Do LEDs Increase the Accuracy of LED Aviation Signal Light Color Identification by Pilots With and Without Color-Deficient Vision?

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LRC and Aviation Lighting Research

Aviation Lighting Research at the LRC

Human Factors

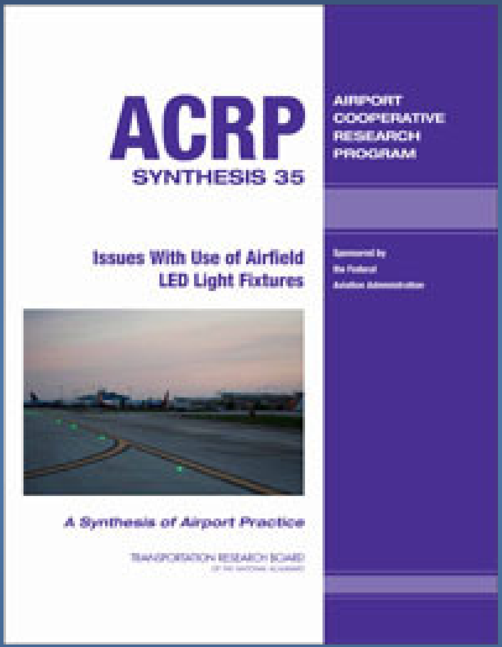
Color Vision Status and LED Identification
Signal Light Brightness
Perception of Linear Lighting
Effective Intensity of Flashing Lights
Stroboscopic Effect Perception
Requirements for LED Runway Guard Lights
Specifications for Remote Airfield Lighting

Solid State Lighting Technology

Heat Transfer in Taxiway Edge Lights
Life Testing for Airfield Lighting Fixtures
Solar-Powered LED Fixtures
Volatile Organic Compound Effects in LEDs
LED Driving Circuitry and Flicker
Photometric Testing for LED Fixtures
Electrical Infrastructure Research Team Support
Phosphor-Converted Amber LEDs
Junction Temperature Estimation for AC LEDs
LED Electrical and Thermal Parameters Under Stress

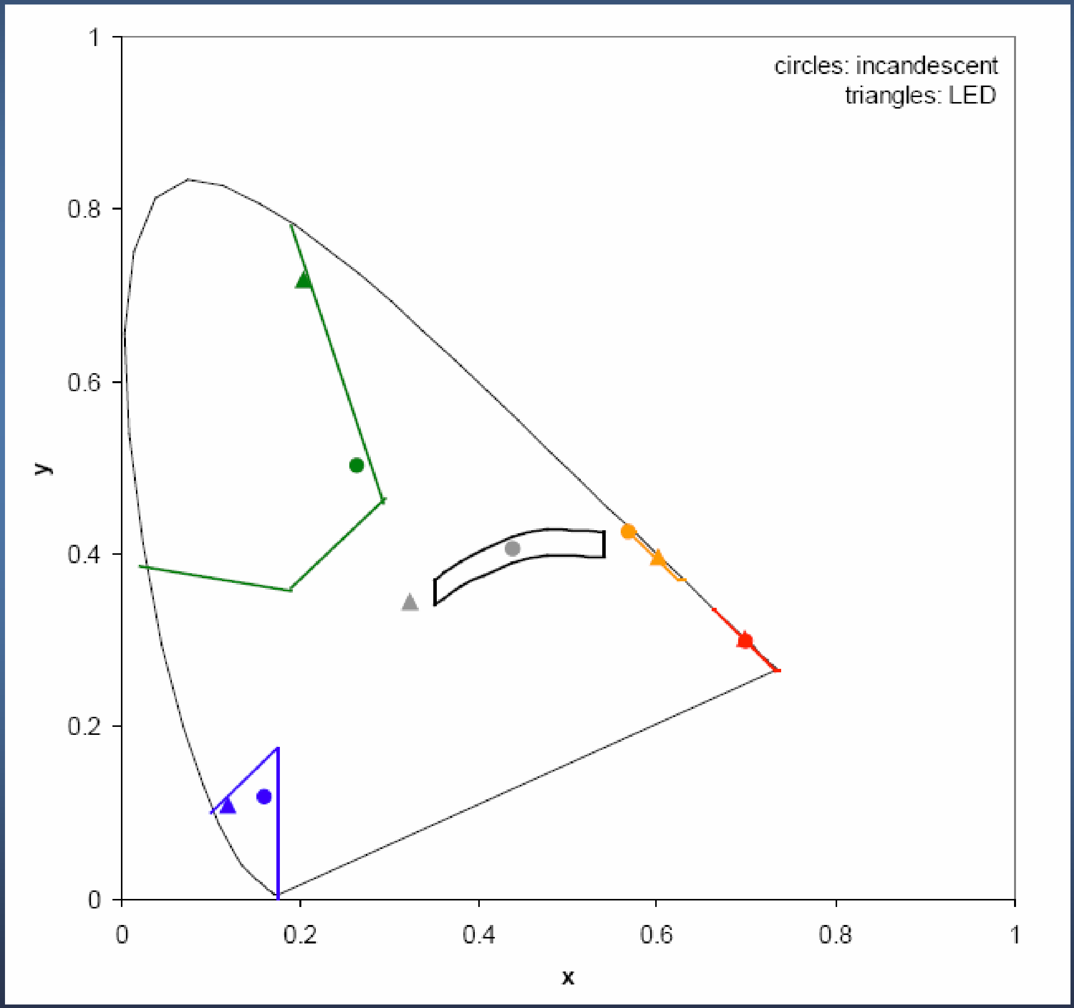
Background

- LED lighting technology is increasing in use for airfield lighting
  - Potential for maintenance and energy benefits
- LEDs differ from incandescent sources in several important ways:
  - Increased color saturation and higher correlated color temperature (CCT) for white
- How do the differences in spectral distribution affect color identification by color-normal and color-deficient pilots?



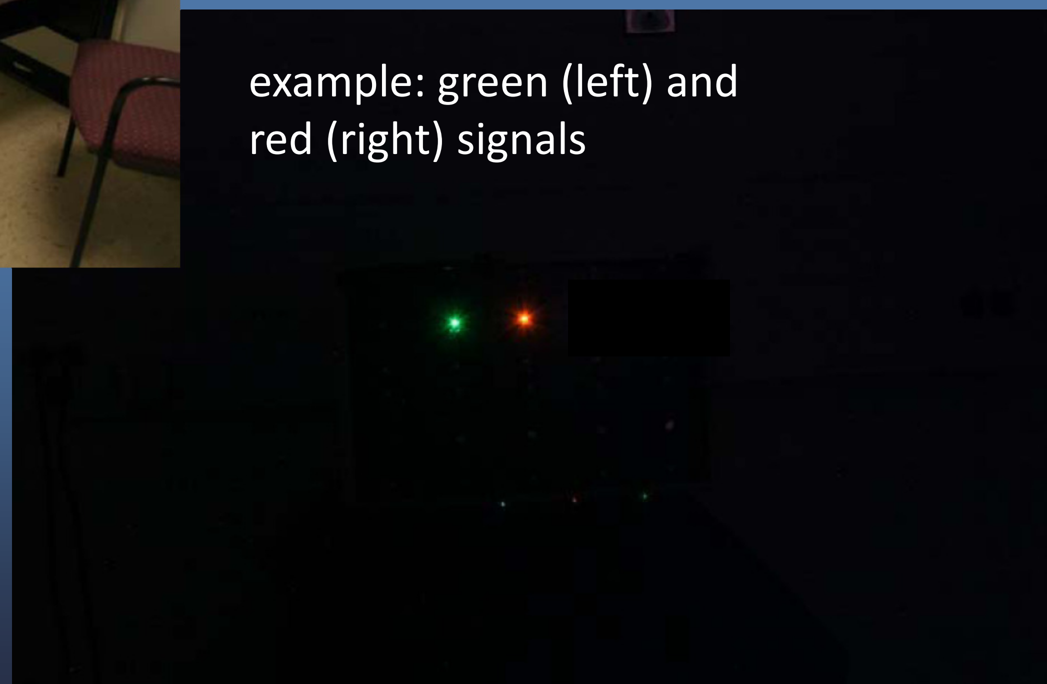
(Bullough 2012)

Incandescent and LED Signal Chromaticities



Method: Color Identification Study

Subjects viewed each color individually and in combination with each other color present, and had to identify the color of each signal presented; most subjects completed four repetitions of each color/light source combination



example: green (left) and red (right) signals

Method: Color Identification Study (cont'd.)

- Experimental subjects
  - Recruited through FAA Civil Aerospace Medical Institute (CAMI): ~half color-normal, ~half color-deficient
  - Color vision diagnosis provided by CAMI
  - Performance of signal light gun test as screen for color-deficient subjects (*excluded if failed*)
- Final tally: 29 color-normal (ave. age 27), 8 protan (ave. age 28), 13 deutan (ave. age 33)

Signal light gun test

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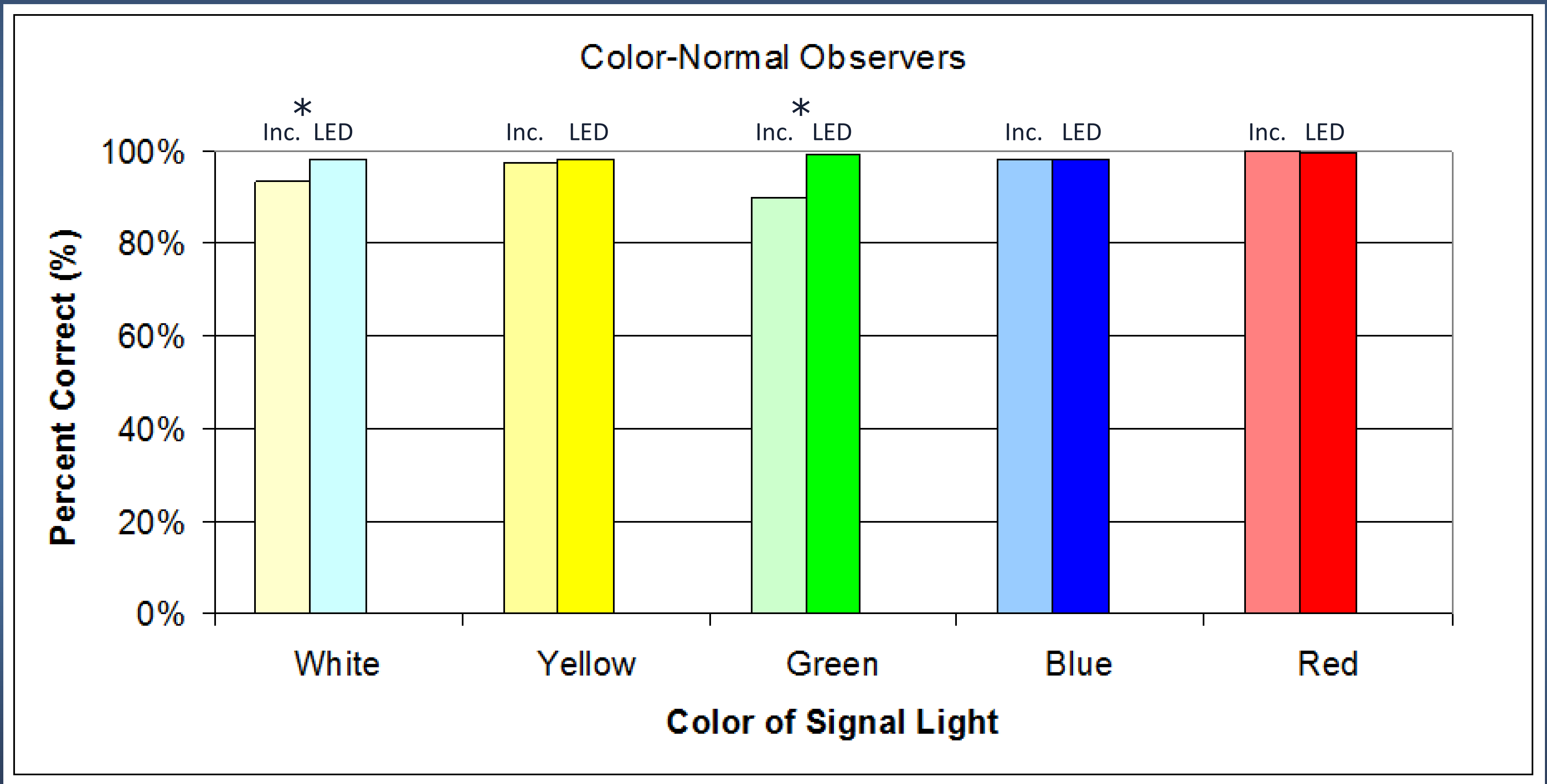
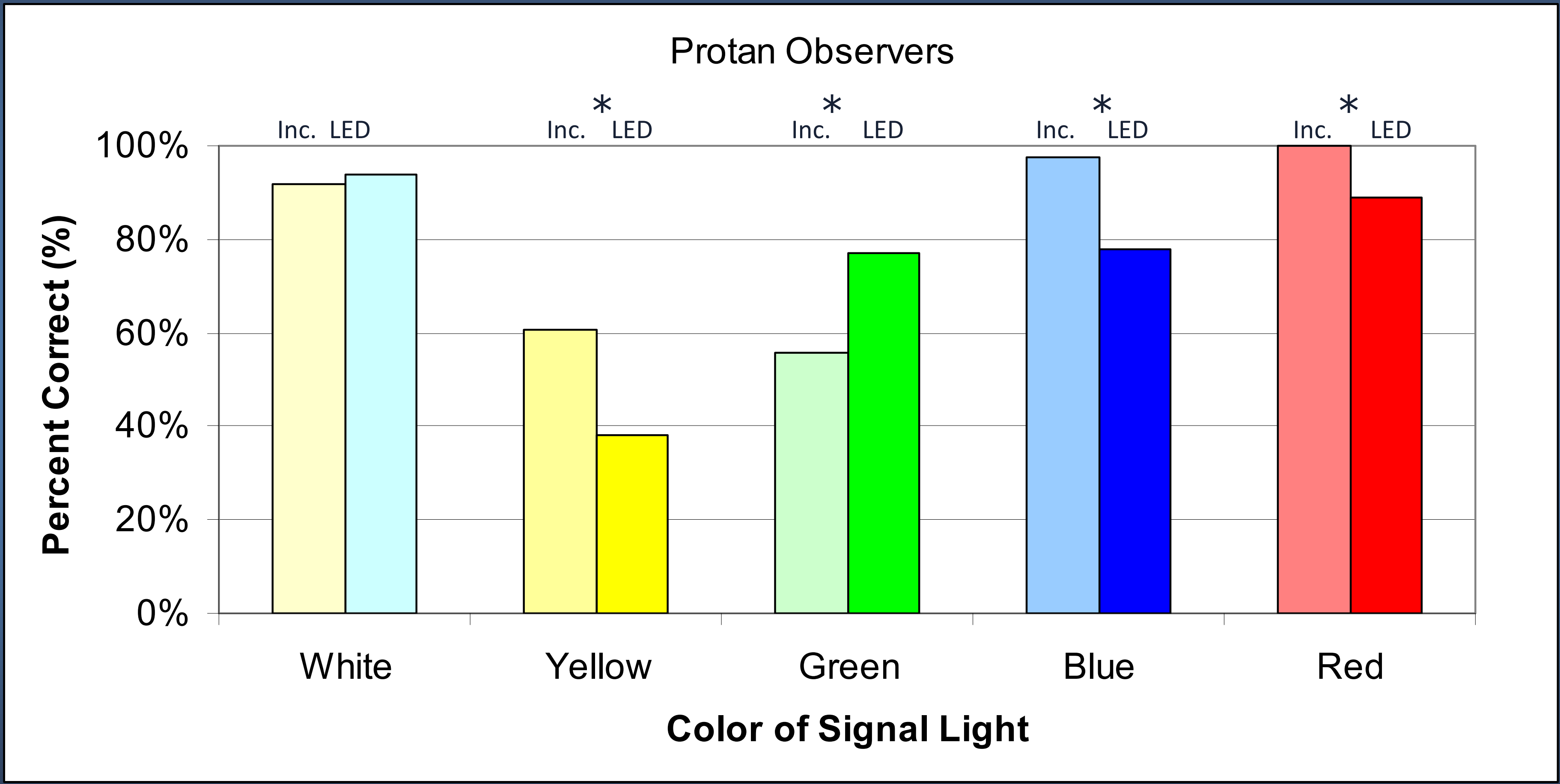
Results: Color-Normal Observers



**Statistically significant ($p<0.05$, Fisher's exact test) difference between incandescent and LED sources.*

Results: Protan Observers



**Statistically significant ($p<0.05$, Fisher's exact test) difference between incandescent and LED sources.*

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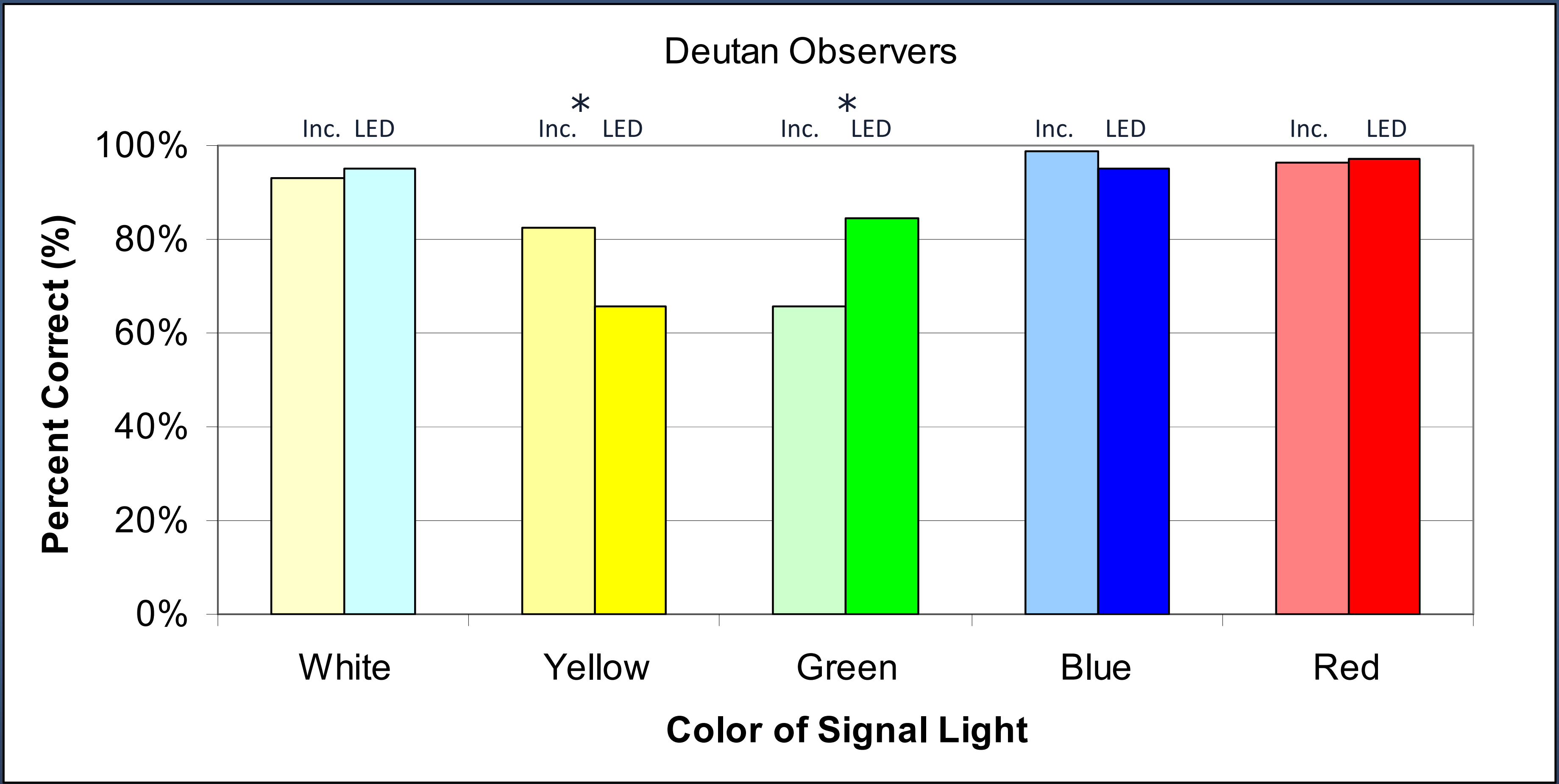
Results: Deutan Observers



**Statistically significant ($p<0.05$, Fisher's exact test) difference between incandescent and LED sources.*

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Summary of Results

- Color-normal subjects:
  - Identification improved with white and green LEDs
    - White: Incandescent sometimes called "yellow"
    - Green: Incandescent sometimes called "white"
- Color-deficient subjects:
  - Identification sometimes better, sometimes worse with LEDs
    - Green: Incandescent often called "white"
    - Yellow: LED often called "red"
    - Red: LED sometimes called "yellow" by protans
    - Blue: LED sometimes called "white" by protans
  - Very little effect of relative LED intensity

Discussion

- LEDs do not present any problems for color-normal observers
  - Color identification is improved for white and green/cyan LEDs and never worse for any other color
- White and green LEDs also improve color identification for color-deficient observers
- Long-wavelength yellow lights may be problematic for color-normal and color-deficient observers

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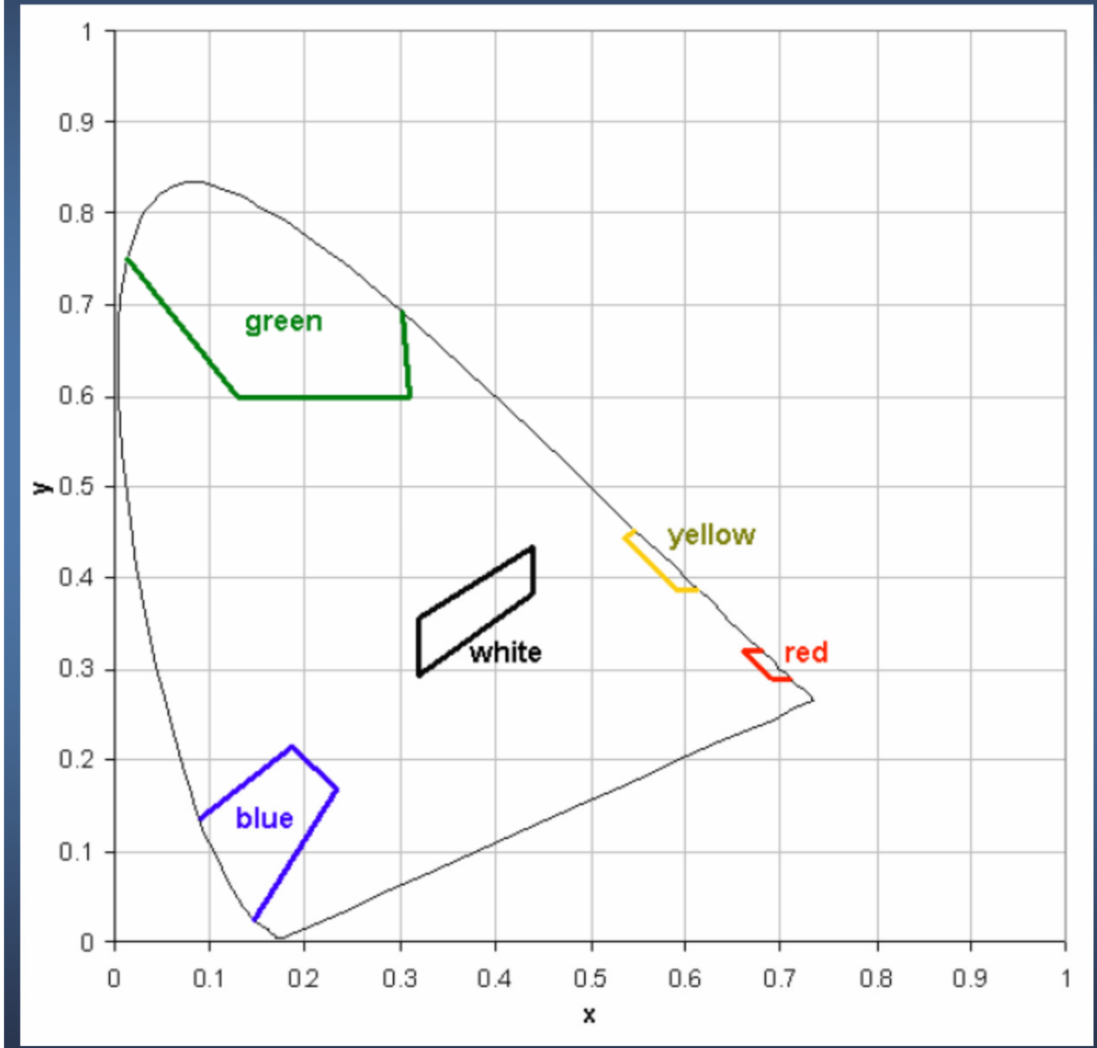
Discussion

- Both "red" and "red-orange" LEDs fall within AS25050, CIE 107 and ICAO Annex 14 recommendations, and are reliably identified as red
  - Extending red boundary region beyond ~650 nm seems unnecessary
- "Blue" and "royal blue" fall within AS25050 and ICAO Annex 14 (but not CIE 107) boundaries, and are reliably identified as blue
  - Extending blue boundary region shorter than ~450 nm seems unnecessary

Chromaticities for LED Signals (DOT/FAA/TC-TN12/61)



- Blue: Maintain ICAO (1975) boundary so blue (470-nm) LEDs can be used
- White: Delete portion near yellow (since dimming LEDs doesn't make them yellower) and allow CCT higher than 6000 K
- Green: Increase saturation to avoid confusion with white
- Yellow: Allow slightly desaturated colors and shift toward slightly shorter wavelengths (since confusion with dimmed white is not relevant)
- Red: Allow slightly desaturated colors and cut off long-wavelength portion to ensure detection by protans

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