Colorimetric Analysis of the Farnsworth-Munsell D-15 Color Vision Test in Trichromatic And Dichromatic Color Spaces

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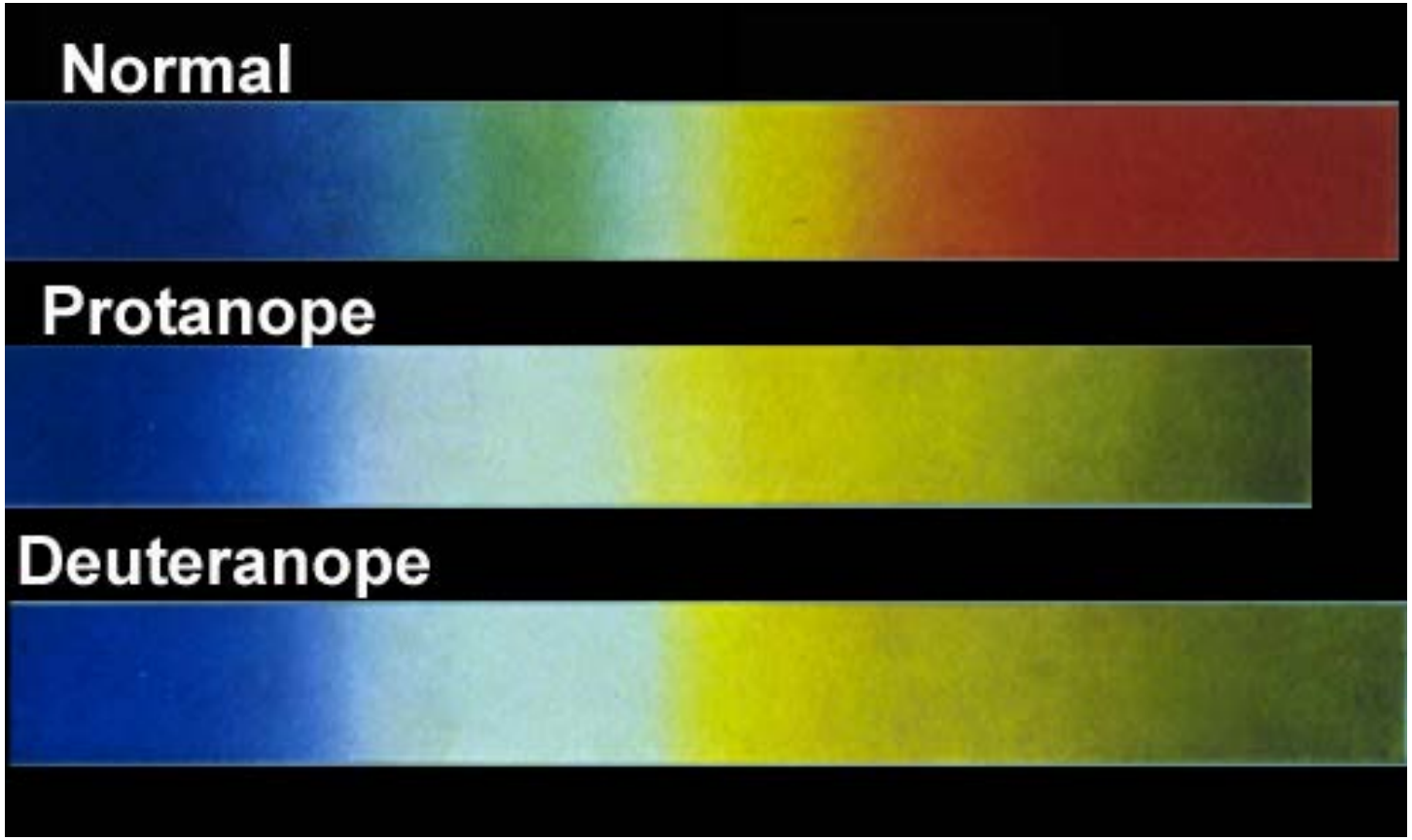
Introduction

- Continuing interest to illustrate how individuals with congenital color vision defects perceive colors



Missing L-cone

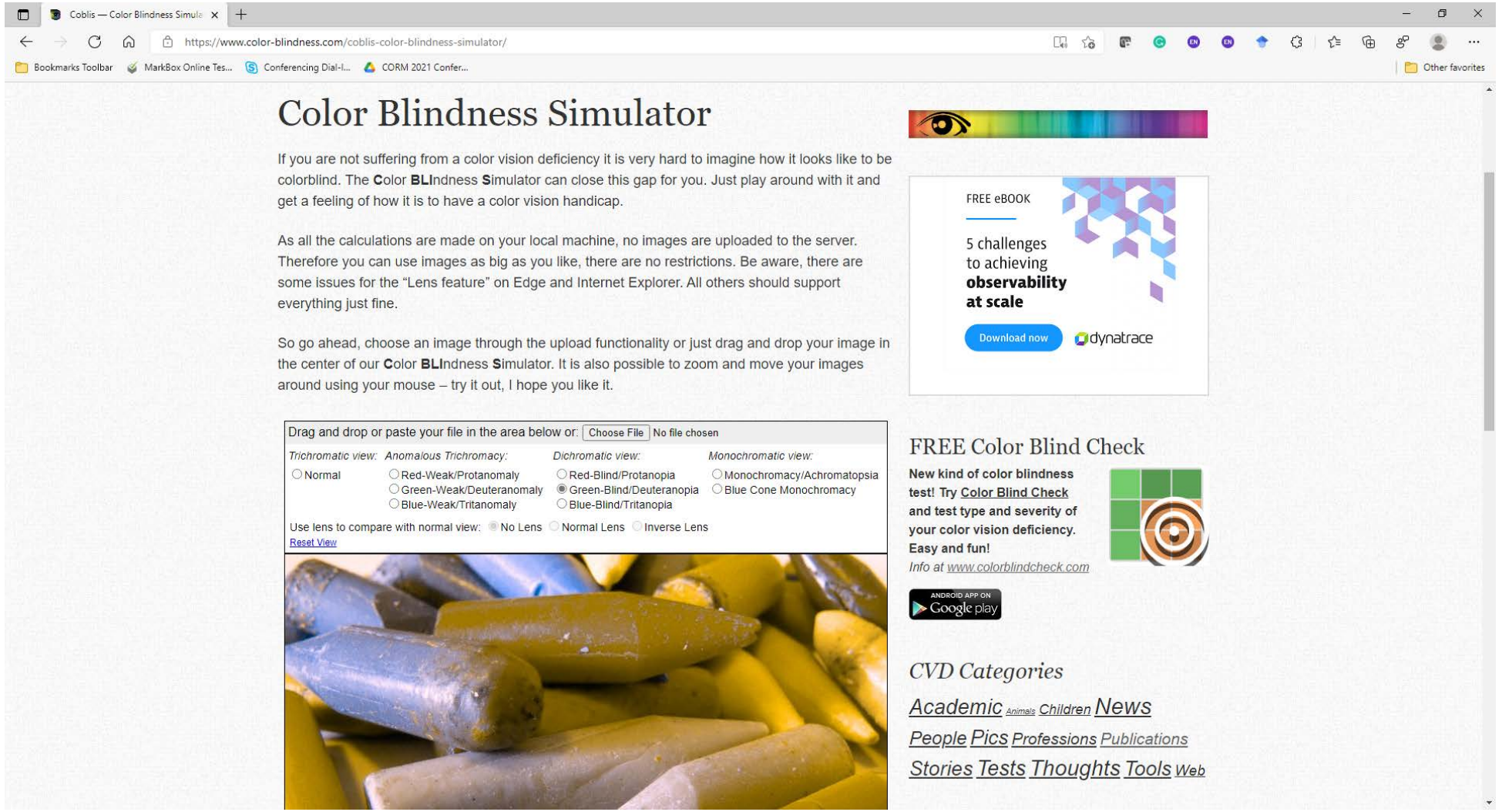
Missing M-cone

From Trendelenburg, 1952

Based on a Neural Network

From Usui & Nakauchi, 1993

Web based simulations



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Conversion Algorithm (Brettel et al. J Opt Soc Am (A) 1997)

- Measure 1931 X, Y, Z tristimulus values of the objects
- Convert to L-, M-, S-, cone responses
- Convert L, M, S responses to dichromatic cone responses
  - Protanope – just S & M cones
  - Deuteranope – just S & L cones
  - (colors on a line a parallel to the M-cone axis are represented as a point in a S-cone-L-cone plane)
- Convert to dichromatic X_D, Y_D, Z_D values
- Both Color-Normal and Dichromatic X, Y, Z values were transformed to CIELAB coordinates

The issue

Previously

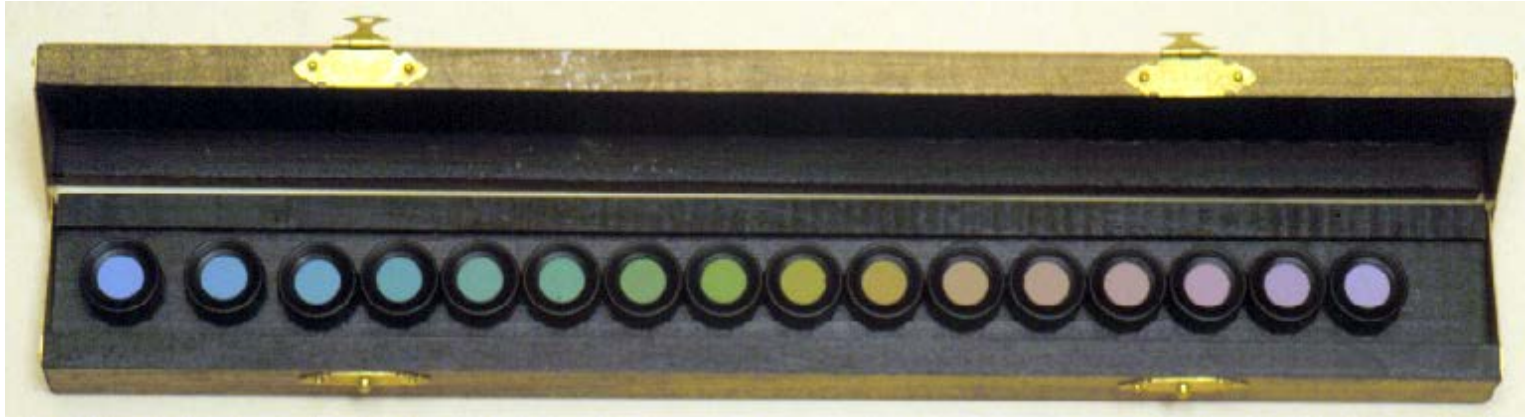
- Used this transformation L*a*b* space to determine whether the calculated dichromatic color differences correlated with color naming errors
- But the correlation was low-to-moderate
  - colored objects had brightness differences also

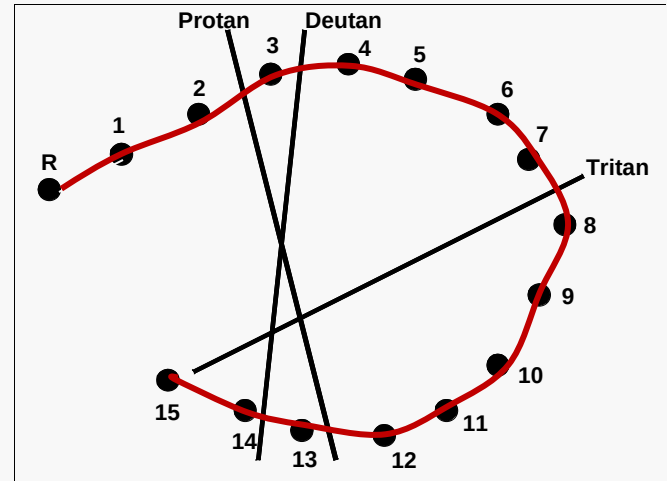
Would this transformation be successful in predicting the dichromatic arrangements for the D-15?

- luminance differences between caps are small
- the primary task is hue discrimination.

The “objects”

Farnsworth-Munsell D15

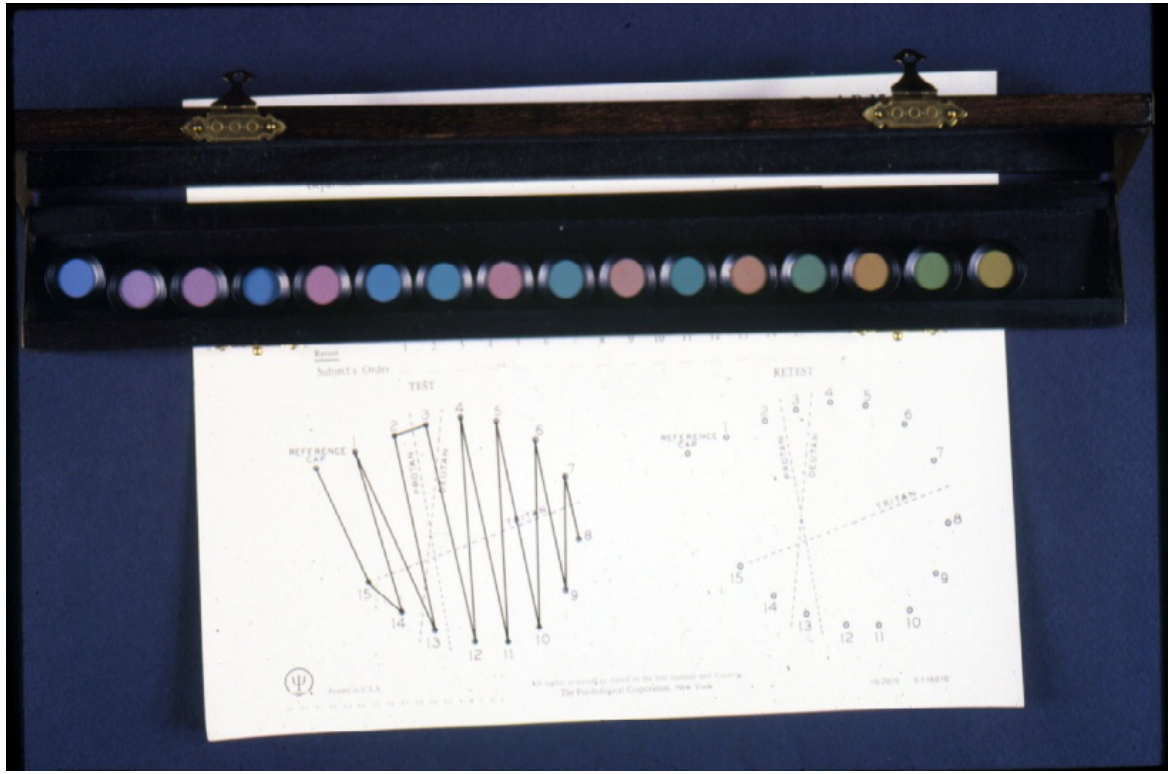




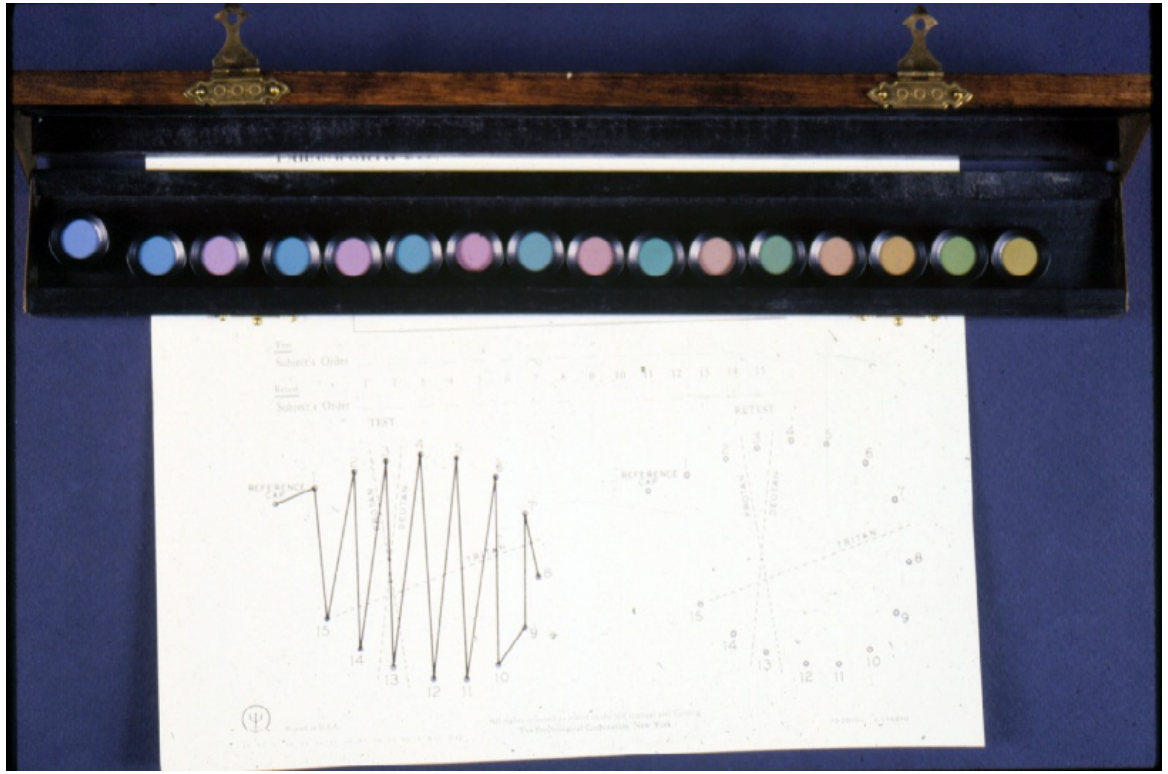
Remove loose caps

- “place the loose cap that is most similar in color to the last one placed in the box"

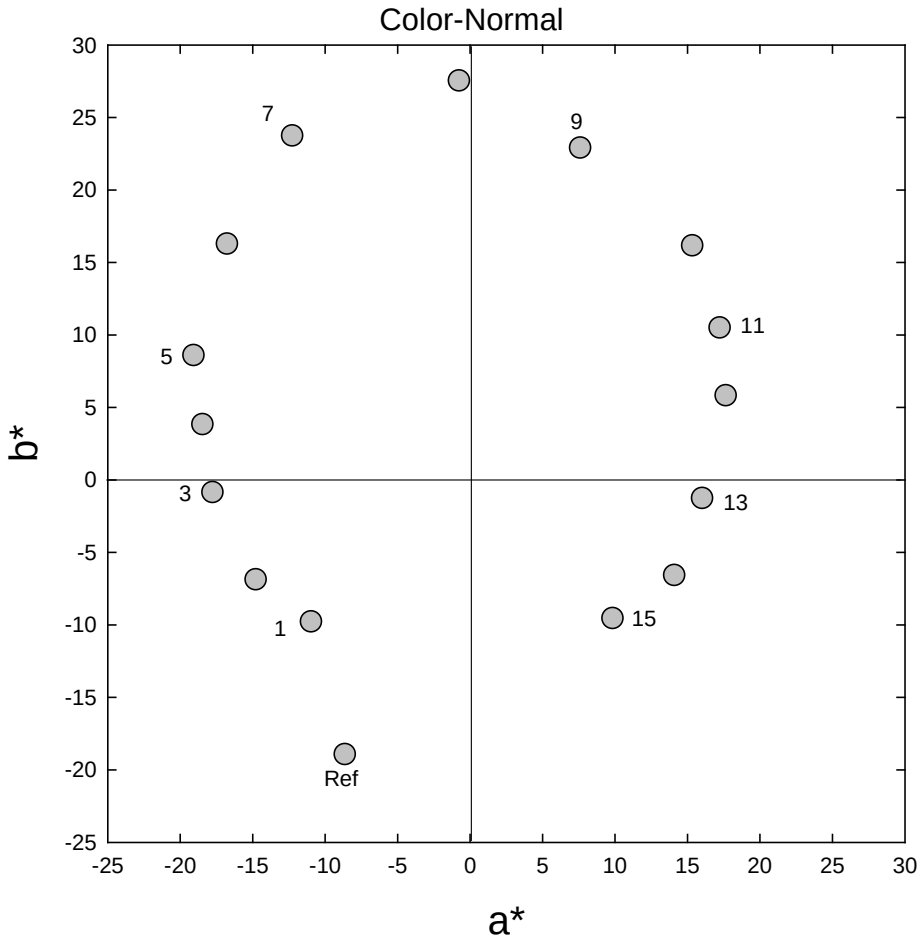
Protanopic Arrangement

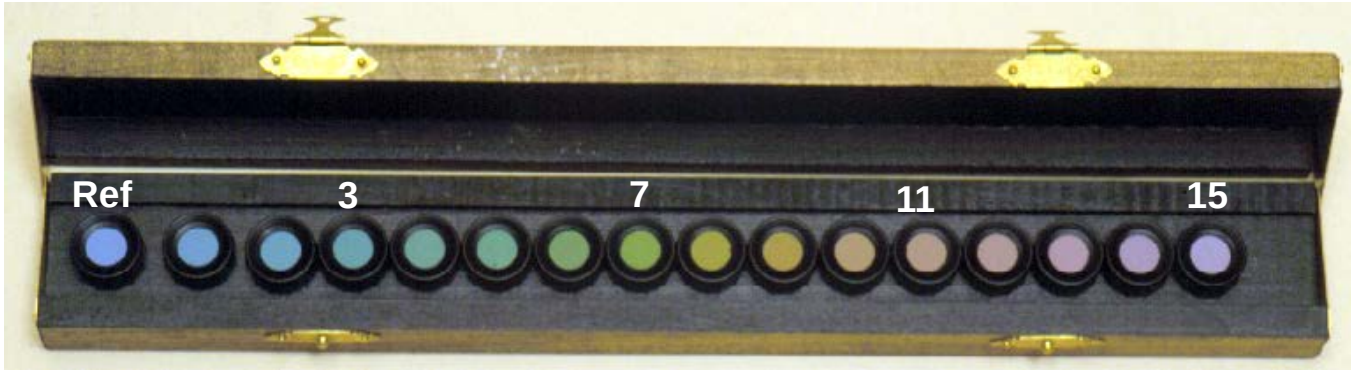


Deuteranopic Arrangement



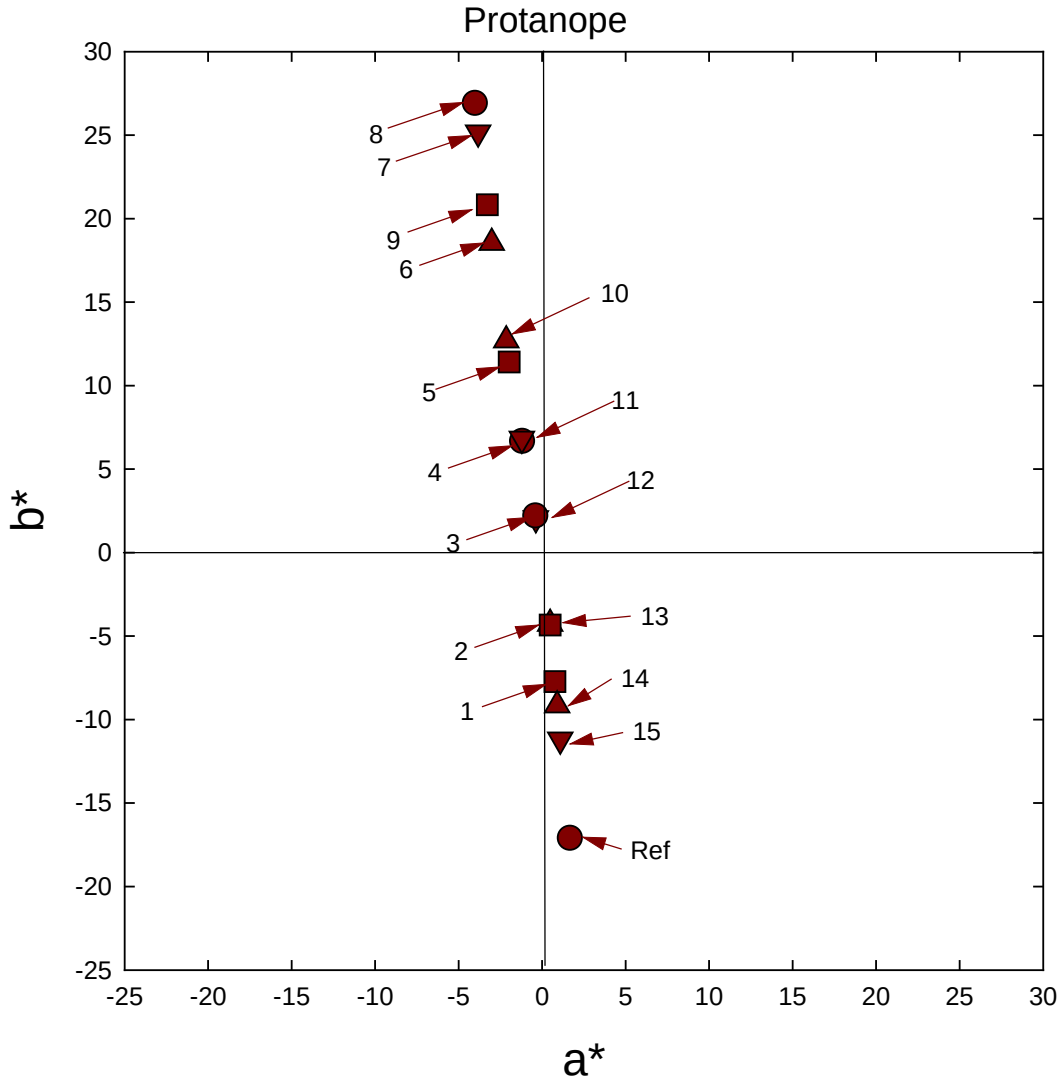
Plotted in CIELAB





- **Theoretical Arrangement**
  - select the “loose” cap with the smallest ΔE relative to the one in the box

Protanope


Protanope
b*
a*
30
25
20
15
10
5
0
-5
-10
-15
-20
-25
-25
-20
-15
-10
-5
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5
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14
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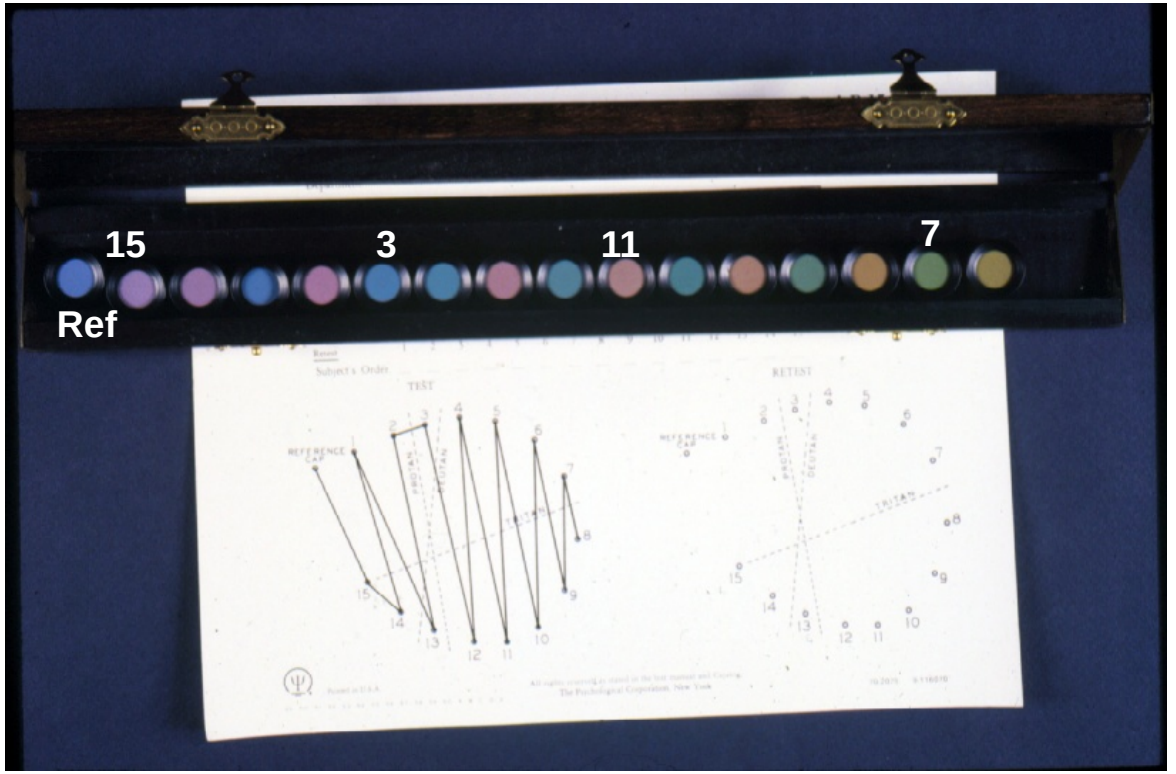
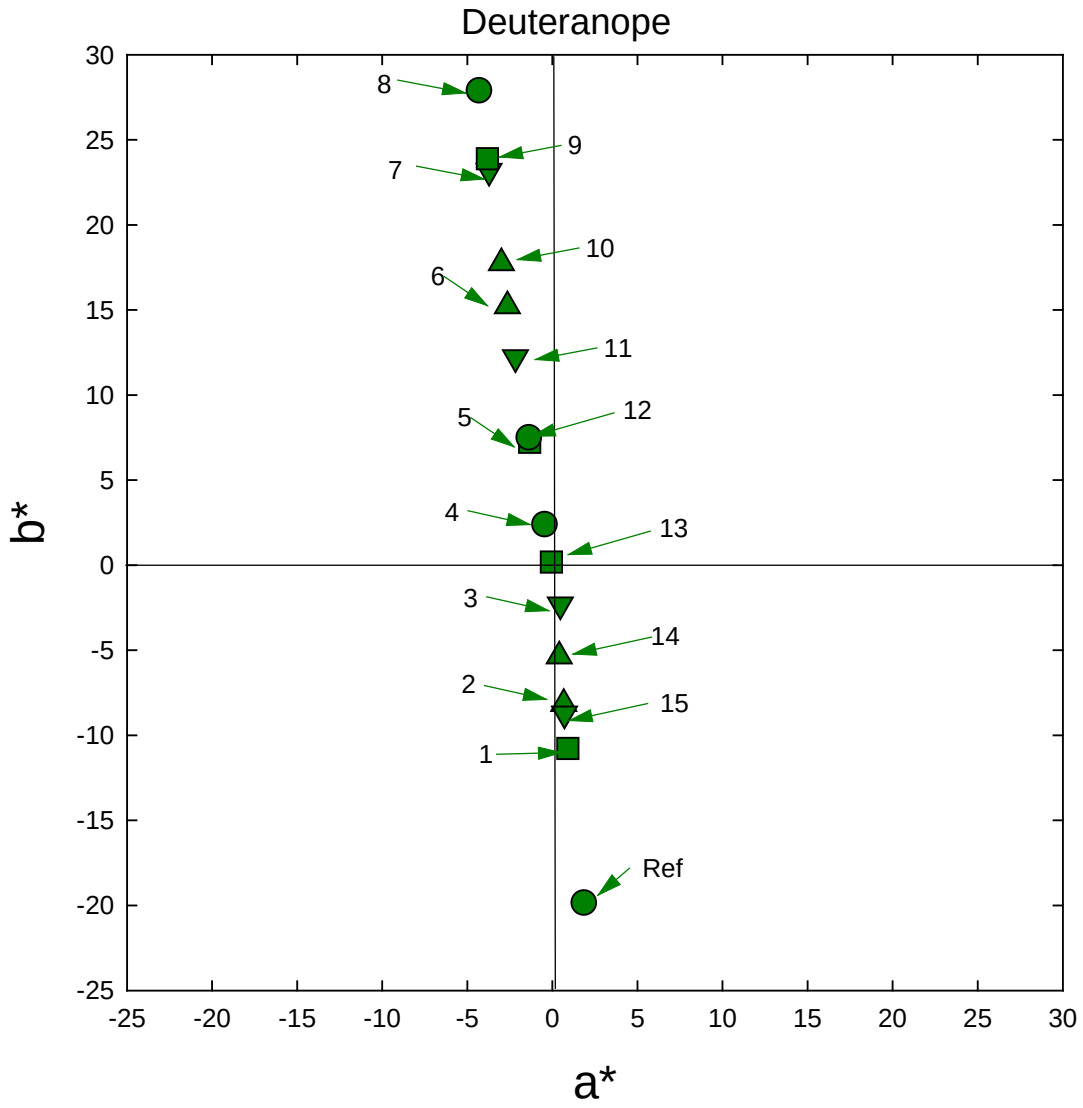
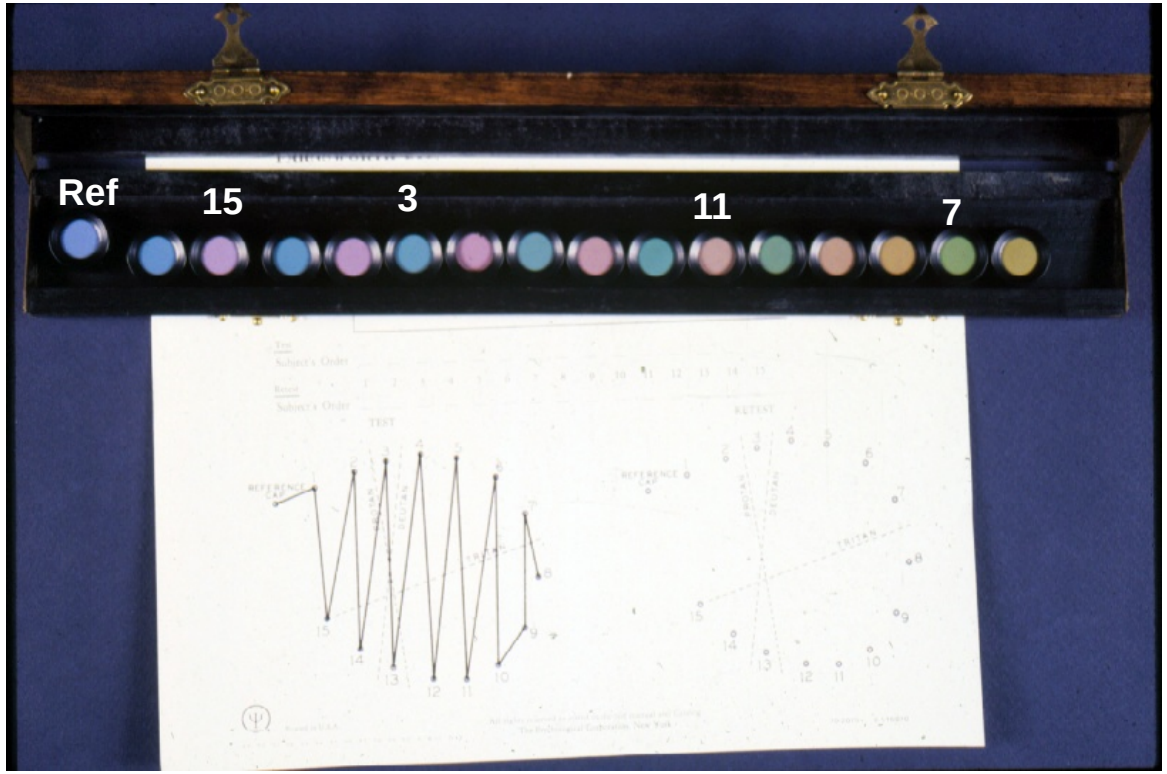
Ref


15
3
11
7
Ref

Deuteranope





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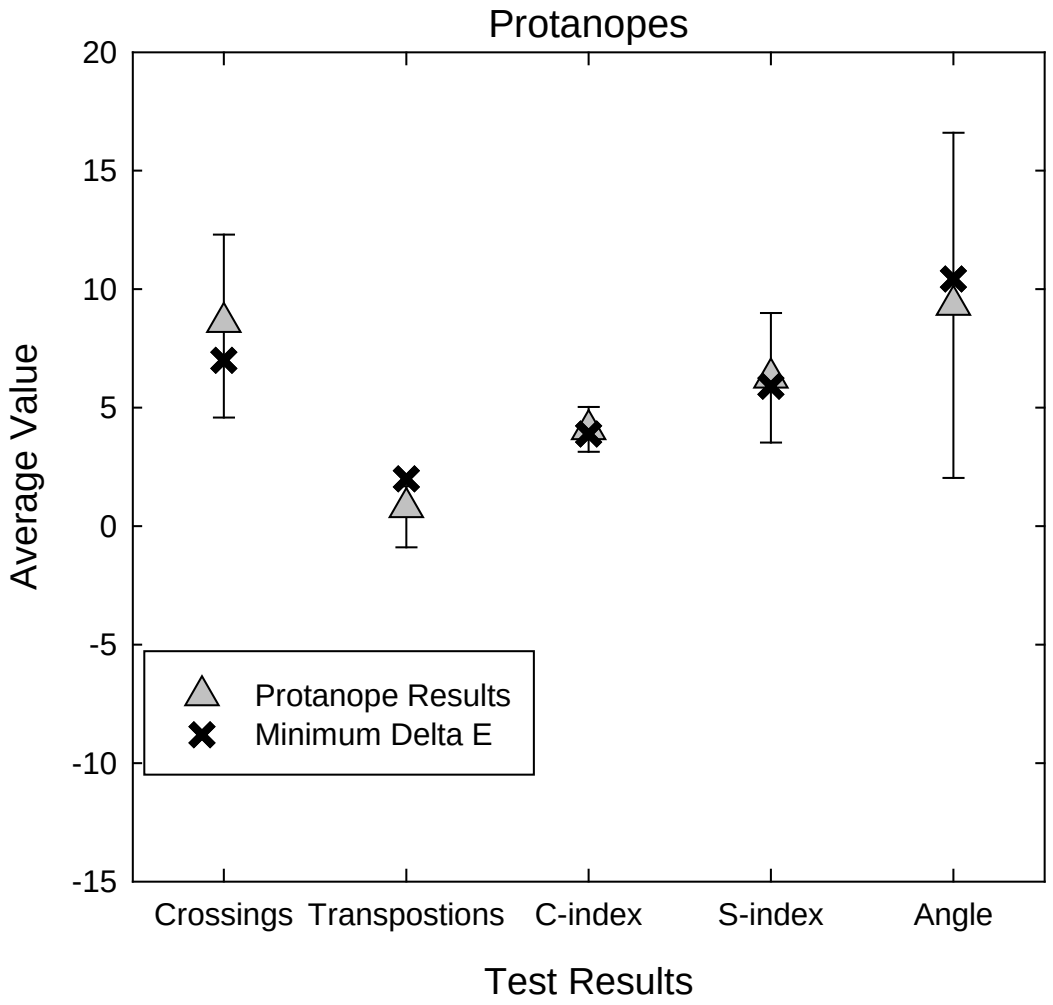
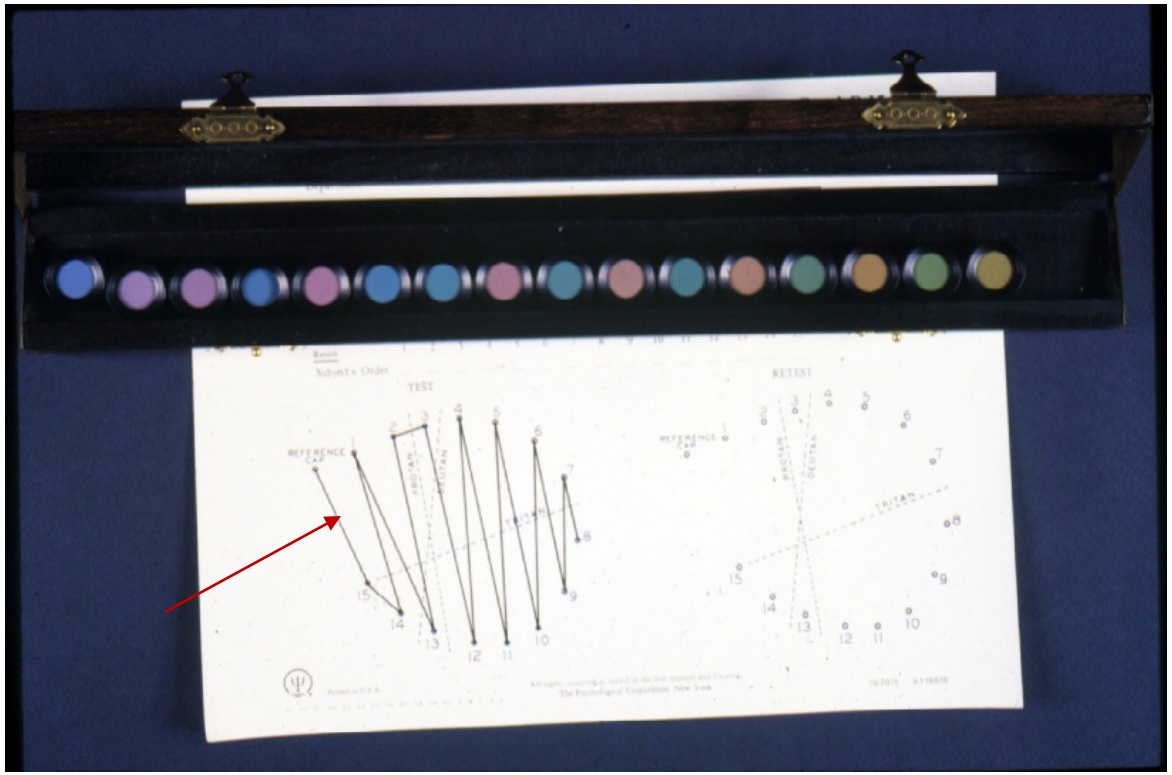
Subjects

- **The predicted arrangements were compared with the results from**
  - 8 deuteranopes (no M-cones)
  - 19 protanopes (no L-cones)

Protanopes





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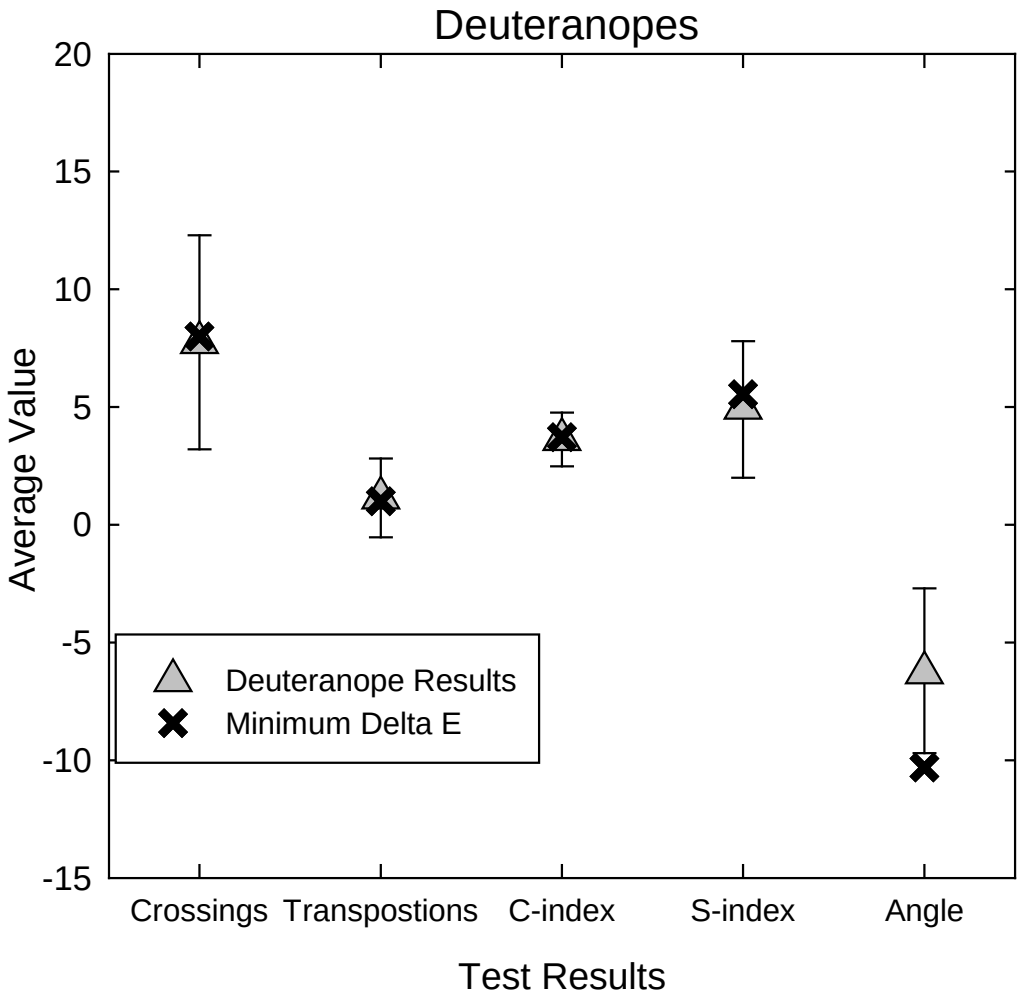
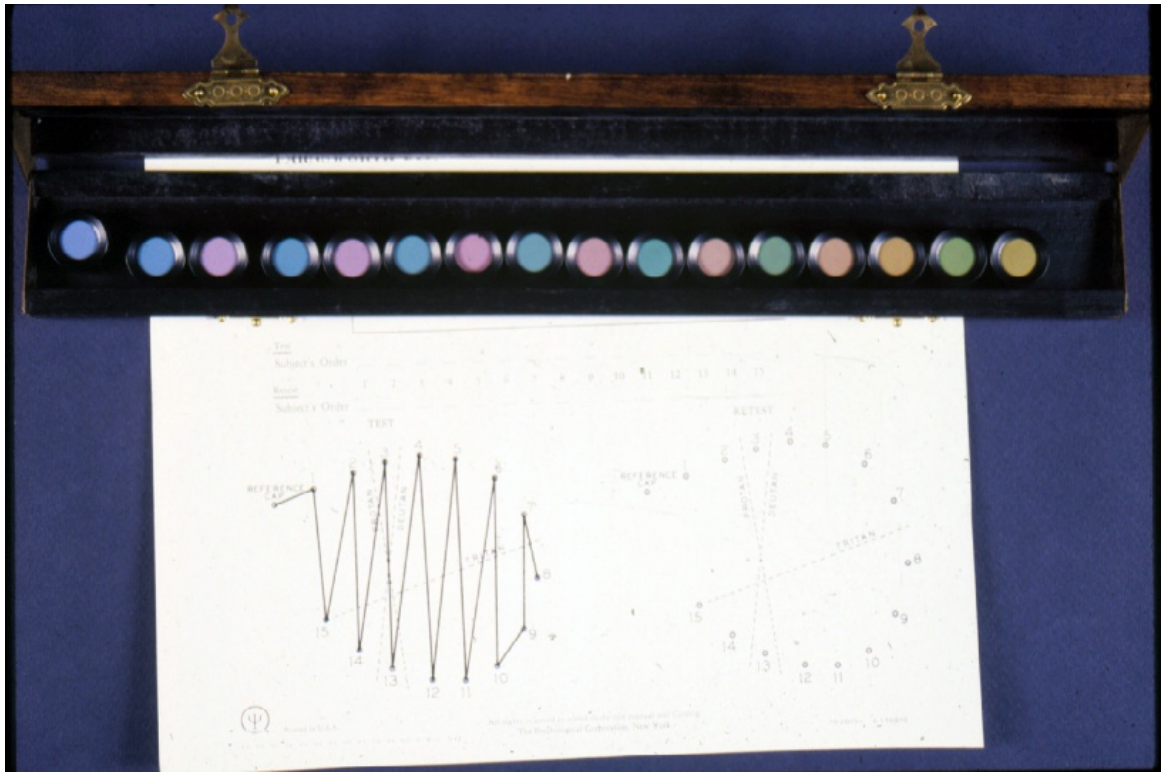
Deuteranopes





Conclusions

- Translating the Farnsworth D15 colored caps into dichromatic CIELAB space provides a very good prediction of protanopic and deuteranopic arrangements
- Although the translation may not be optimal to predict color naming errors when brightness differences are present, this approach is useful in predicting/illustrating dichromatic hue discrimination

Thanks

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