ANOMALOUS COLOUR PERCEPTION

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THIS CHAPTER WILL INCLUDE A REVIEW OF:

- Anomalous colour perception
- Colour labeling
- Hereditary colour anomalies

ANOMALOUS COLOUR PERCEPTION

V(Λ) FUNCTION

The V(λ) or luminous efficiency function may be altered in a person with anomalous colour vision. Recall that the luminance efficiency function, or V(λ) curve, is bell-shaped with a broad peak at about 555 nm. The V(λ) curves for a protanope, dueteranope and trichromat are shown in Schwartz, 2004 Fig. 6-3.

The protanope (missing erythrolabe) curve is shifted toward shorter wavelengths. The shift is due to the absence of input from erythrolabe, which is sensitive to longer wavelengths.

The deuteranope (missing chlorolabe) curve is nearly normal, since the M-cone (chlorolabe) input is not as important in the V(λ) function as the L-cone input.

Since protanopes have reduced sensitivity to long wavelengths, compared to normal trichromats, red lights appear dimmer or less saturated to them than to normal trichromats. Protanomalous trichromats show a similar change as a protanope, though less pronounced. Deuteranomalous trichromats have a nearly normal V(λ) function.

ANOMALOUS COLOUR PERCEPTION (CONT.)

WAVELENGTH DISCRIMINATION

Wavelength discrimination for a colour anomalous person is illustrated in Schwartz, 2004 Fig. 6-4. The normal wavelength discrimination function (ability to detect small changes in wavelength) has a W-shaped curve, with best sensitivities at about 500 and 600 nm. Protanopes and deuteranopes both show significantly altered wavelength discrimination (Fig. 6-4A):

Only one minima (wavelength of best wavelength discrimination)

Much worse wavelength discrimination at other wavelengths (higher values)

No wavelength discrimination (essentially monochromatic) above about 545 nm

Relate this to the spectral absorption characteristics of the cone photopigments (Figure 24-1 below). If a person is missing either the L or M-cone pigments, then he/she is essentially monochromatic beyond the range for the S-cones (about 545 nm). Monochromats are incapable of discriminating wavelengths based on wavelength information alone. See Schwartz, 2004 Fig. 6-5.

Tritanopes show an abnormal wavelength discrimination function (See Schwartz, 2004Fig. 6-4B), but at long wavelengths it is relatively good, since they are still dichromats (normal) in that range. They are also dichromatic at shorter wavelengths, but at about 500 nm, the spectral sensitivities of the M and L cones are nearly identical, so wavelength discrimination is poor in that range.

DATA COLLECTION METHOD

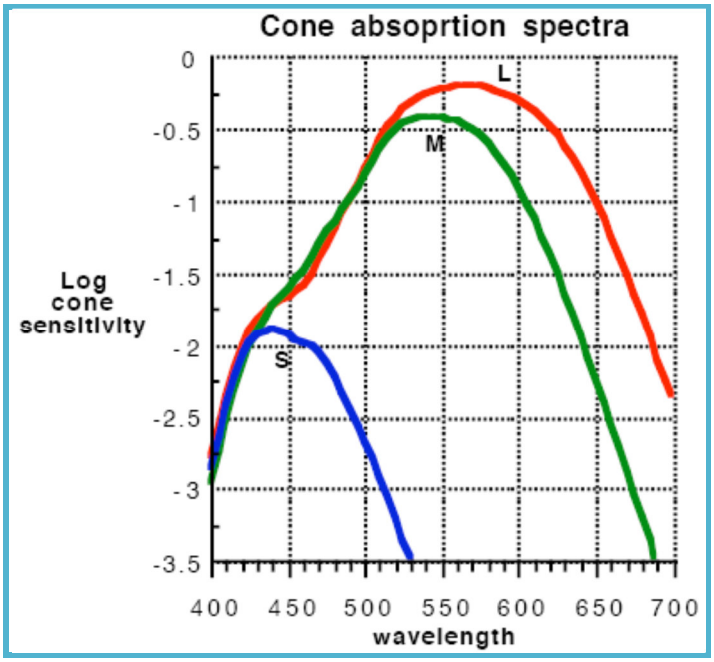

Figure 24-1: *Normal sensitivity spectra for L, M & S*

COLOUR CONFUSION

Because of their limited wavelength discrimination, dichromats confuse certain colours. A specific pattern of colour confusion characterizes each of the different dichromats. This is illustrated by the colour confusion lines on the CIE chromaticity diagram shown in Figure 24-2 and Schwartz, 2004 Fig. 6-6.

All colours falling on the same line appear to be the same colour. Note that the colour confusion lines converge to a **copunctal point** (points P, D and T on Figure 24-2)

- The protanope confuses colours such as blue-green (492 nm) with red (700 nm)
- The deuteranope confuses blue-green (498 nm) with reddish-purple (See Schwartz figures.)

COLLECTION METHOD (CONT.)

Since protanopes and deuteranopes are essentially monochromatic above 545 nm, they both share a colour confusion line that runs from 545 nm through red (600-700 nm) to the copunctal point. Since protanopes and deuteranopes easily confuse reds and greens, both anomalies are sometimes referred to as red-green colour blindness.

The tritanope confuses violet (400 nm) with yellow (570 nm). They are sometimes referred to as being blue-yellow colour blind.

Note which colours appear the same as white for the different dichromats: about 492 nm for protanopes, 498nm for deuteranopes, 569 for tritanopes. These wavelengths are known as **neutral points**.

Q. Can you see a problem in designing a traffic light with the following dominant wavelengths: Red (650 nm), yellow (570 nm), green (550 nm)?

A. _____

The most common colour anomaly is **deuteranomaly**. Why then would it be better to make the green traffic light blue-green rather than pure green?

Colour confusion helps us understand how to create a colour vision test, such as a pseudoisochromatic plate test. Just create a figure made of dots in a sea of dots. The dots that make up the figure and background should be made up of colours that lie on a colour confusion line.

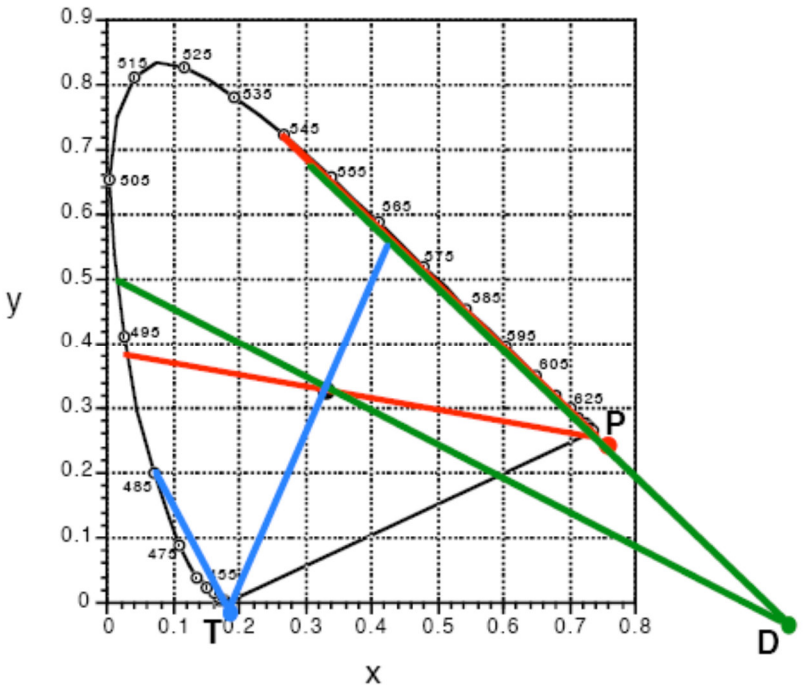

Figure 24-2: *Copunctal points and a few of the colour confusion lines. See Schwartz for details*

RELATIVE SPECTRAL SATURATION

Schwartz, 2004 Fig. 6-7A shows the relative saturation of different wavelengths. For a normal trichromat, yellow (~570 nm) appears to be the least saturated colour. The relative spectral saturation function for protanopes and deuteranopes is shifted toward shorter wavelengths, and the minimum saturation value approaches zero. This means that those wavelengths are indistinguishable from white or gray.

- For the protanope, the saturation function falls to zero at ~492 nm
- For the deuteranope it falls to zero at ~498 nm
- The tritanope neutral point is ~569 nm

COLLECTION METHOD (CONT.)

The wavelengths where the colours appear to be white are called the **neutral points** (mentioned above).

Schwartz, 2004 Fig. 6-7B shows that anomalous trichromats show a similar shift in their relative saturation functions, but they do not have neutral points.

COLOUR LABELING

Dichromats and anomalous trichromats may have little difficulty identifying the colours of objects in real life since they base their colour labeling on other factors learned from experience, such as context, object shape, relative luminance, etc. For example, they can easily identify the colour of different fruits.

When these cues are absent, and they are forced to rely on wavelength alone, they will probably make mistakes. Schwartz, 2004 Fig. 6-8 shows a band of colours representing how the spectrum might appear to persons with normal and anomalous colour vision. The width of the bands represents the span of wavelengths that appear to be the same colour. Where the wavelength discrimination is best, the bands are narrow.

NORMAL TRICHROMAT

- Full spectrum from violet to red
- Two regions of very good wavelength discrimination ~ 500 and 600 nm

PROTANOPE

- Monochromatic above 545 nm
- Poor colour saturation (nearly white) around 492 nm
- Short wavelength discrimination poor – all look blue
- Spectrum is cut short at about 650 nm due to absence of erythrolabe

DEUTERANOPE

- Monochromatic above 545 nm and poor colour saturation (nearly white) around 498 nm
- Short wavelength discrimination poor – all look blue
- Spectrum extends to 700 nm as in normals.

Protanomaly is between normal trichromacy and protanopia. Deuteranomaly is between normal trichromacy and deuteranopia.

HEREDITARY COLOUR ANOMALIES

- Protan and deutan (red-green) anomalies are passed on as a recessive trait on the X chromosome
- The defect will only be expressed when two affected X'X' chromosomes are present (female; rare) or if the affected X' chromosome is paired with a Y chromosome (X'Y; male ; more common)
- Therefore, red-green colour anomalies are predominantly seen in males (8% of males); incidence in females is about 0.4%
- Although the anomaly will not be expressed in a female with an X'X pair, she can still pass it to her children
- Any male who inherits a colour anomaly, must inherit the anomalous gene from his mother

Review Schwartz, 2004 Fig. 6-9 and be able to predict the pattern of inheritance for each possible case.

Among the four red-green anomalies (protanopia, deuteranopia, protanomaly, deuteranomaly), the most common is deuteranomaly (5% incidence in males). The others have a male incidence of 1% each (Schwartz, 2004 Table 6-2).

Inherited tritanopia and tritanomaly are very rare (male incidence 0.005%) and are passed on as autosomal dominant traits.

HEREDITARY COLOUR ANOMALIES (CONT.)

ACHROMATOPSIA

In this condition the patient apparently has no colour perception, and he/she usually has other severe visual anomalies including poor VA, nystagmus and photophobia. There are several types:

- **Rod monochromat** (typical achromacy) – Very rare hereditary (autosomal recessive) condition in which the patient has only rods. He/she will have poor VA, nystagmus, photophobia & abnormal colour perception
- **Blue cone monochromacy** (incomplete congenital cone dysfunction or cone monochromacy) – rare hereditary (X linked recessive) condition; has rods and S cones only
- **Green cone monochromacy** – has rods and M cones only. Very rare.
- **Red cone monochromacy** – has rods and L cones only. Very rare

SELECTED READING/REFERENCES

- Schwartz SH. **Visual Perception - A Clinical Orientation, 3rd Edition**. Appleton & Lange, Stamford, Connecticut, 2004