A Conclusion...
“There is another reason why it may be desirable to use desaturated primaries in a television receiver. It has been found in direct colorimetry that observer differences can be minimized by making the color triangle of the primaries no larger than is necessary to include the variation of chromaticities to be measured.”
Observer Metamerism

A metameric match for one observer is likely to mismatch for another.
Terms

Mean Observer Metamerism $\neq$ Mean-Observer Metamerism
CIE TC1-36

- CIE 170-1:2006
- Cone Fundamentals (CMFs)
- Function of Field Size
- Function of Age
- Mean Functions
CIE 2006 Model

Cone Fundamentals

\[ \bar{l}(\lambda) = \alpha_{i,l}(\lambda) \cdot 10^{-D_{\tau,\text{max},\text{macula}} \cdot D_{\text{macula,relative}}(\lambda) - D_{\tau,\text{ocul}}(\lambda)} \]

\[ \bar{m}(\lambda) = \alpha_{i,m}(\lambda) \cdot 10^{-D_{\tau,\text{max},\text{macula}} \cdot D_{\text{macula,relative}}(\lambda) - D_{\tau,\text{ocul}}(\lambda)} \]

\[ \bar{s}(\lambda) = \alpha_{i,s}(\lambda) \cdot 10^{-D_{\tau,\text{max},\text{macula}} \cdot D_{\text{macula,relative}}(\lambda) - D_{\tau,\text{ocul}}(\lambda)} \]
Notation

- CIE2006(field size, age)
- e.g. CIE2006(2,32)
- 2-Degree Field, 32 Years Old
Examples: Field Size

L-, M-, & S-Cone Fundamentals (2- & 10-Deg. @ Age 32)

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<th>Wavelength (nm)</th>
<th>Relative Sensitivity</th>
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- l-bar (2)
- m-bar (2)
- s-bar (2)
- l-bar (10)
- m-bar (10)
- s-bar (10)
Examples: Age

L-:, M-:, & S-Cone Fundamentals (10-Deg. @ Ages 20 & 80)
CIE 2006 Code

mcsl.rit.edu/online/cie.php

Excel Spreadsheet & MATLAB Code
Select Original Colors
24-Patch ColorChecker
CIE Illuminant D65

Define Simulated Display Primaries

Define CMFs
CIE2006(FS,Age)

Compute Display Matches

Use Matching Spectra to Compute CIELAB $\Delta E^*_{ab}$
for CIE 1931 CMFs

Repeat for Broad- and Narrow-Band Primaries

Repeat for
FS = 1°, 2°, 4°, 7°, 10°
Age = 20, 32, 40, 60, 80

Compute Statistics
Across 24 Patches

Compare Effects
of Primaries, Field Size, and Age

Computational Experiment
Computational Match

Original Colors (D65, ColorChecker)

CIE2006 (fs, age)

fs = 1, 2, 4, 7, 10°
age = 20, 32, 40, 60, 80 y

Broad-Band Primaries

Narrow-Band Primaries
Evaluation of Matches

Original Colors (D65, ColorChecker)

CIE 1931 Std. Obs.

CIELAB Color Differences

Broad-Band Primaries

Narrow-Band Primaries
Display Primaries

- 450, 540, 610nm Peak Wavelengths

Matches to D65 White
Chromaticity Gamuts
Results

• Color Differences (CIELAB, 1931)
• Chart (D65) vs. Simulated Display Match
• Averaged Over 24 Patches
## Results

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32 Year-Old Observers

Field Size (Deg.) for 32-Years Age

CIELAB Delta-E*

- Broad-Band Primaries
- Narrow-Band Primaries
10-Deg. Observers

![Graph showing age (years) for 10-deg field size with CIELAB Delta-E* values for broad-band and narrow-band primaries.](#)
White Patch

Broad Band

Narrow Band
Visualization

- Take Matching RGBs and Display on a Single sRGB Display
- Center: Broad-Band “Original”
- Surround: 4 Computed Narrow-Band Matches
- Illustrates Changes in Device RGB Needed to Compensate for Observer Variability
Visualization Key

CIE2006(2,32)  CIE2006(1,0,32)

CIE2006(1,0,20)  CIE2006(1,0,80)

Original
Full ColorChecker
Pictures
Conclusions

- Narrow-Band Primaries
  - More Observer Variability
- Mean Observer Metamerism is Significant
- Individual Observer Metamerism is Even Greater
- Consider the CIE 170-1:2006 CMFs
Also ...
High-luminance desaturated primaries appear more colorful than dimmer monochromatic primaries...
Thank You

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