

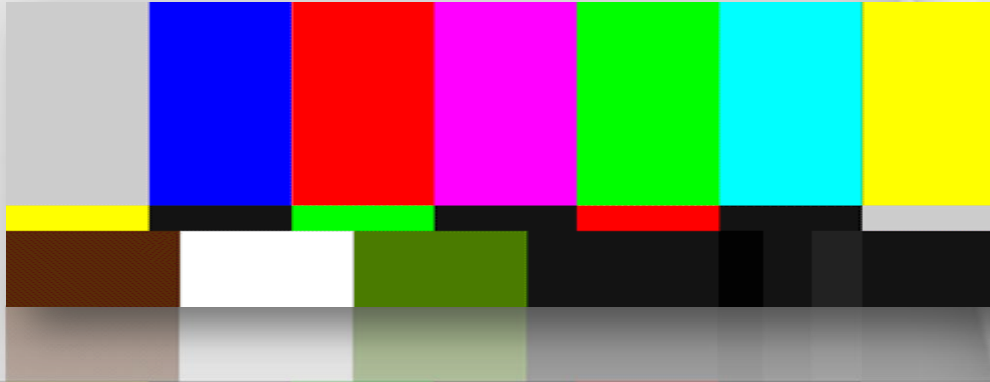
# Color Fidelity and Color Preference : Questioning reality

Lighting scientists, color specialists and the academic community have delved far into ways of quantifying the color of light. Fidelity measures the accuracy of a light source in relation to reference sources.

Visual perception occurs in the mind and similar to many topics related to vision, there is more than one version of the truth. Not only is there a range of quality, there is also a range of preference within a certain target application.

The latest updates relating to fidelity, gamut and preference will be presented along with accompanying graphics and example light sources in order to help simplify what traditionally has not been 'simple' for those tasked with specifying an LED lighting solution.





# Color Fidelity and Color Preference : Questioning reality

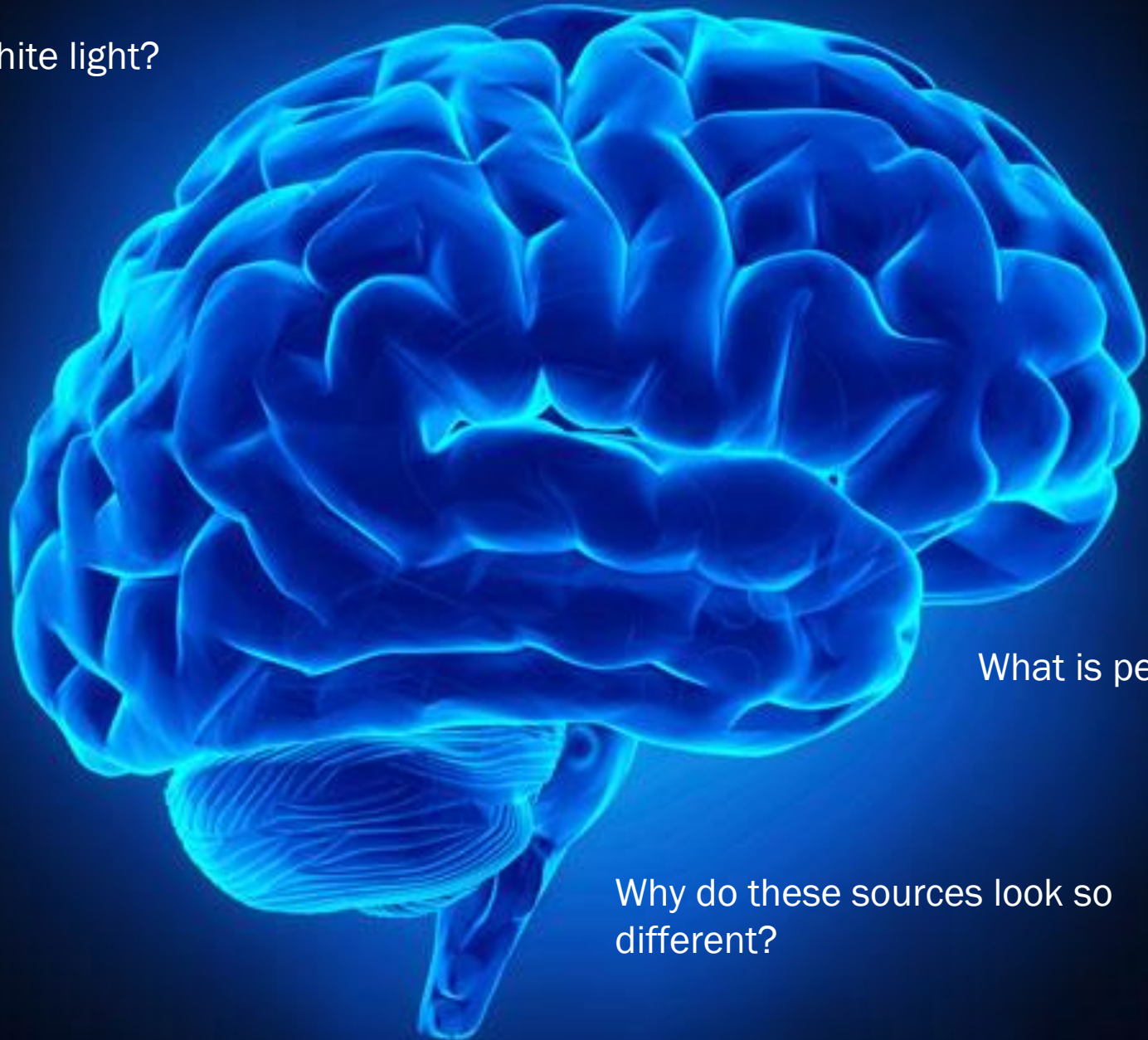
LINDSAY STEFANS, LC, IESNA, LEED AP

BUSINESS DEVELOPMENT MANAGER

XICATO

What is measured?

What is white light?



What is perceived?

Why do these sources look so different?

- Light Source Color Rendition and the Basics of Color Science that support the evaluation method(s)
- Color Preference Research Study
- Research Study that Combines Preference and Fidelity

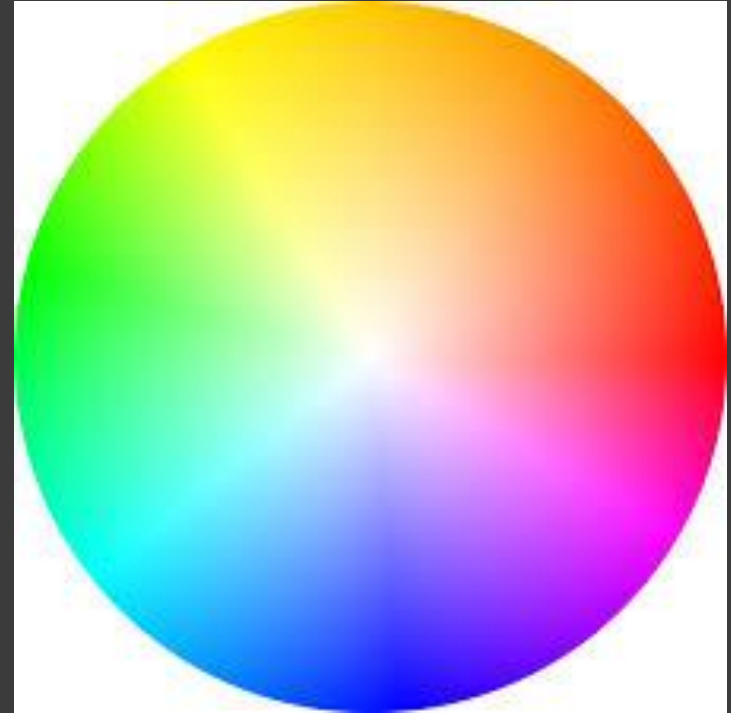
**Demonstrations of Light Sources**

What is fidelity? the degree of exactness with which something is copied or reproduced.

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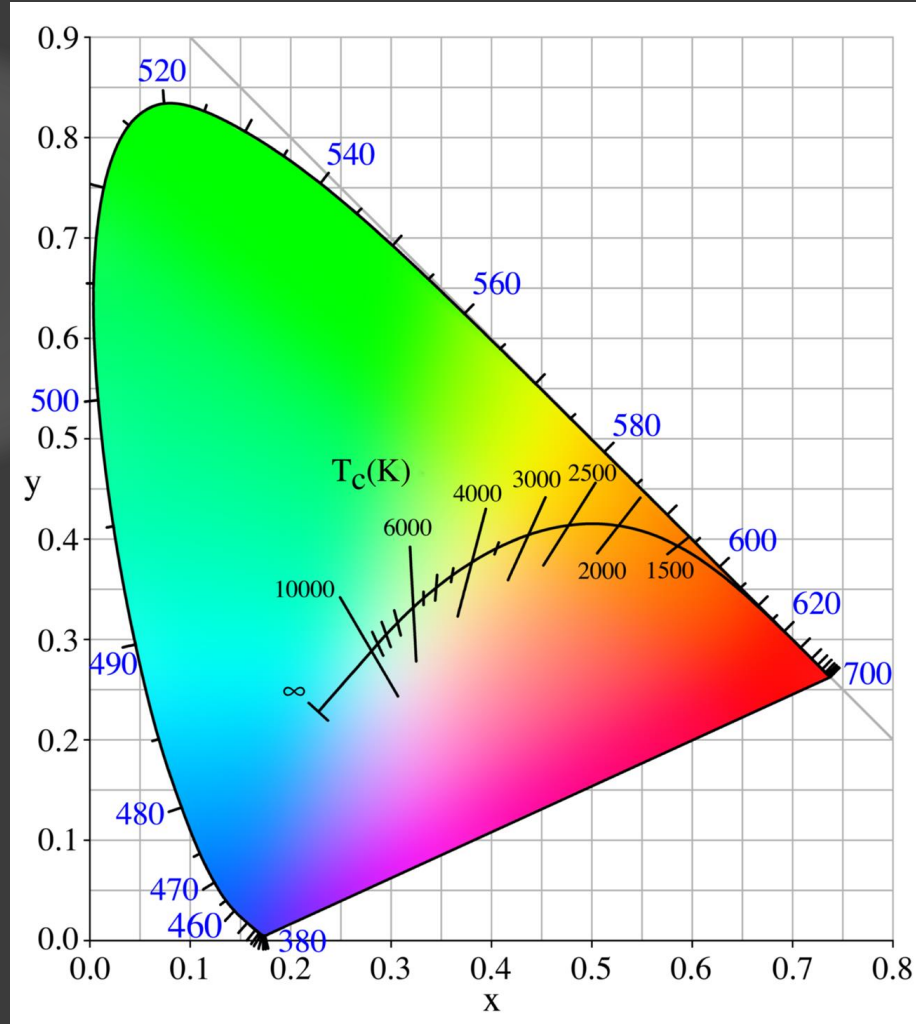
Fidelity has to do with the measurements of machines: goniophotometers, etc.

What is fidelity? the degree of exactness with which something is copied or reproduced.



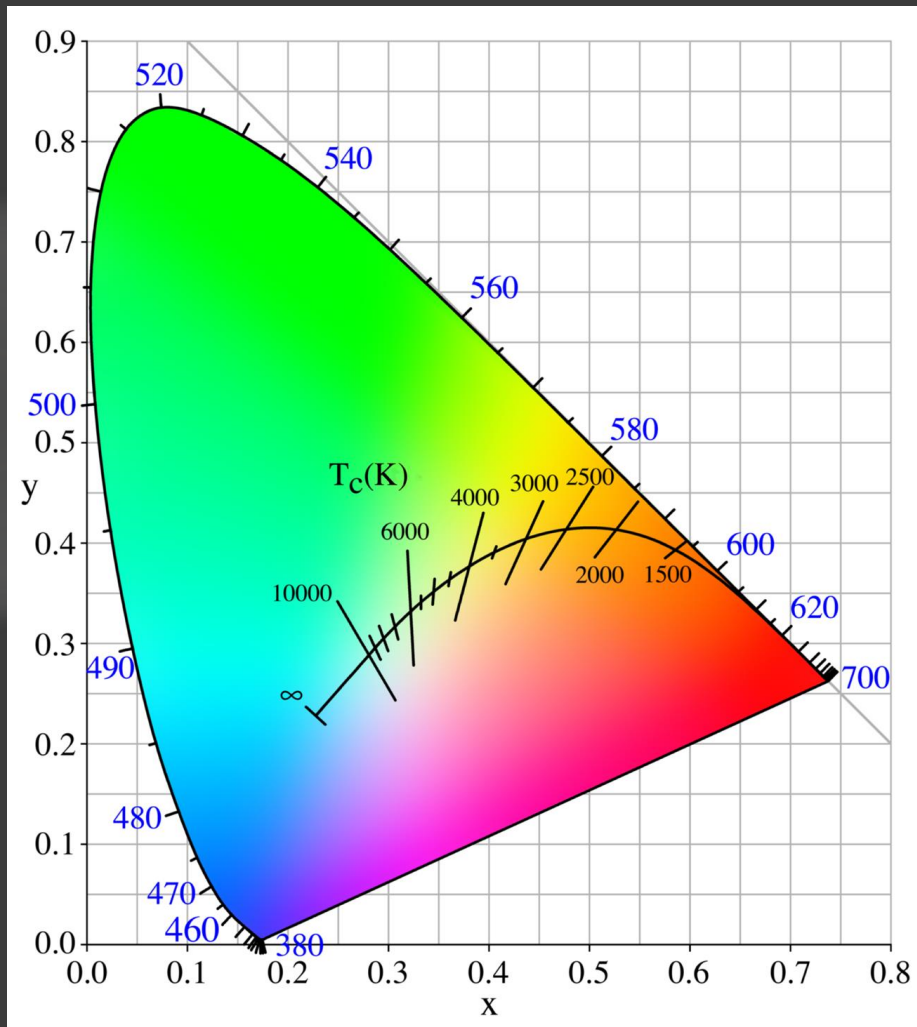
Gamut has to do with the increase or decrease of chroma : saturation.

# What is the black body locus?

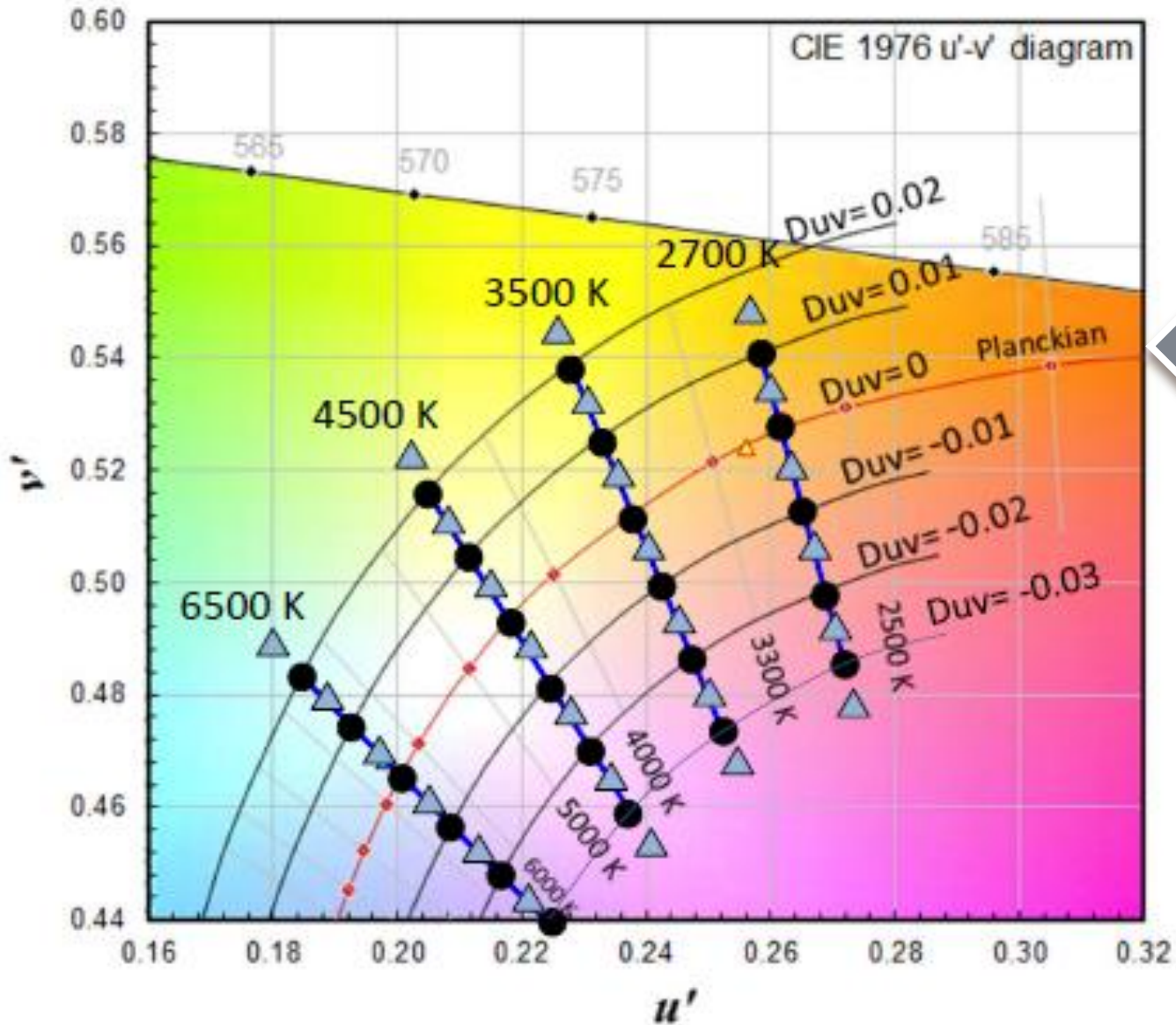




# What is Duv?



Yoshi Ohno (2014) Practical Use and Calculation of CCT and Duv, LEUKOS, 10:1, 47-55, DOI: 10.1080/15502724.2014.839020



Positive  $D_{uv}$

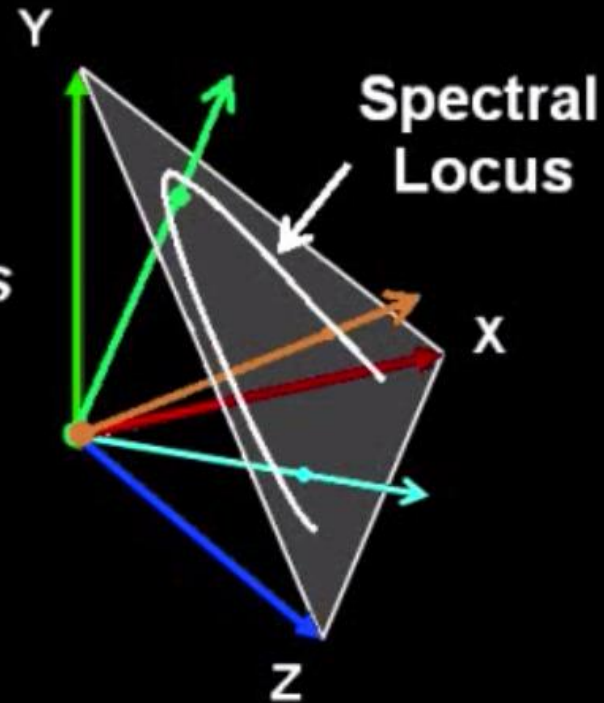


Negative  $D_{uv}$

# What are tri-stimulus values?

## Color Space X-Y-Z

*Series of  
Tristimulus Vectors  
Map Out the  
Chromaticity  
Diagram*



# The IES Method (TM-30-15)

“This Technical Memorandum describes a method for evaluating light source color rendition that takes an objective and statistical approach, quantifying the fidelity (closeness to a reference) and gamut (increase or decrease in chroma) of a light source.

Importantly it does not attempt to evaluate human color preference or provide a single number that captures the combined color rendition qualities.”

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- **Attributes of Color Rendition include:**

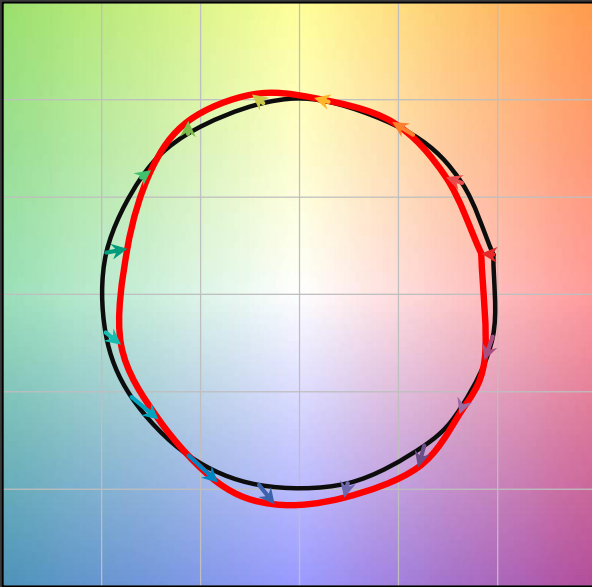
- **Color Fidelity**

- **Color Discrimination**

- **Color Preference**

Tend to be related to saturation, which can be quantified with gamut

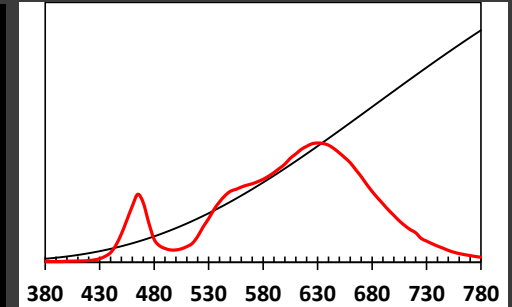
# Color Vector Graphic



Color Vector Graphic



Color Distortion Graphic



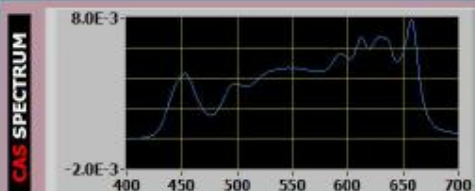
$R_f$  = 81  
 $R_g$  = 101  
CCT = 2496 K  
 $R_a$  = 88

(Source No. 286)



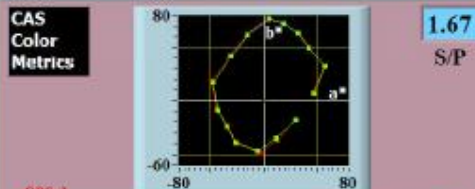






Single Continuous IntegrationTime: 100 Accumulations: 5

Save 5nm-Spectrum



CQS 1

97 99 93 96 99 96 97 10 98 98 10 98 98 98 97 Qa 97

CRI Ra  
99 99 95 96 99 98 98 97 97.7

x y  
0.4043 0.3903  
u' v'  
0.2352 0.5109

CCT 3519

Duv -0.0000

W/m<sup>2</sup> 1.09 lx 339.91

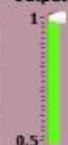
STLS MODE

1. Auto
2. File
3. \* Manual

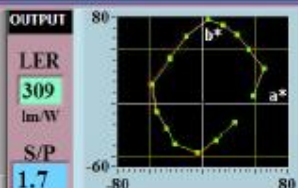
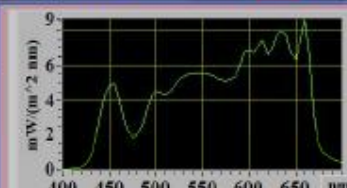
DATA FILE

CCT	Duv	Lx	Comment
3595	-0.0038	401.1	B) Duv=-0.005 Ra=96
3580	0.0010	401.6	4. Duv=0.000 3500K
3595	-0.0038	401.1	A) Duv=-0.005 Ra=96
3580	0.0067	401.9	B) Duv=+0.005 Ra=97
3580	0.0118	402.2	5. Duv=+0.010 Ra=95

Output



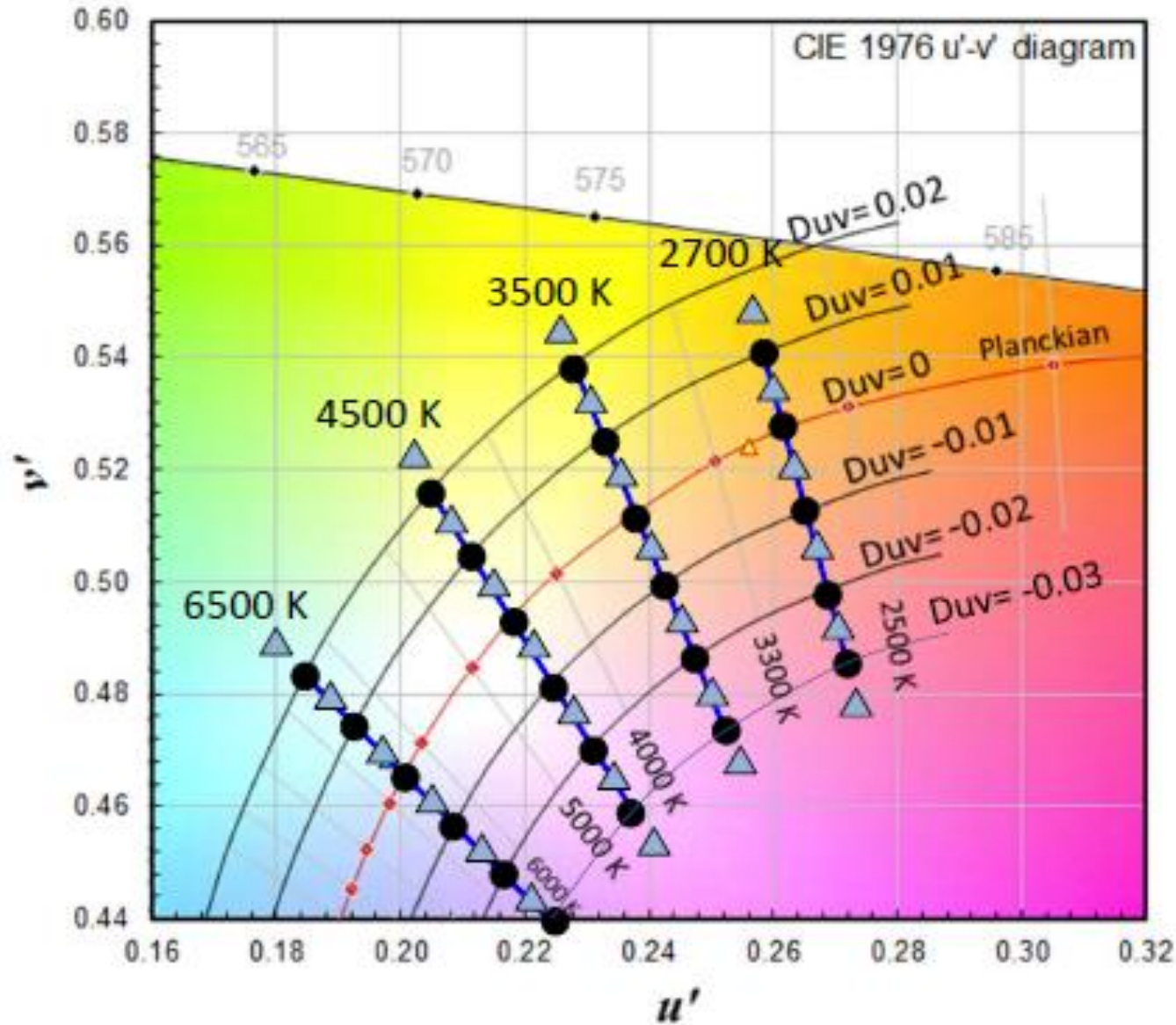
Data File: C:\22Sys\Duv Save Comment: 4. Duv=0.000 3500K



Ra 98 CRI 97 10 93 95 98 98 99 99 95 97 92 85 98 95  
Qa 97 CQS 97 99 94 98 98 96 98 99 98 99 98 96 97 99 98



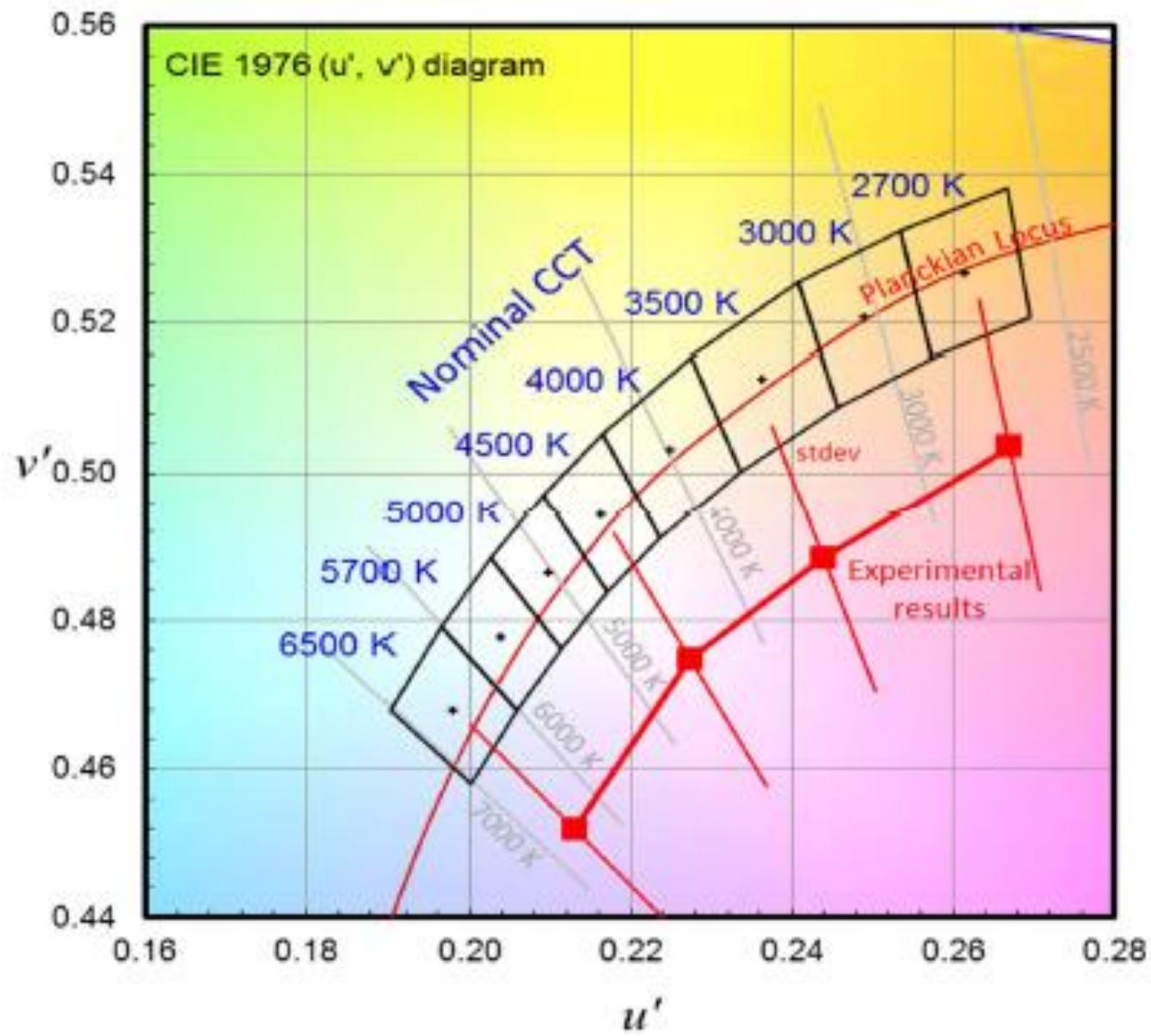




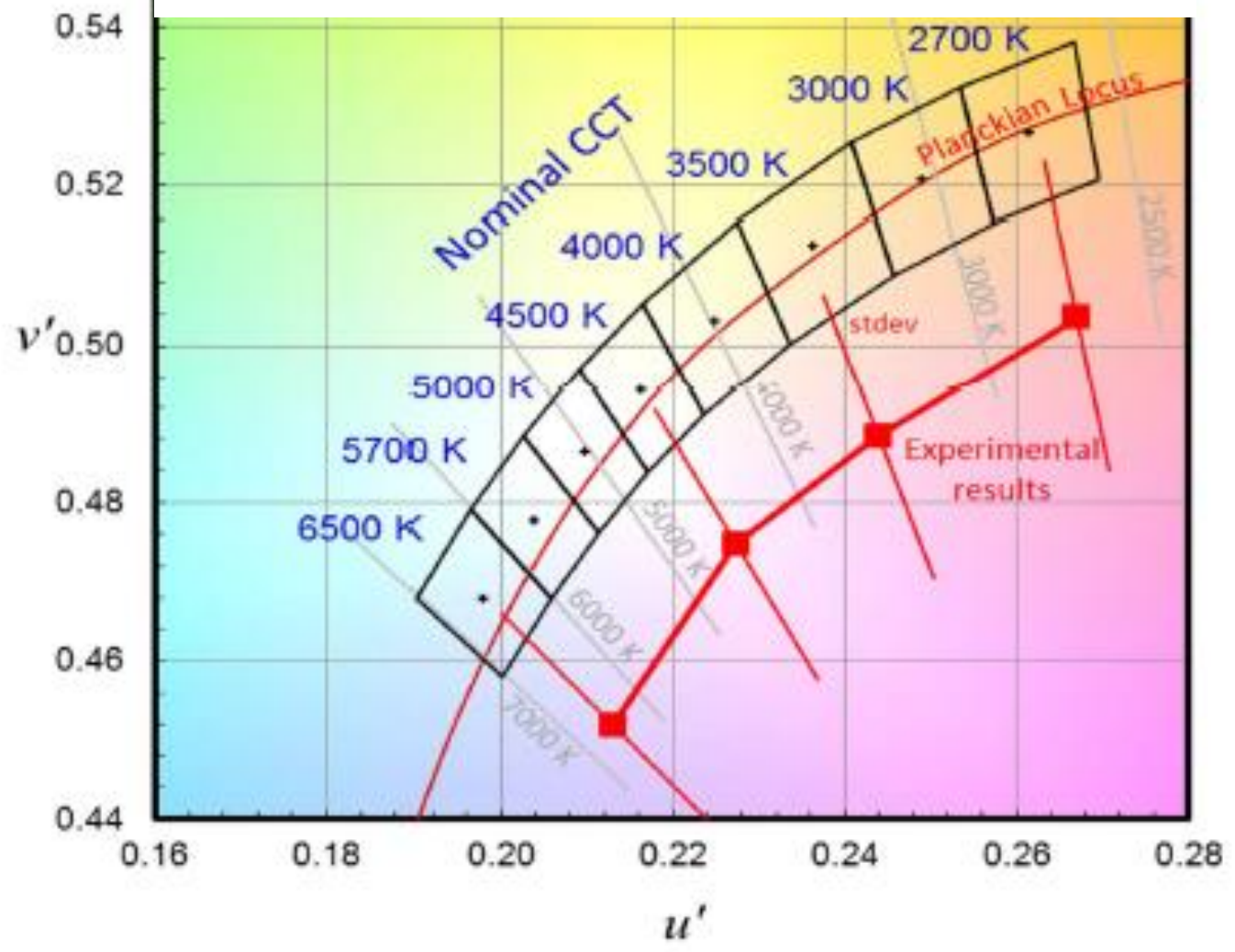
Experiments prepared for 4 CCTs, at 6 Duv points at each CCT, at total **23** points.

Spectra prepared for the 23 points plus points in between and outside, total **50** points.





The chromaticity region below the Planckian Locus (Duv around -0.015) seems to be well preferred over white light on the Planckian locus for typical indoor applications.



**Quantitative** research is a formal, objective, systematic process in which numerical data are used to obtain information about the world. This research method is used to describe variables.

**Quantitative** research is primarily exploratory research. It is used to gain an understanding of underlying reasons, opinions, and motivations.

“The body is never just a body. It is always a lived body.”

“The body is our general medium for having a world.”

— Maurice Merleau-Ponty, *Phenomenology of Perception*





Light Source	6500K-85	2700K-95+	3000K-95+	4000K-95+	2700K-95+Vibrant	3000K-95+Vibrant
CCT	6444	2707	2981	4139	2710	3060
x	0.314	0.457	0.435	0.372	0.447	0.425
y	0.328	0.406	0.397	0.363	0.389	0.387
Ra 8	80	97	97	96	95	97
Ra14	71	96	96	95	95	97
R9	1	98	95	88	92	98

## Category 2: How do you feel under the light?

2.1 Circle below, how do you feel today?



BAD



POOR



AVERAGE



GOOD



EXCELLENT

2.3 How does the light make your skin feel? (Tick as many options as relevant)

EVEN  WARM  HEALTHY  GLOWING

UNEVEN  COLD  UNHEALTHY  MATTE

2.4 Do your imperfections stand out more? I.e Spots/Blemishes/Small veins

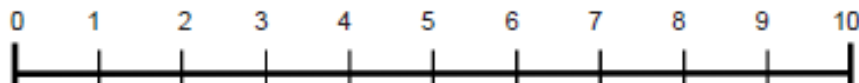
YES  NO  SOME

Please Elaborate

2.5 Does this light source complement your skin?

YES  NO

2.6 Circle between 1-10, How well would you rate the light source?



2.7 Comments?

## Category 3: How does the merchandise appear under the light?

3.1 How do the products appear under the light source?



BAD



POOR



AVERAGE



GOOD



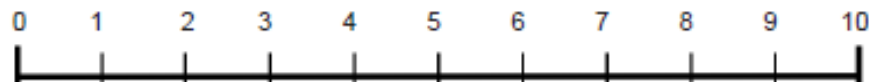
EXCELLENT

3.2 How do the colours on the packaging look?

BRIGHT  VIBRANT  WARM  ATTRACTIVE

DULL  FLAT  COLD  UNAPPEALING

3.3 Circle between 1-10, How appealing does the merchandise look?



3.4 Would you purchase any of these products under these light conditions?

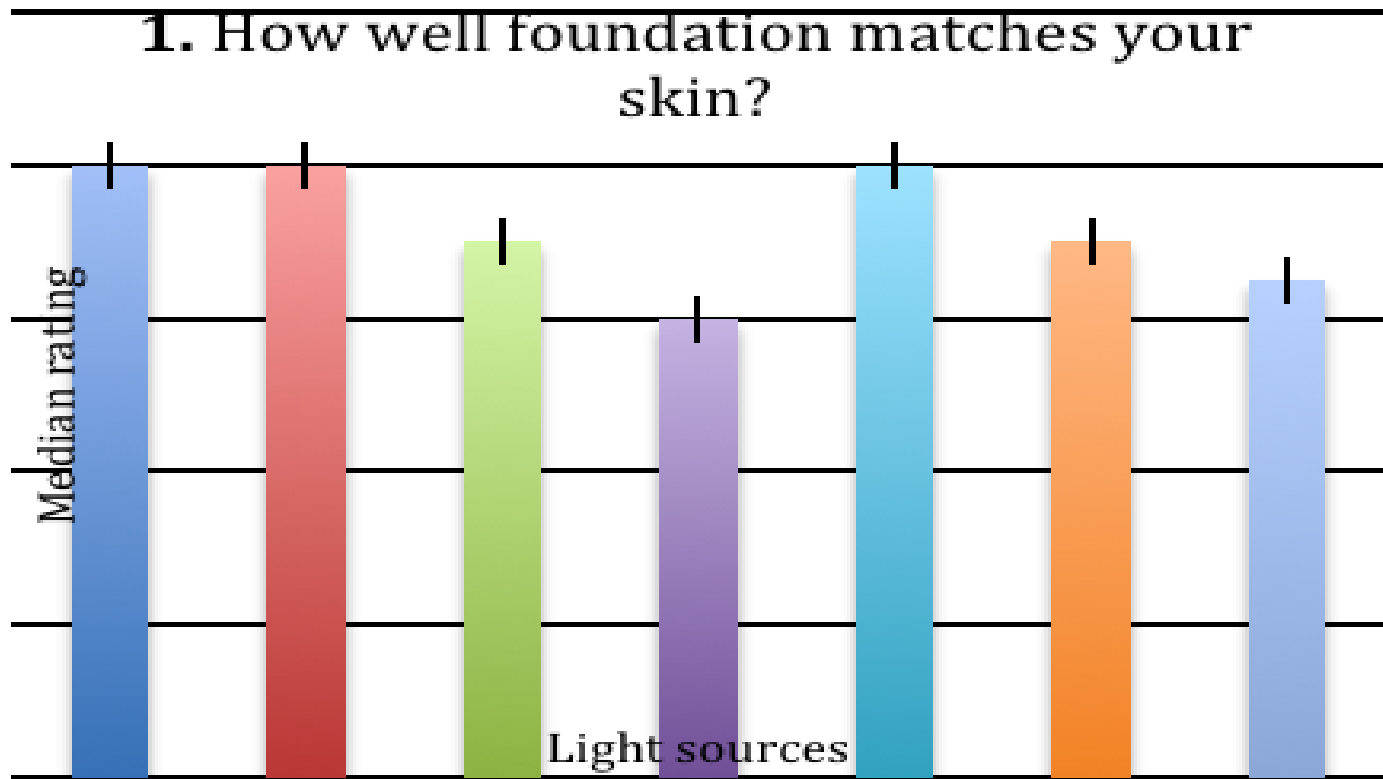
YES  NO

3.5 Comments?



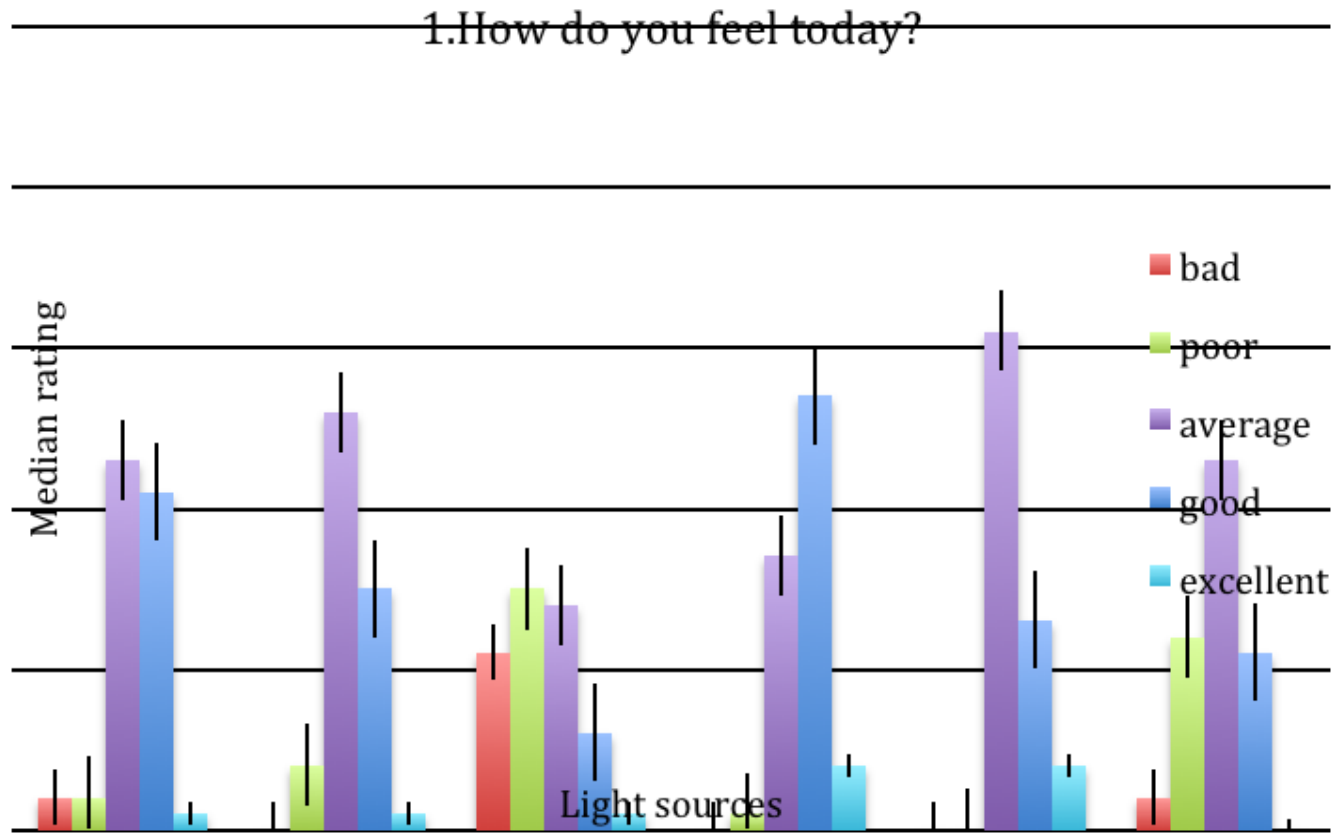
# Colour Matching

2700 K 95+ and 2700 K Vibrant (Beauty Series) are significantly more preferred than other sources by subjects,



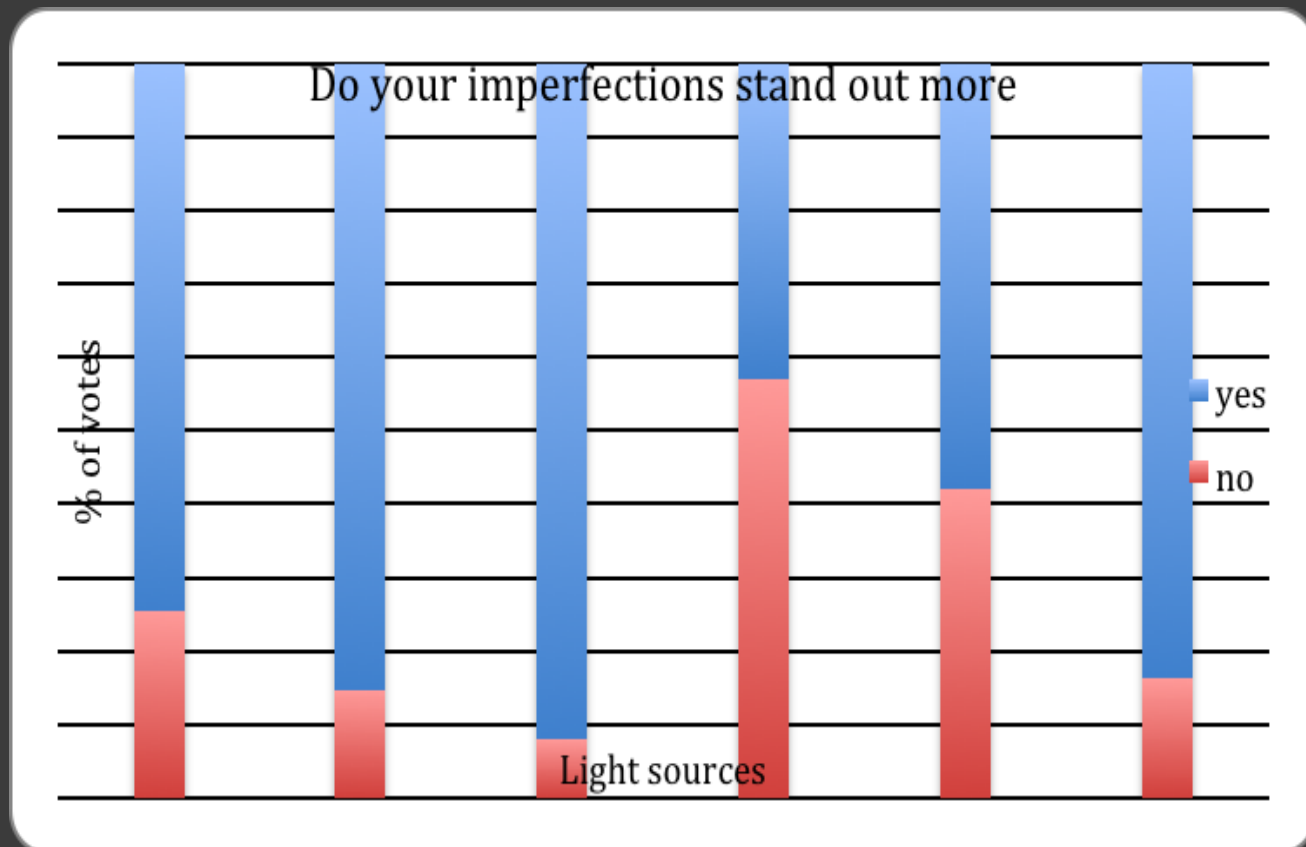
# General mood and skin appearance

2700 K 95+ and 2700 K Vibrant (Beauty Series) are significantly more preferred than other sources by subjects,



# General mood and skin appearance

2700 K 95+ and 2700 K Vibrant (Beauty Series) are significantly more preferred than other sources by subjects,



# SUMMARY OF RESEARCH FINDINGS

## Colour matching section:

- The result consistently suggests 2700 K 95+ and 2700 K Vib (**Beauty Series**) the best light sources in this category.
- The result consistently suggests 6500 K 85 and 4000 K 95+ the least preferred light source.

## “How do you feel under the light?” section:

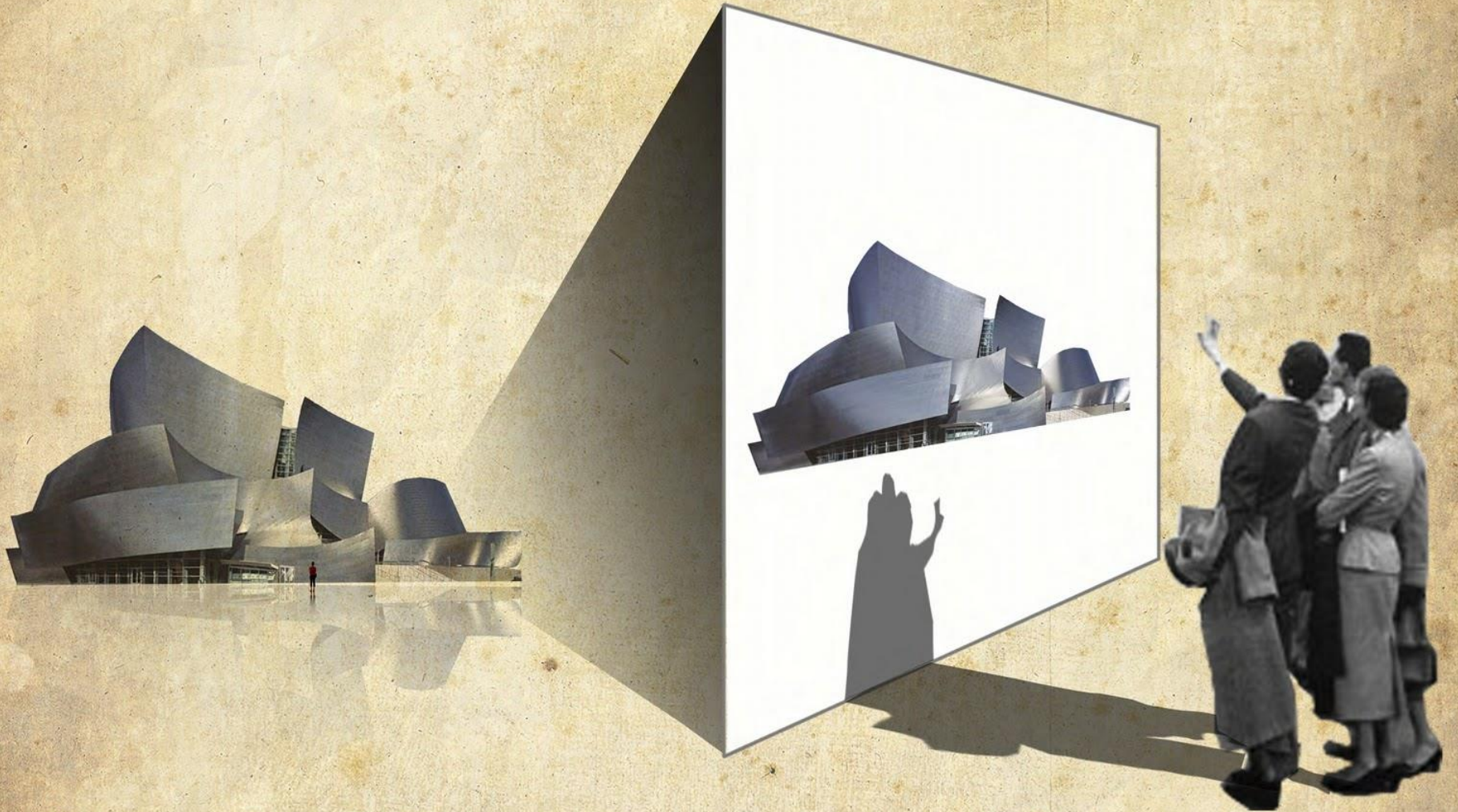
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- The result consistently suggests 6500 K 85 the least preferred light source.

# COMMENTS ON RESEARCH FOR LIGHTING FOR SKIN TONES

- The connection between a sense of well-being and the 2700K 'Vibrant' (**Beauty Series**) light source is interesting.
- As well as the quantitative data, qualitatively the light was described as “comfortable”, “cosy” and “warm” by participants.
- There seems to be a fit with ‘human centric lighting’ goals and the creation of enriched and relaxing atmospheres.
- Additional applications such as spas, changing rooms and restaurants can be considered.

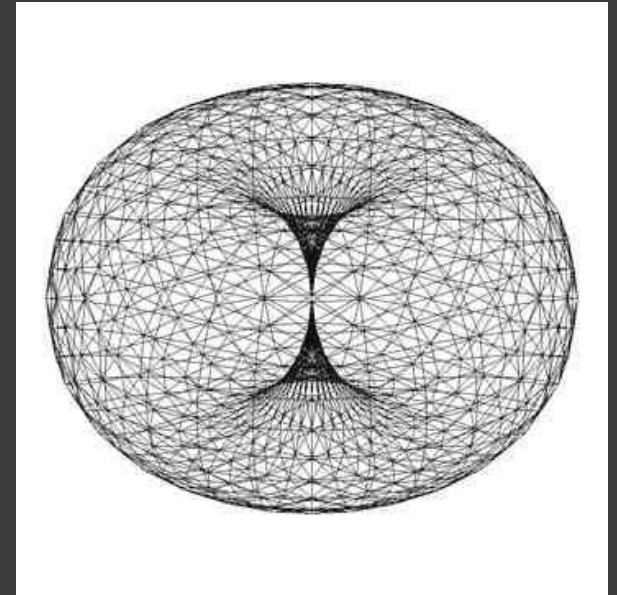


# Metrics and Preference



“We know not through our intellect  
but through our experience.”

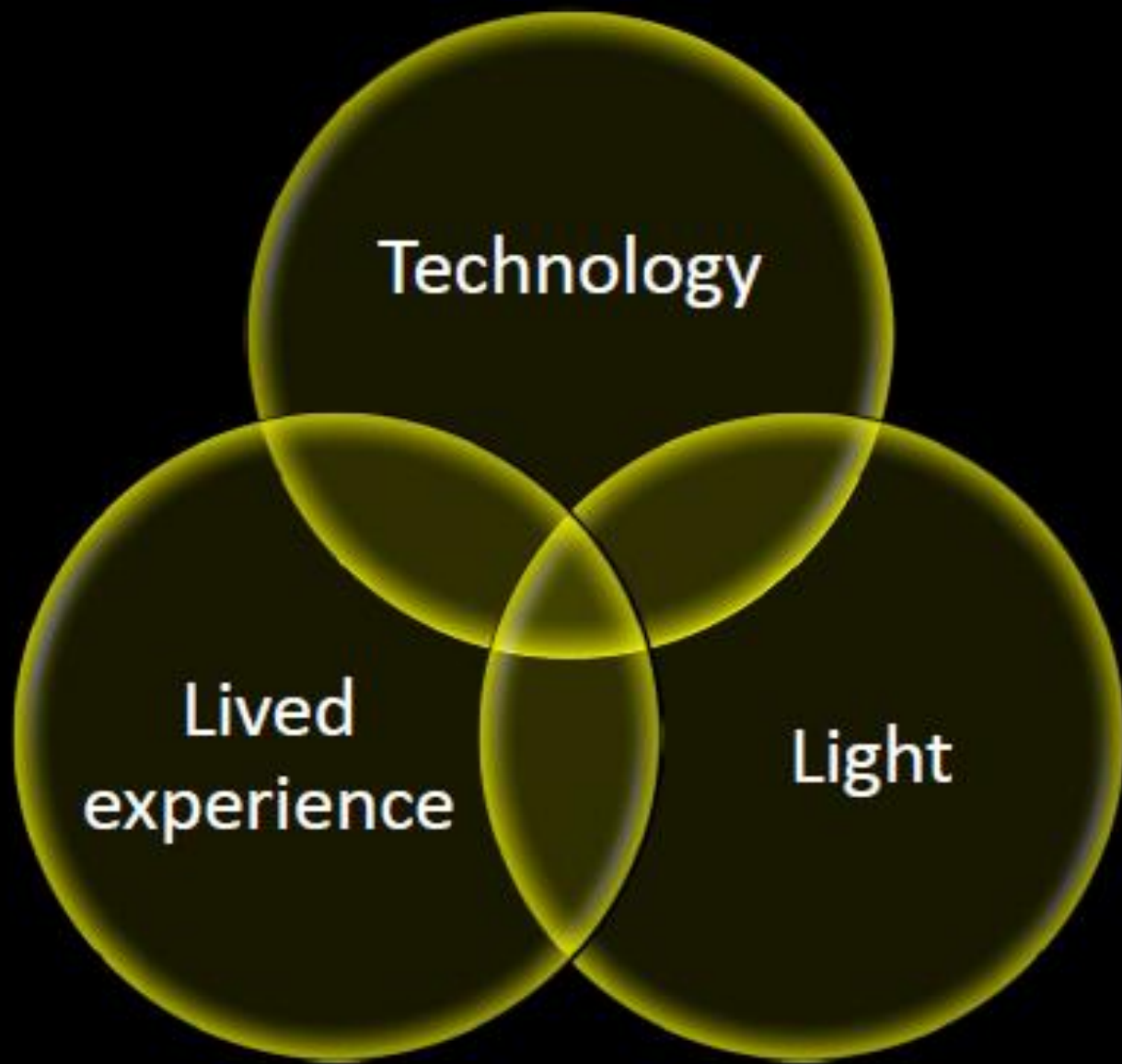
— [Maurice Merleau-Ponty](#)



“Everything is science and  
everything is philosophy.”

— [Maurice Merleau-Ponty](#)





Technology

Lived  
experience

Light

## Key take-aways:

We cannot ignore chroma and saturation when evaluating light sources.

Concepts of gamut are important to grasp for lighting professionals – It's a good thing!

Being close to the Black Body Locus is not for every application

Lighting is being developed for **humans**, not just objects/architecture/things