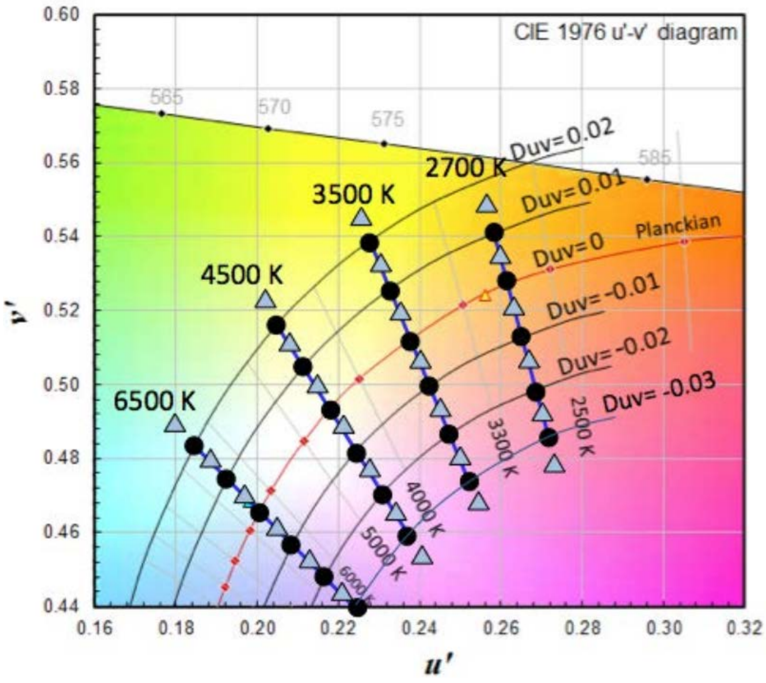
Examples of SPDs (5-channel) adjusted by participants



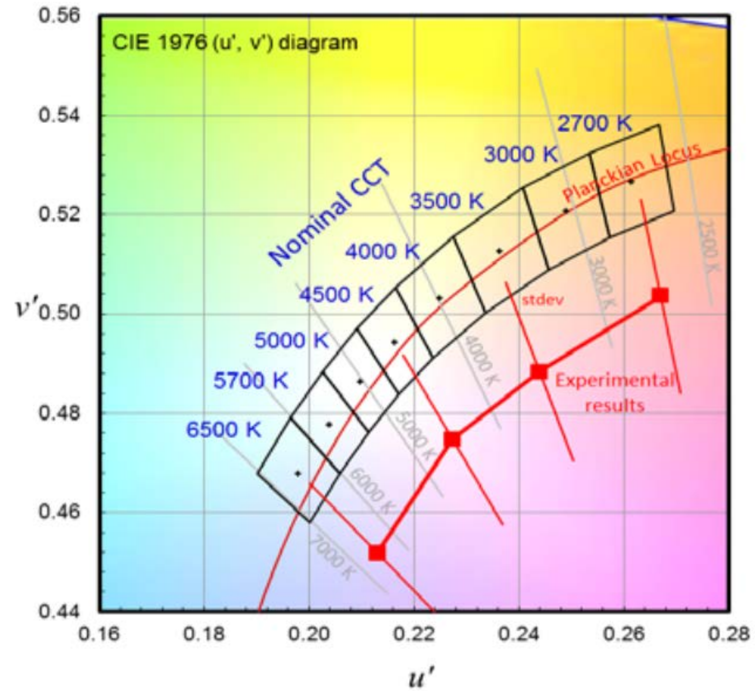
Summary of "preferred" chromaticity

Dikel EE, Burns GJ, Veitch JA, Mancini S, Newsham GR. 2014. Preferred chromaticity of color-tunable LED lighting. *LEUKOS*. 10(2): 101-115.

Ohno and Fein



Chromaticity of conditions seen by participants



Summary of “preferred” chromaticity

Ohno Y, Fein M. 2014. Vision experiment on acceptable and preferred white light chromaticity for lighting. Proceedings of CIE 2014 “Lighting Quality and Energy Efficiency. 2014 Apr 23-26. Kuala Lumpur, Malaysia.

Wei & Houser Analyses (of Dikel and others and Ohno and Fein)

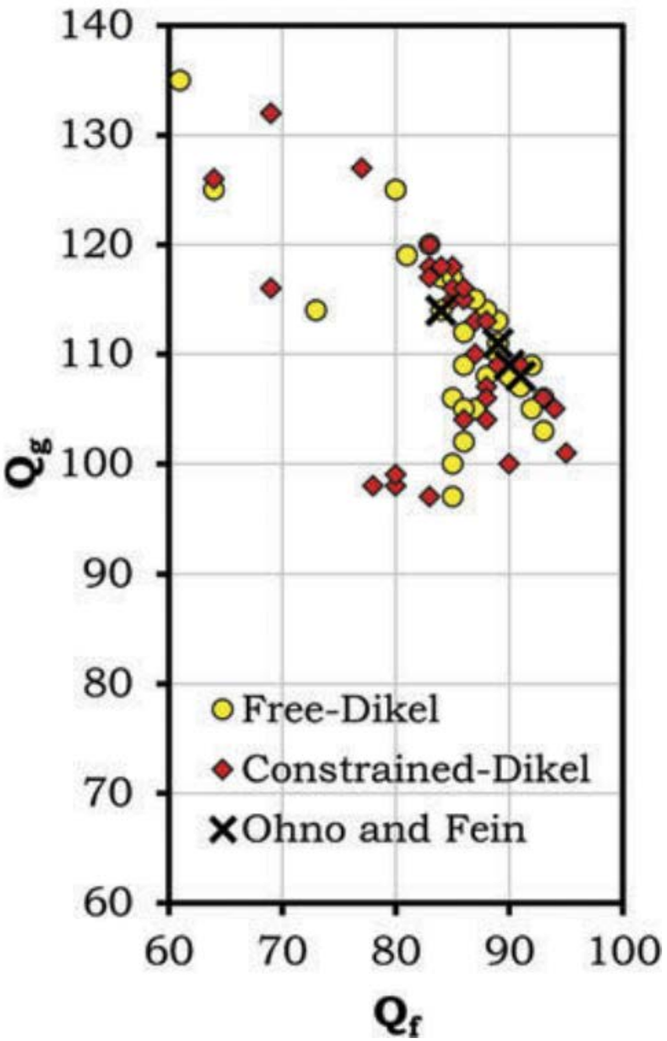
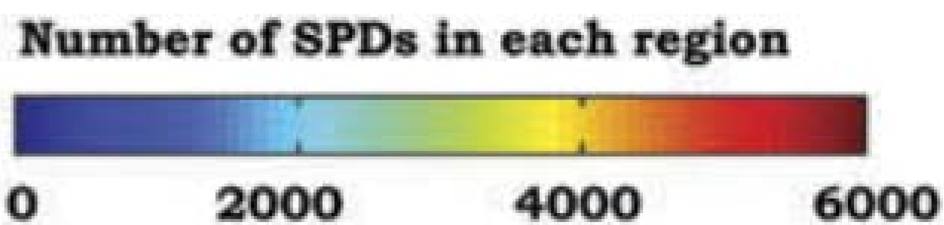
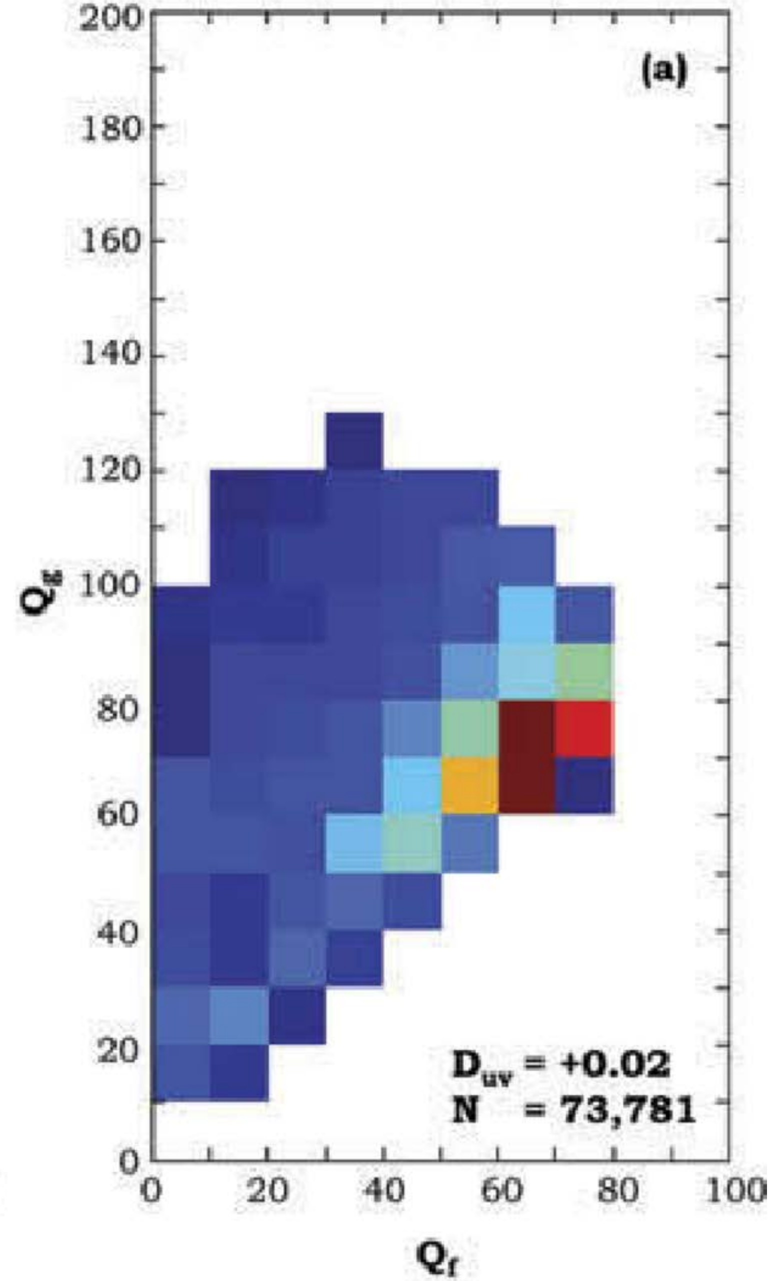


Fig. 3 Scatter plot of Q_f versus Q_g for the SPDs adjusted by the participants in Dikel and others [2014] (there were two sessions included: free adjustment and adjustment constrained by illuminance) and the preferred SPDs selected by the participants in Ohno and Fein [2014].

Wei M, Houser KW. 2015. What is the Cause of Apparent Preference for Sources with Chromaticity below the Blackbody Locus? LEUKOS. 12(1,2):95-99.

D_{uv} = +0.02





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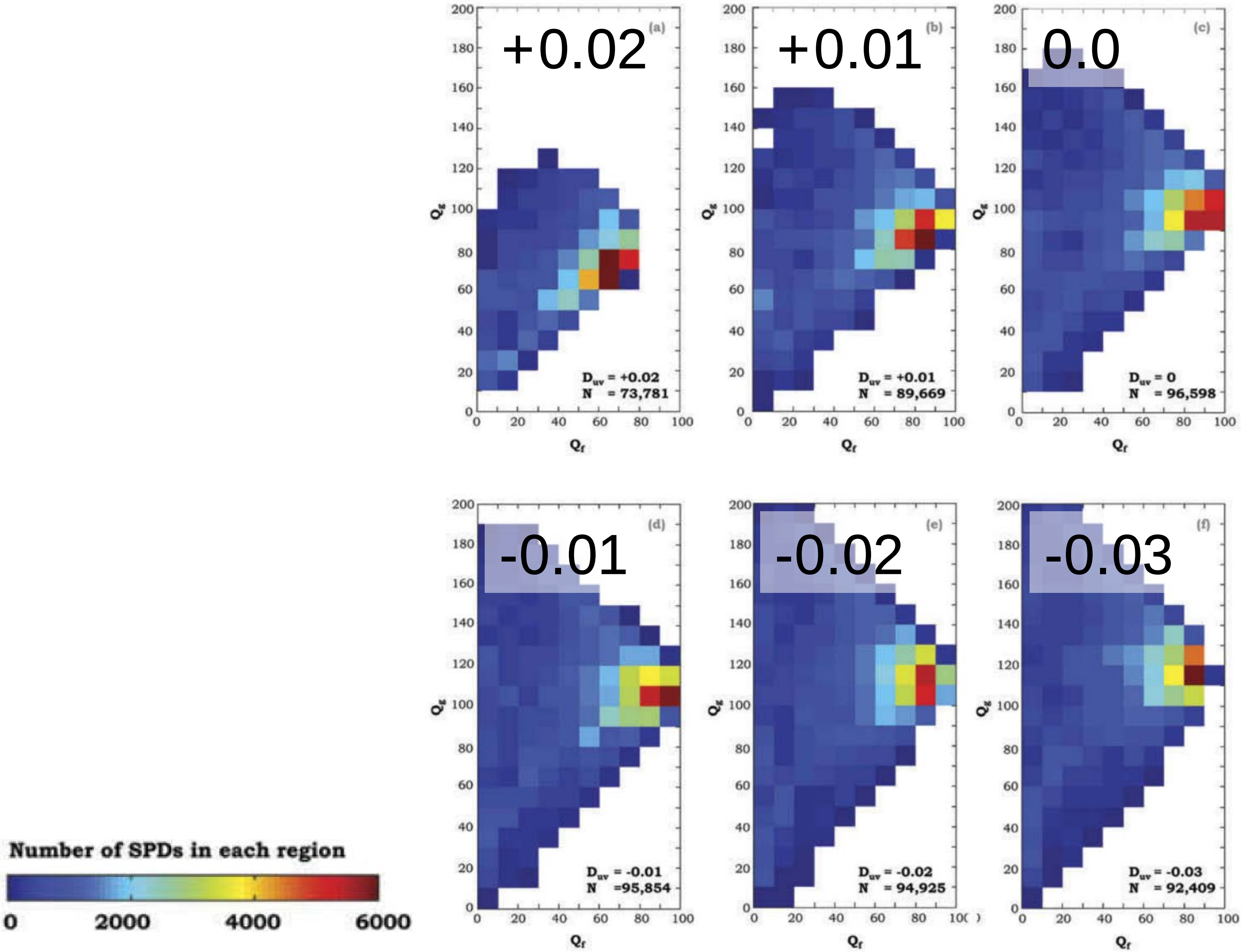

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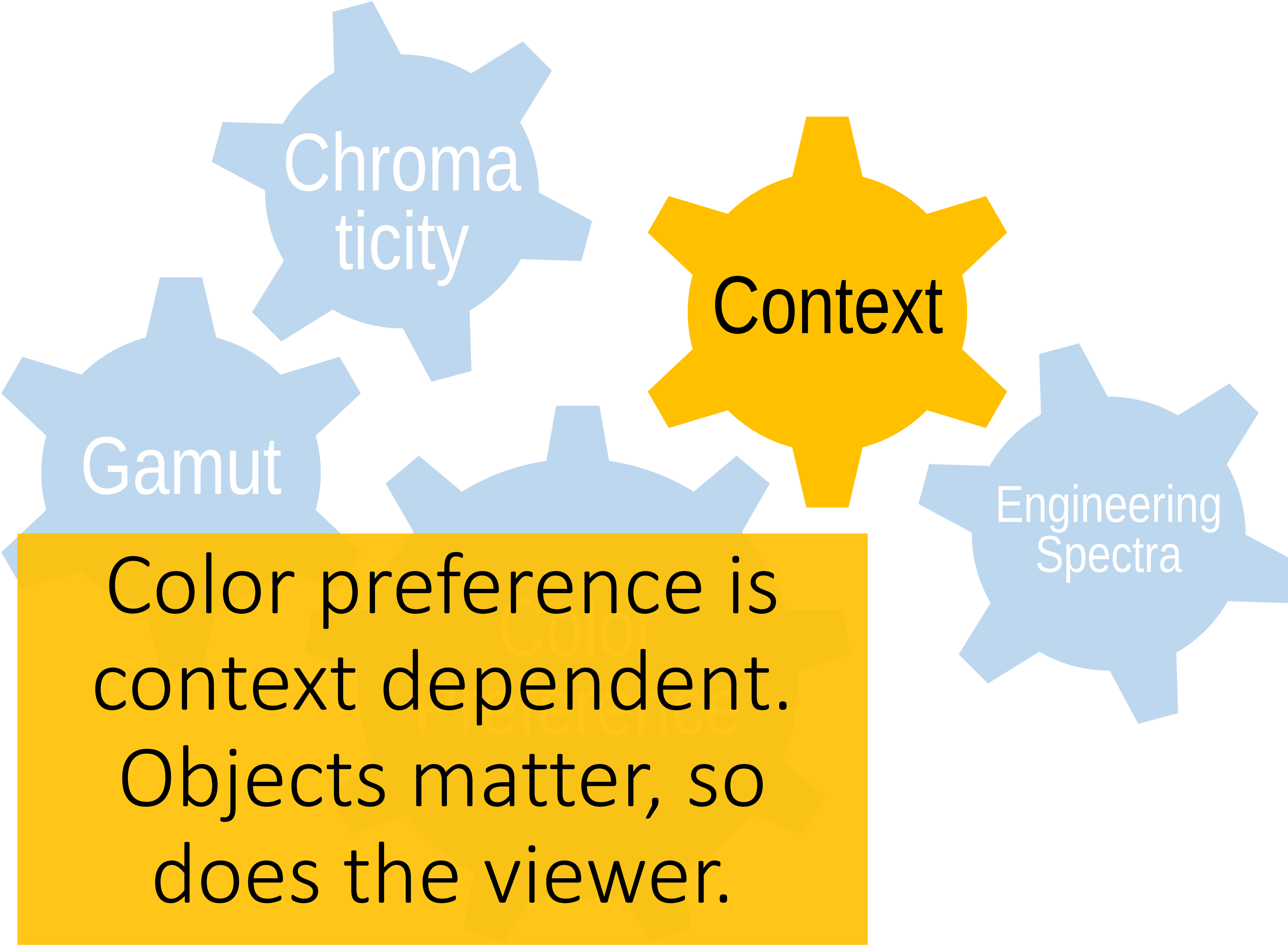


Color preference is context dependent. Objects matter, so does the viewer.

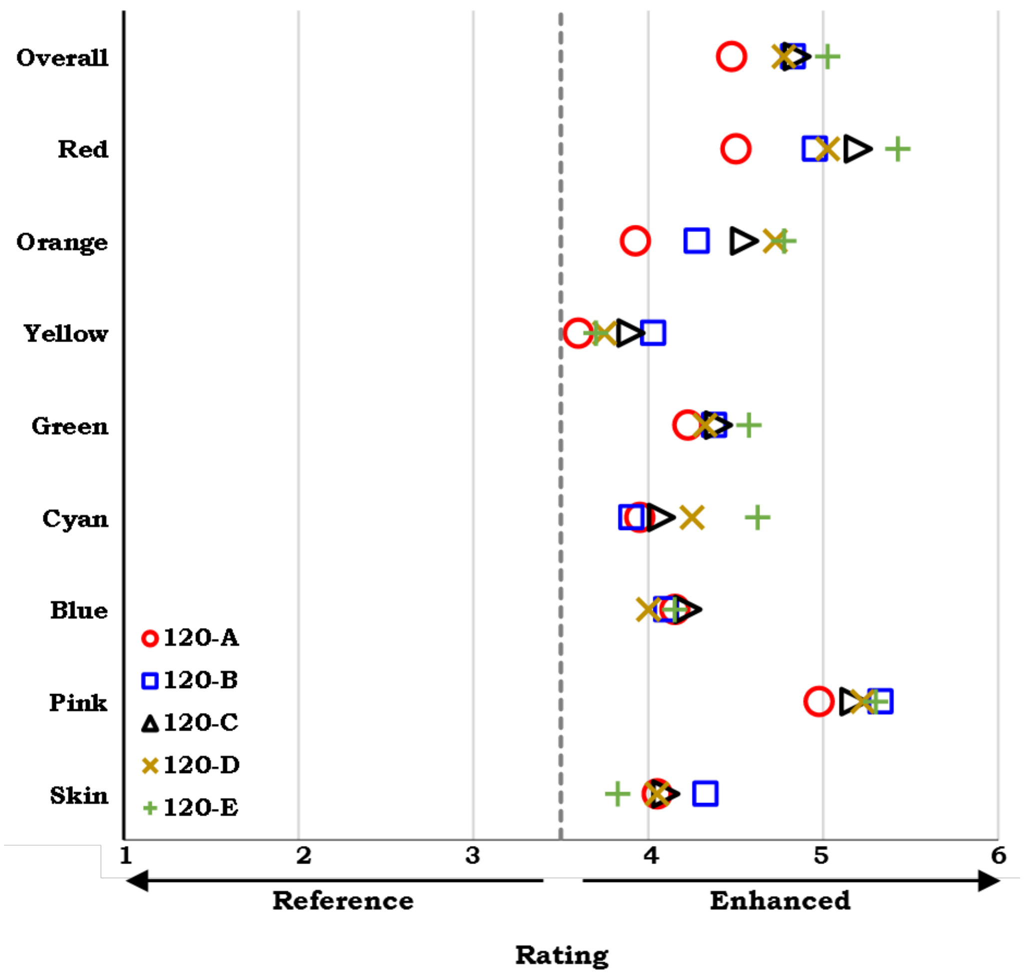
Side-by-side viewing booths employed in the retail setting.

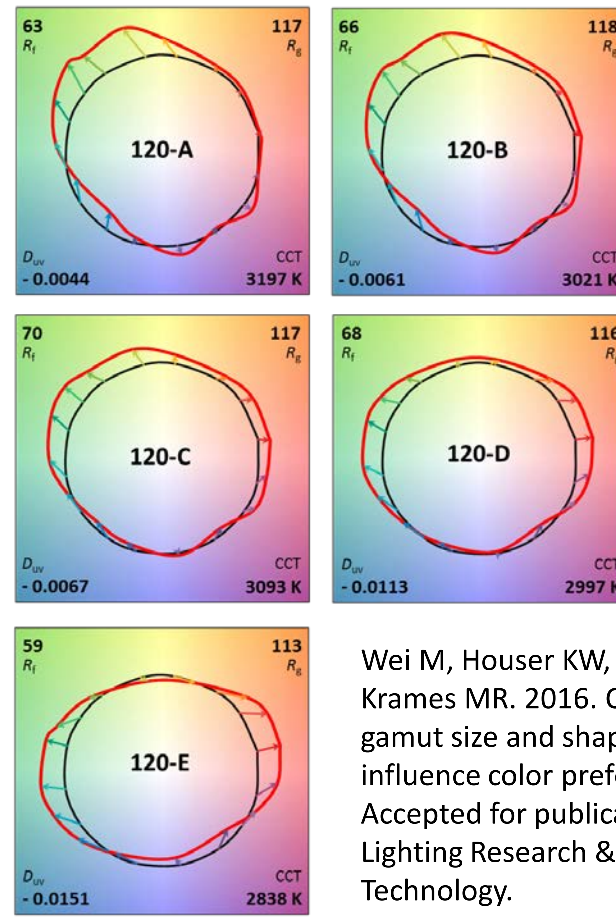
Single viewing booth employed in the restaurant setting. Note mirror that was used for skin-tone evaluation.

Wei M, Houser KW, David A, Krames MR. 2016. Color gamut size and shape influence color preference. Accepted for publication in Lighting Research & Technology.

Fabrics

Participants have no memory, expectations, or context for judging how these objects should look.

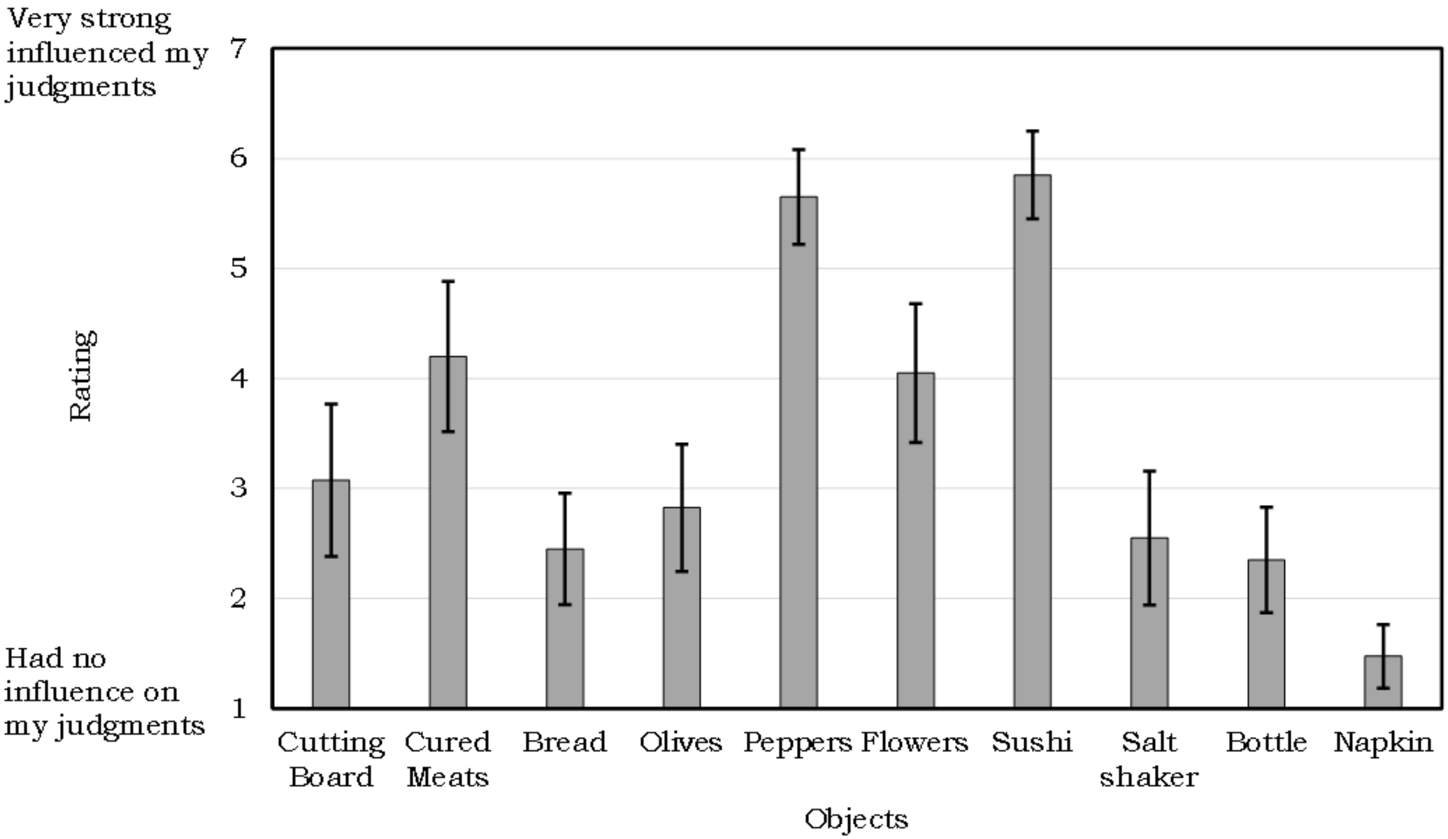




Wei M, Houser KW, David A, Krames MR. 2016. Color gamut size and shape influence color preference. Accepted for publication in Lighting Research & Technology.

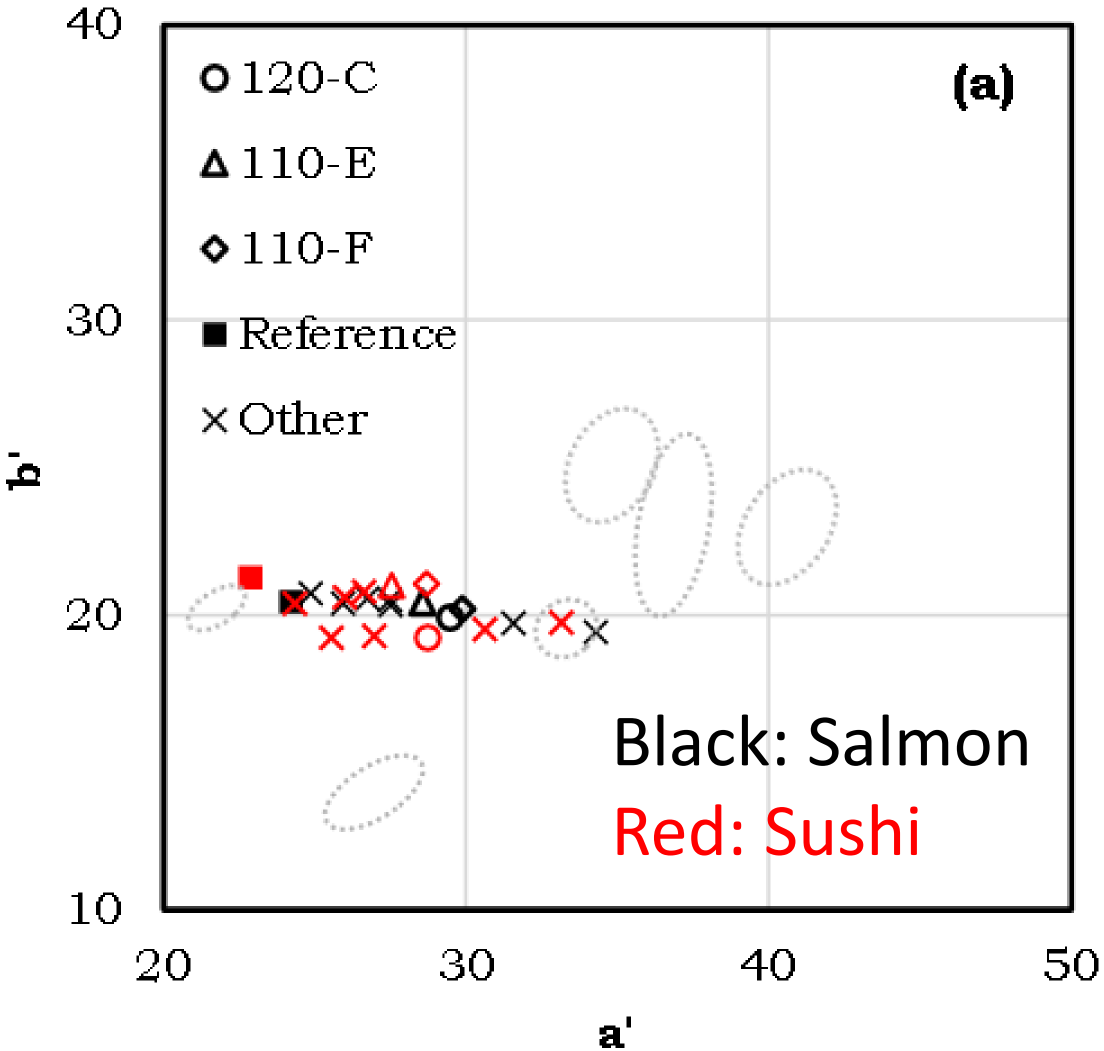
Real Foods/Flowers

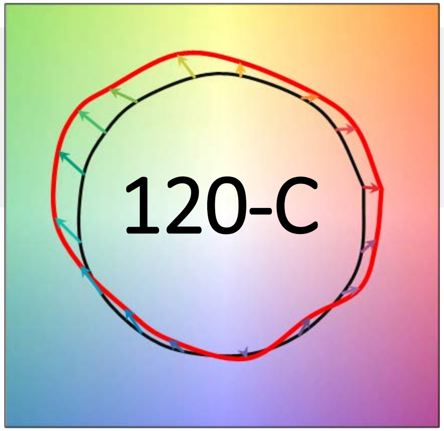
Participants likely have memories and expectations about how these objects should look.

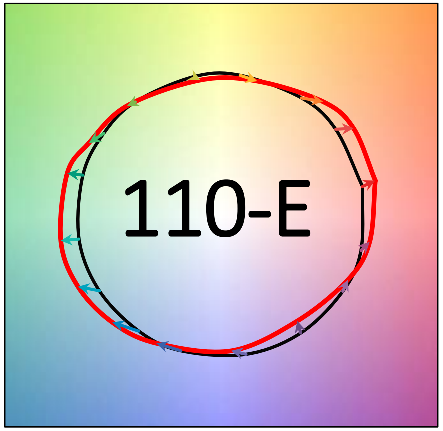


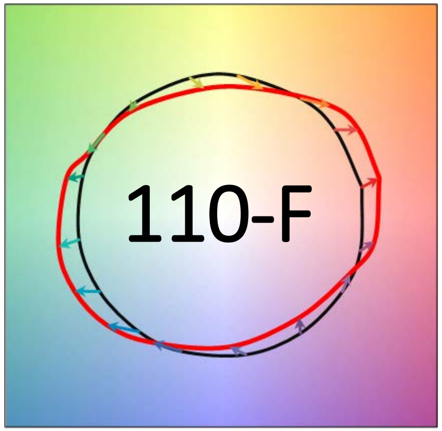
Wei M, Houser KW, David A, Krames MR. 2016. Color gamut size and shape influence color preference. Accepted for publication in Lighting Research & Technology.

Example: Sushi and Salmon









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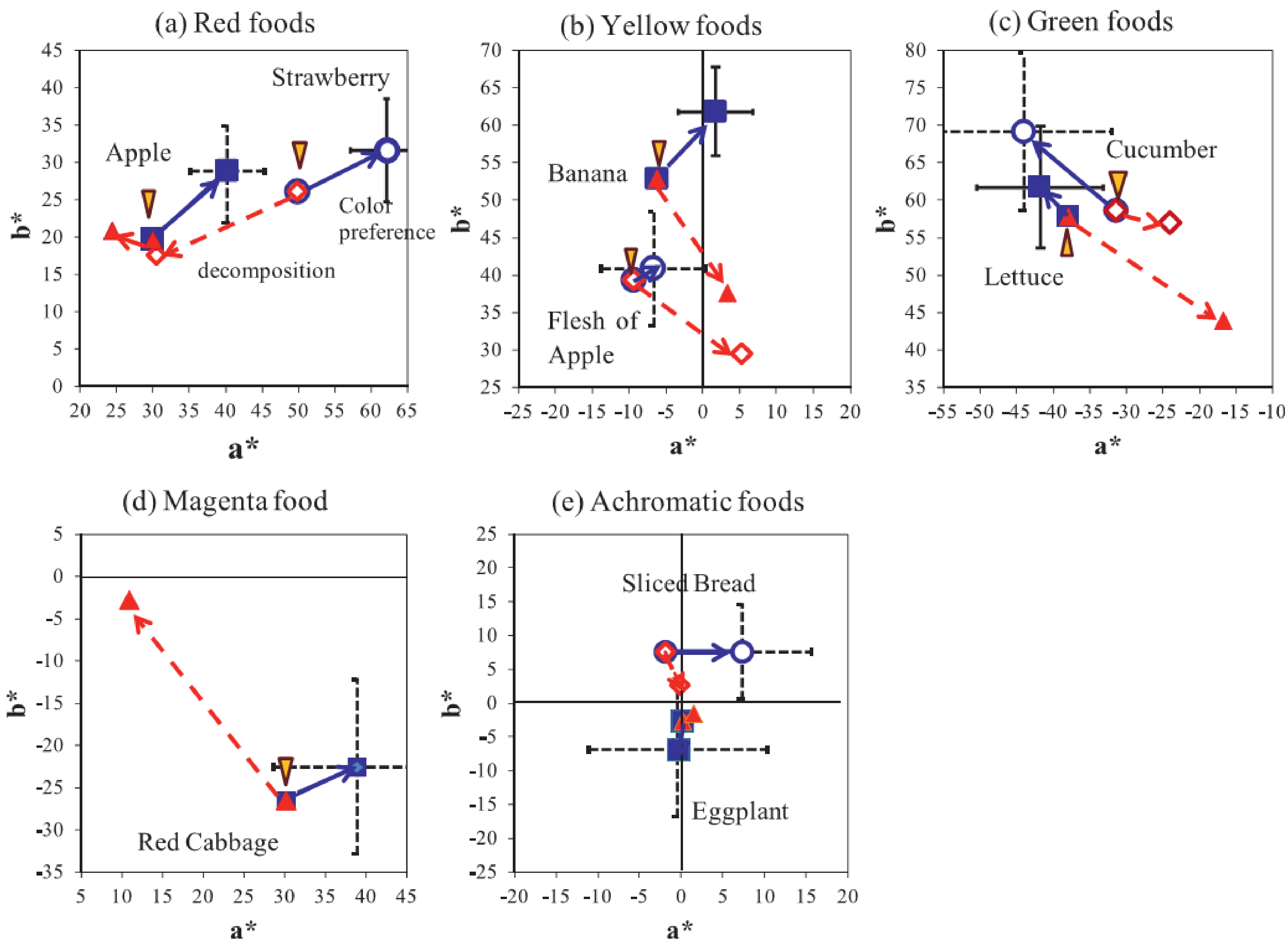
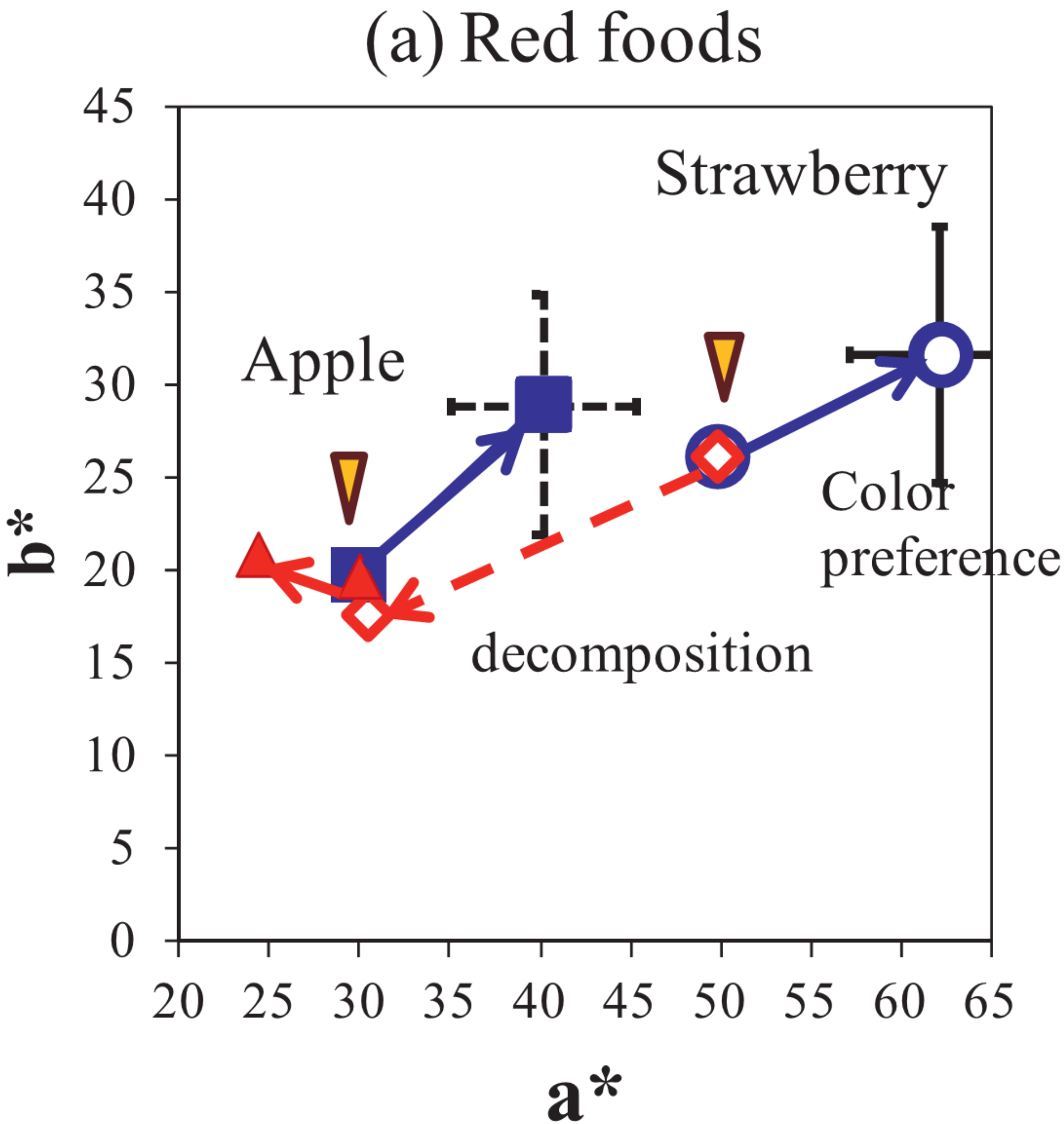


Lee SM, Lee KT, Lee SH, Song JK. 2013. Origin of human color preference for food. Journal of Food Engineering. 119:508-515.



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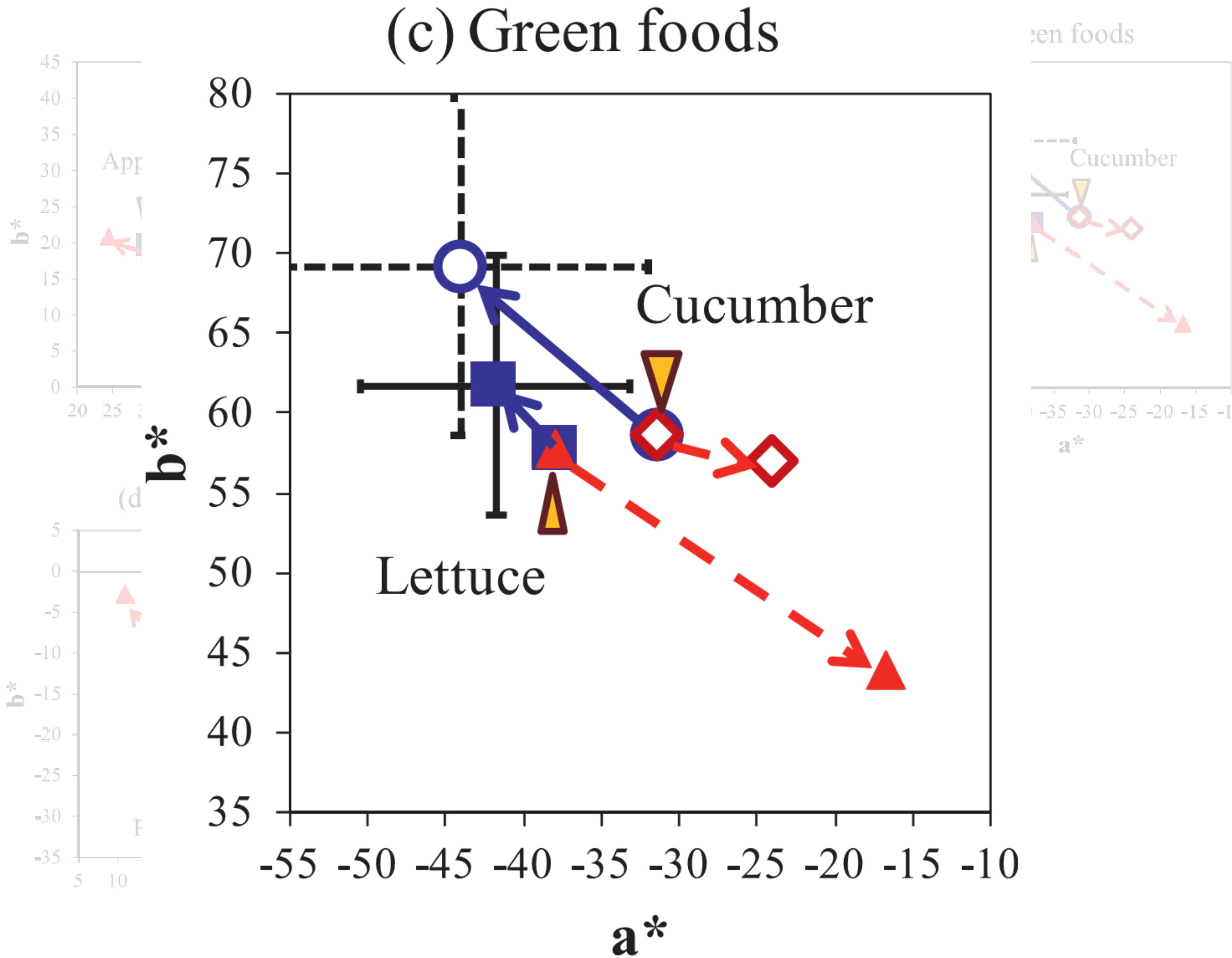

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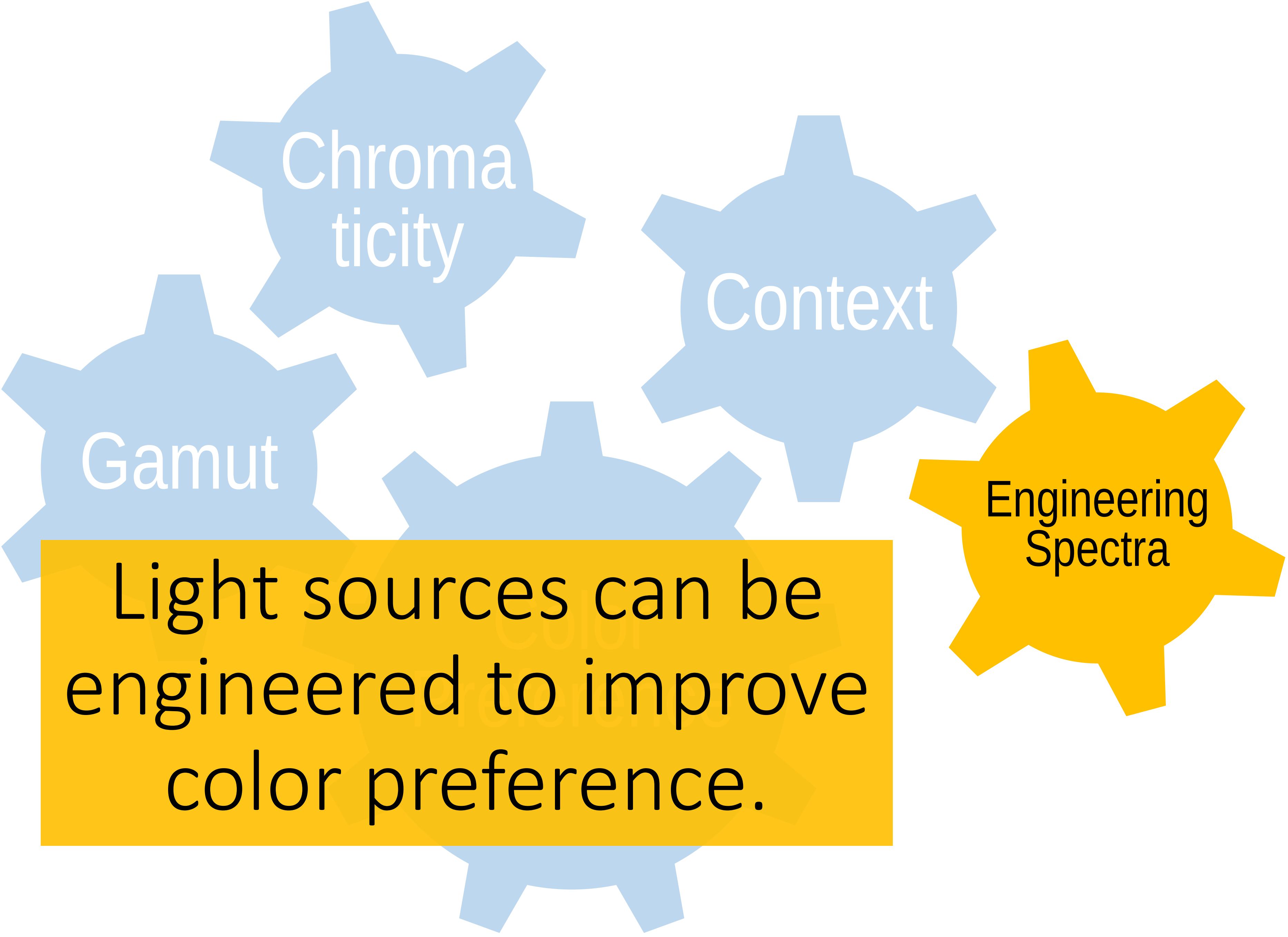
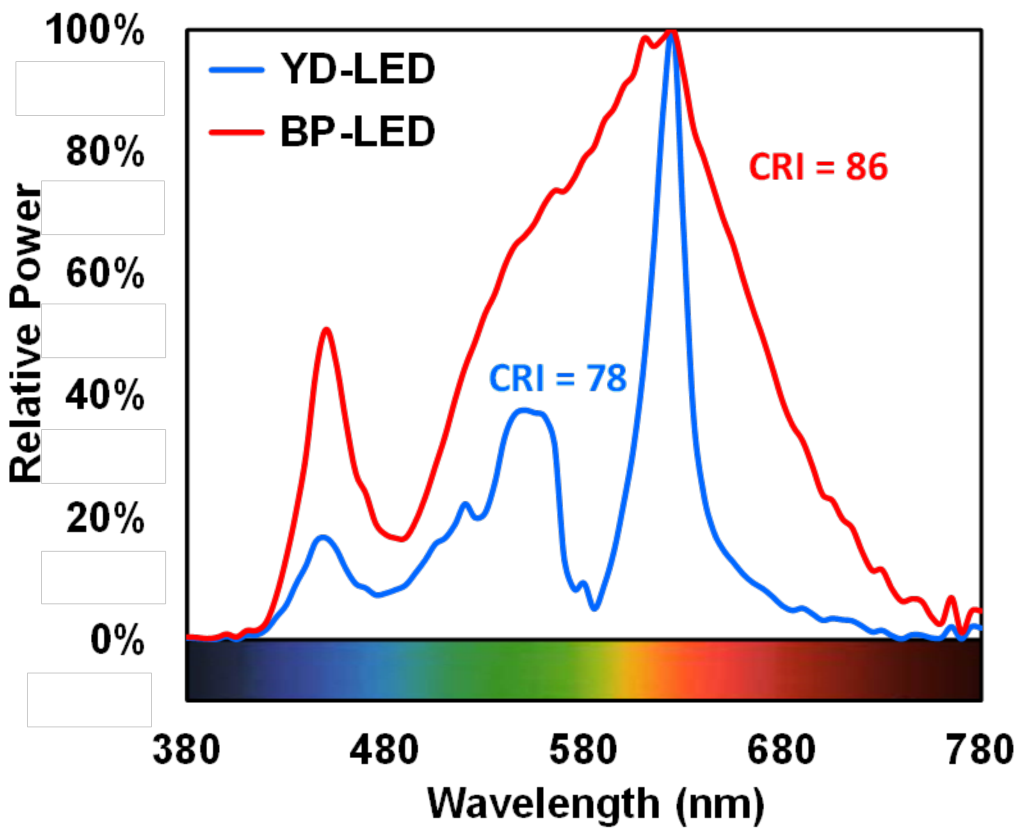
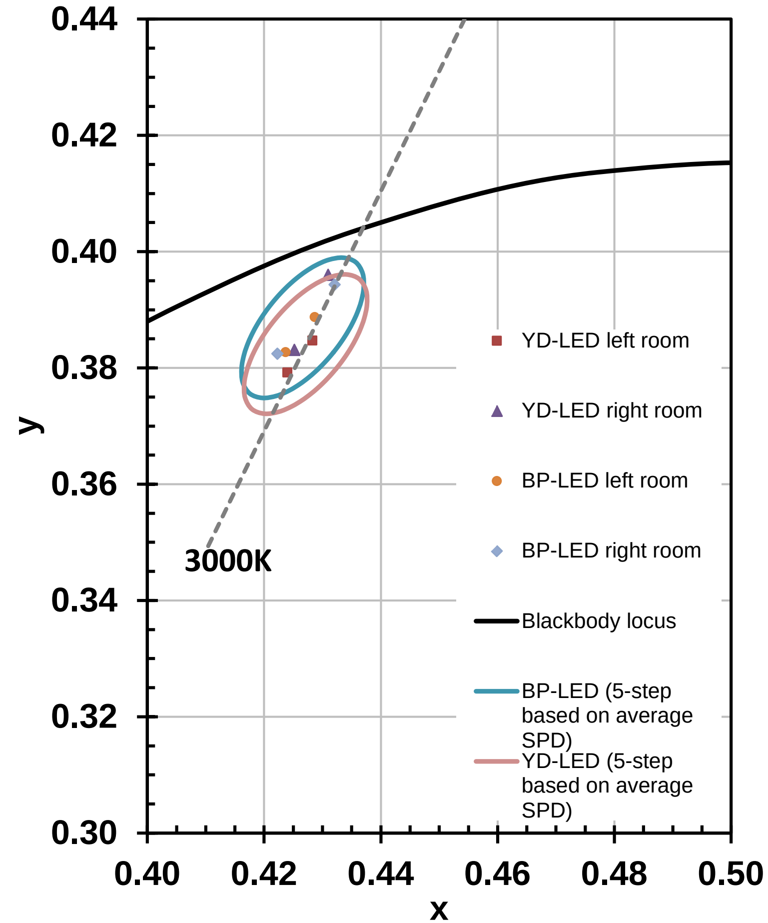


Light sources can be engineered to improve color preference.

Independent Variable

Light Source SPD





Wei M, Houser KW, Allen GR, Beers WW. 2014. Color preference under LEDs with diminished yellow emission. Leukos. 10(3):119-131.

Dependent Variable

Brightness matching was completed first.

Dependent Variable

Then, preference evaluations were made at equal brightness.

Method for evaluating PREFERENCE:

Overall preference was evaluated using a first questionnaire.

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PREFERENCE

Project Title:
Effect of Spectral Modification on Preference

Please answer all the questions below based on your observations and preference. You are free to walk back and forth between the rooms to observe the objects/rooms to make your judgments.

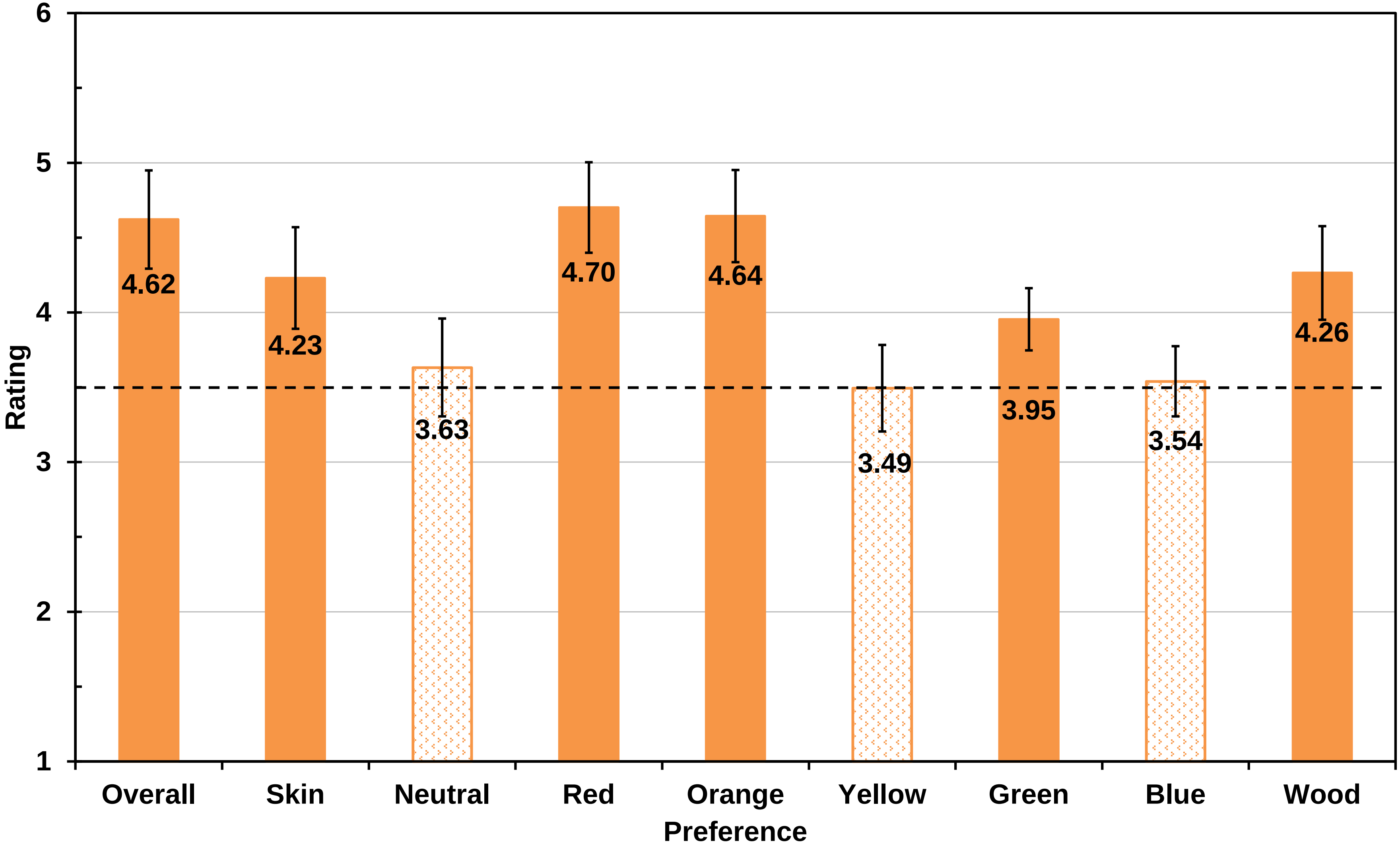
1. Overall Preference:

	Strongly Prefer	Moderately Prefer	Slightly Prefer	Slightly Prefer	Moderately Prefer	Strongly Prefer	
Left	_______	_______	_______	_______	_______	_______	Right

Reason:

Key Results

YD-LED was preferred.



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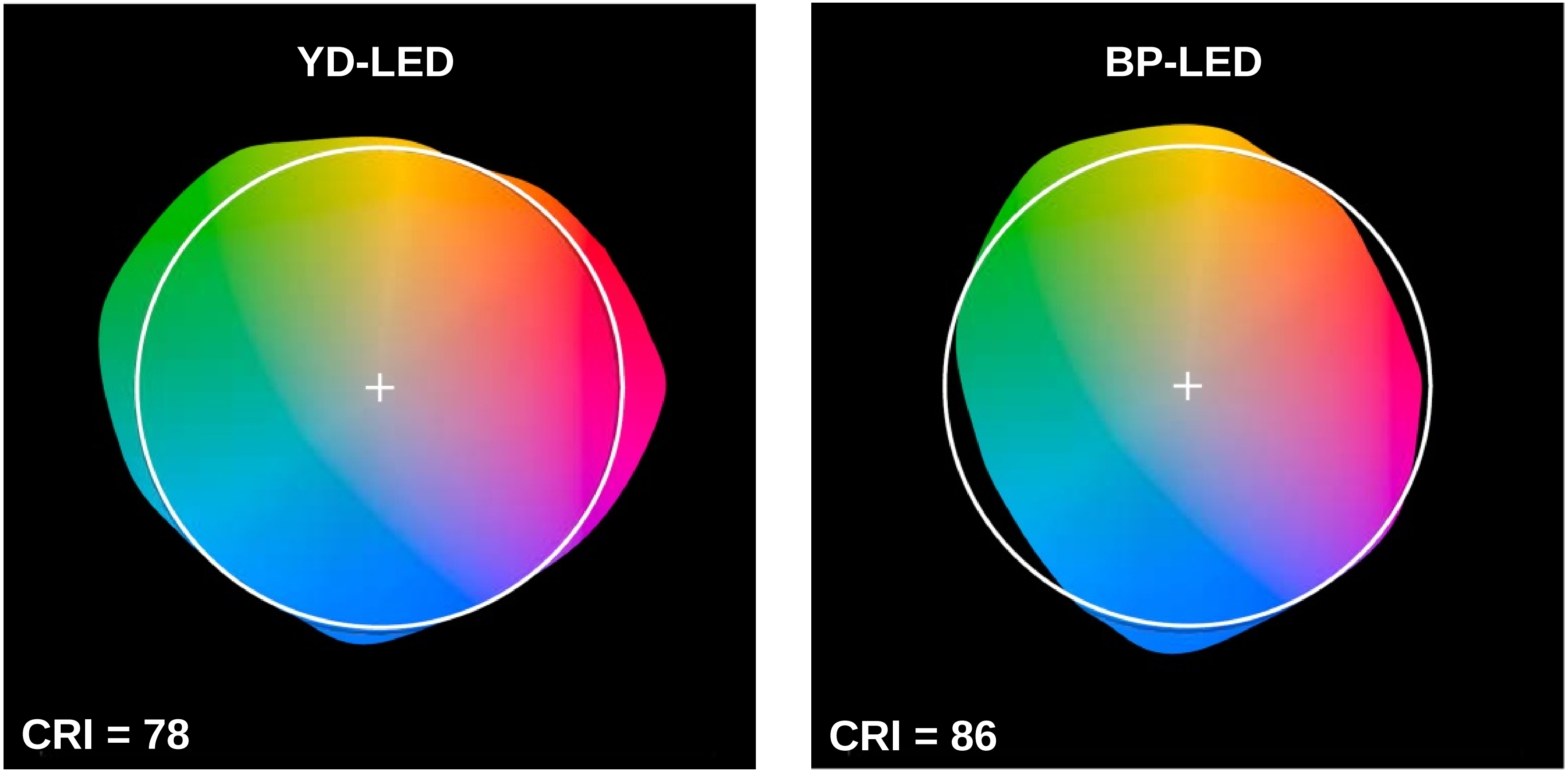
Why does this work?

YD-LED tends to increase red-green saturation with a larger gamut area.



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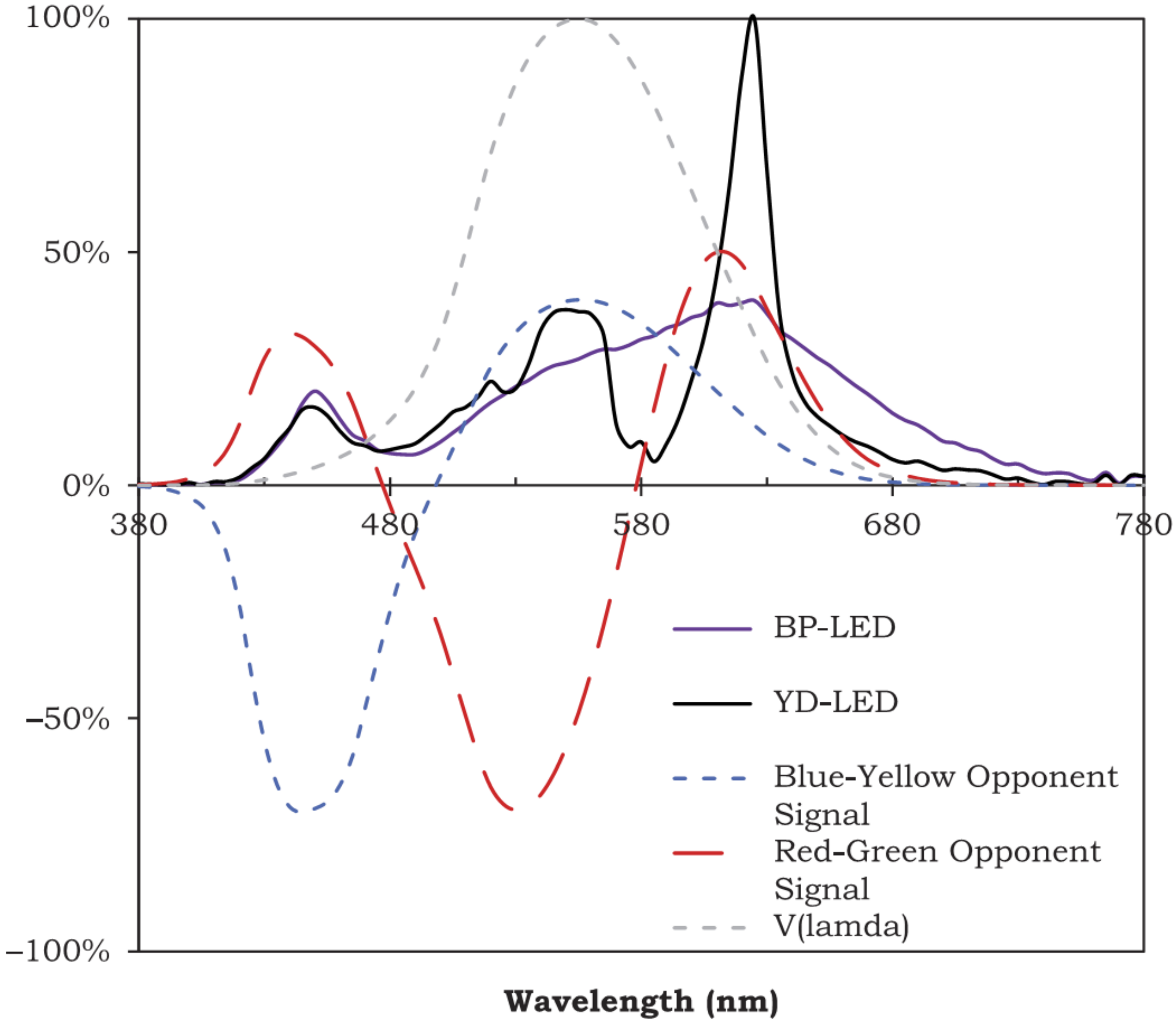
Why does this work?

More fundamental than CVG, analyze opponent signals.



YD-LED to BP LED opponent channel signals at equal brightness:

R/G = 1.22

B/Y = 1.01

Wei M, Houser KW, Allen GR, Beers WW. 2014. Color preference under LEDs with diminished yellow emission. Leukos. 10(3):119-131.

Can preference be explained with measures from TM-30-15?

$$\text{Like} = 7.396 - 0.0408(R_f) + 103.4(R_{cs,h16}{}^3) - 9.949(R_{cs,h16})$$

Model $R^2 = 0.936$

[Royer MP, Wilkerson A, Wei M, Houser KW, Davis RG. Human judgements of color rendition vary with average fidelity, average gamut, and gamut shape. Accepted for publication in Lighting Research and Technology.]

[Refer also to Mike Royer's slides from March 31, 2016 ENERGY STAR Lighting Webinar Series.]

$$\text{Like} = 2.537 + 0.01615(R_f) + 4.403(R_{cs,h15}) - 8.91(R_{cs,h15}{}^2)$$

Model $R^2 = 0.784$

[Esposito T. Mapping color equivalency in a two metric system of color rendition [dissertation in progress]. University Park (PA): The Pennsylvania State University.]

What light source spectra are less likely to disappoint?

- Relative Gamut: Equal or greater than that of reference illuminants.
- Gamut shape: Important to get red rendition right
- Chromaticity: Below blackbody is probably not critical. Past work suggests this is a proxy for gamut.
- Objects and Context: Cannot ignore what is being illuminated.
- Fidelity Index: High score is "safe", but unnecessary and suboptimal for many situations.

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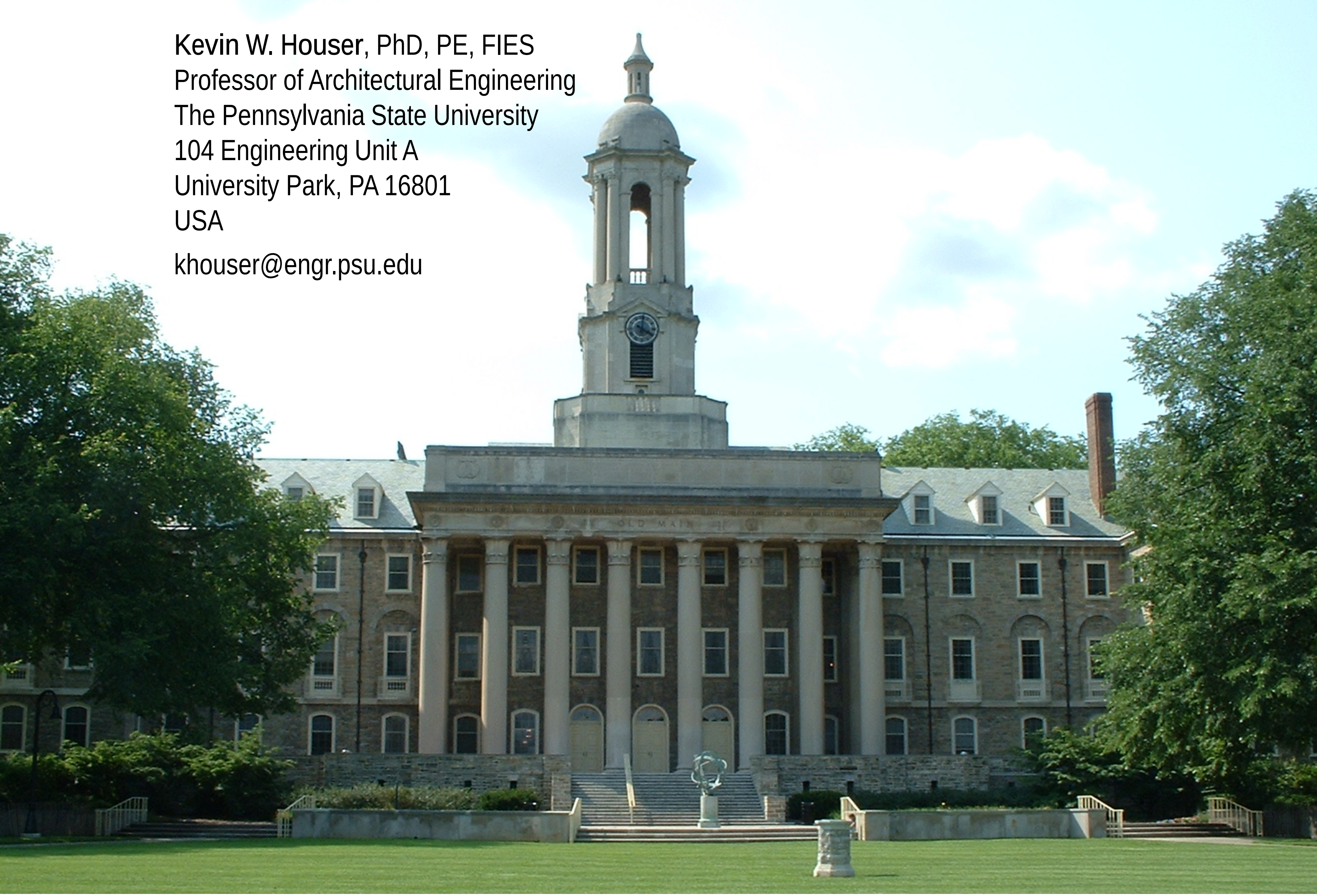

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