COLOUR OPPONENT THEORY AND COLOUR ANOMALIES

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THIS CHAPTER WILL INCLUDE A REVIEW OF:

- Colour opponent theory
- Anomalies of colour vision
- Types of colour anomalies

COLOUR OPPONENT THEORY

The trichromatic theory of colour vision is based on three cone types, each of which is sensitive to a different range of wavelengths. This explains how we can discriminate different wavelengths, and the trichromatic theory is supported by colour matching experiments and neurophysiological studies.

The neural processing of colour becomes more complex beyond the photoreceptors. There is evidence that, after the cones, neural signals are processed through a **"colour opponent"** system. Opponent processing begins within the retina at the level of the horizontal cells. The theory states that signals from the S, M and L cones are processed by three neural channels known as the **red-green**, **blue-yellow** and **brightness channels**.

Evidence of this kind of neural processing:

- The observation that you never see a mixture of red and green in the same place at the same time. When it comes to red and green, they appear to be opposite responses of a neural system that can signal either red or green but not both at the same time. Although people may mix colours such as blue-green, most cannot conceive of a mix of red and green
- Similarly, with blue and yellow, you cannot see both colours at the same time in the same place. It's either blue or yellow. Most people cannot conceive of a mixture of blue and yellow
- Research by Hurvich and Jameson using the hue-cancellation method (See Schwartz, 2004 p. 119) support colour opponent theory. They proposed that the response of certain neuronal channels in the visual system varies in according to wavelength as shown in Schwartz, 2004 Fig. 5-14
- Neurophysiological recordings from monkey LGN cells showed that certain neurons respond with opposite polarity depending on the wavelength (Schwartz, 2004 Fig. 5-16A). For example, if the animal is exposed to a short wavelength, the neuron shows a reduced rate of firing; that is, inhibition. However, when exposed to long wavelengths, the neuron responds with excitation
- Colour afterimages. If you stare at a green image, then view a white field, you see a red afterimage. Likewise, if you stare at a blue image, then view a white field, you see a yellow afterimage

COLOUR OPPONENT THEORY (CONT.)

Neurons that respond with opposite signals depending on the stimulus wavelength are known as colour **opponents cells**, and they are capable of relaying colour information. It is evident that our visual system includes colour opponent neurons as well as non-colour opponent neurons (Schwartz, 2004 Fig. 5-16B). Non-opponent cells respond with the same polarity for all wavelengths, though the magnitude of the response varies depending on wavelength.

Over 100 years ago, Hering proposed that human colour perception is based on red-green and blue-yellow colour opponent channels, but scientists of that time thought opponent theory contradicted the accepted trichromatic theory. Hering's opponent theory of colour vision was therefore not accepted.

Vision scientists now believe that both the trichromatic and opponent systems work together. At the receptor level, our visual system is trichromatic, but at higher levels, perhaps beginning with the horizontal cells, the visual system appears to use colour opponent mechanisms. This combined model of colour vision is called a **"zone model."** One example of a zone model is illustrated in Figure 23-1, below, and similar concepts are illustrated in Schwartz Fig. 5-17.

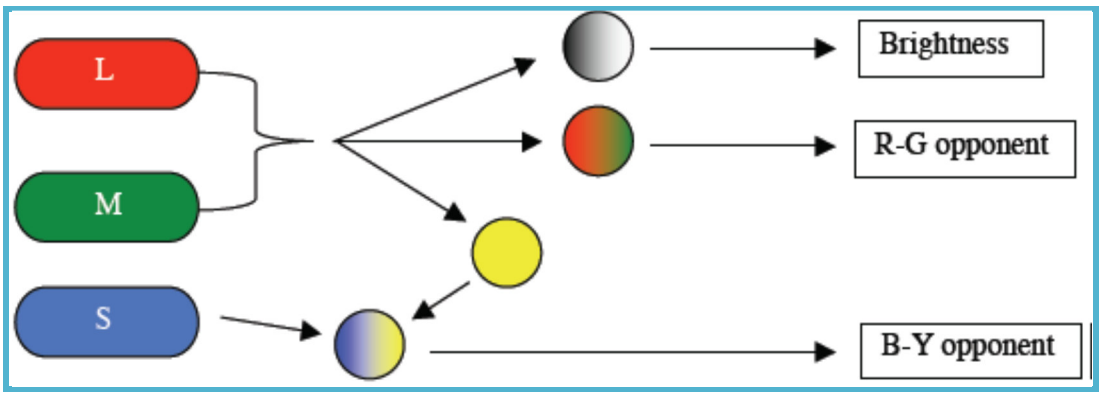

Figure 23-1: *One example of a zone model that shows the relationship between the trichromatic and opponent parts of the visual system.*

INTRODUCTION TO ANOMALIES OF COLOUR VISION

Anomalies of colour vision affect about 4.5% of the general population, or nearly 1/20 people. You will therefore certainly see many patients who have some degree of anomalous colour vision. Colour anomalies may be broadly classified by aetiology as either hereditary or acquired colour defects. Characteristics of these two groups are distinct and are summarized below.

HEREDITARY DEFECTS

- More common
- Non-progressive, stable
- Relatively few colour naming errors in real life
- Not sight threatening
- May affect job performance when colour perception is critical to certain tasks
- Mostly affects males (96%)
- Binocular
- Diagnosis and classification straight-forward
- 99% of these are red-green defects

INTRODUCTION TO ANOMALIES OF COLOUR VISION (CONT.)

ACQUIRED COLOUR DEFECTS

- Rare but more dangerous
- Associated with ocular disease, therefore potentially sight threatening
- Recent onset, progressive, variable
- Colour naming errors more common
- Can affect males or females
- Monocular or asymmetric
- Diagnosis and classification more difficult
- Red-green as well as blue-yellow defects

TYPES OF COLOUR ANOMALIES

The defects can be classified according to which cone photopigment is either missing or anomalous.

- **"Protan-_____"** refers to an anomaly with erythrolabe (red deficient)
- **"Deutan-_____"** refers to an anomaly with chlorolabe (green deficient)
- **"Tritan-_____"** refers to an anomaly with cyanolabe (blue deficient)

Colour defects may also be classified according to the magnitude of the defect. Absolute colour blindness of some kind ends with the suffix **"-opia."** Normal vision is trichromatic, but people who are completely missing one of the cone types are known as **dichromats**.

DICHROMACY

- Absence of one of the three cones photopigments
- A more absolute form of "colour blindness"
- Three types depending on which pigment is missing: **protanope, deuteranope, tritanope**

Other people may have all three cone types, but there may be a weakness or anomaly in one of the photopigments. These partial colour anomalies use the suffix, **"-anomaly."** These people are known as **anomalous trichromats**.

ANOMALOUS TRICHROMACY

- All three photopigments present (erythrolabe, chlorolabe, cyanolabe)
- One has an abnormal absorption spectrum that is shifted toward one of the other pigment's spectra
- Protanomalous trichromat - erythrolabe spectrum shifted toward shorter wavelengths, making it closer to chlorolabe
- Deuteranomalous trichromat - chlorolabe spectrum shifted toward longer wavelength, making it more similar to erythrolabe
- See Schwartz, 2004 Fig. 6-1

Protans and deutans are sometimes referred to as **red-green** anomalous. These defects are usually hereditary, and are more common. The colour response of patients with red-green anomalies are well defined.

Tritans are referred to as **blue-yellow** anomalous. Hereditary blue-yellow defects are very rare. If detected, you should presume that it is an acquired defect caused by an ocular disease, until proved otherwise. You may see references to another colour anomaly called, **tetartanomaly**. It is a rare subtype of tritanomaly.

TYPES OF COLOUR ANOMALIES (CONT.)

Table 23-1: *Summary of classifications*

	RED (PROTAN)	GREEN (DEUTAN)	BLUE (TRITAN)
DICHROMAT	Protanope; No erythrolabe	Deuteranope; No chlorable	Tritanope; No cyanolabe
ANOMALOUS TRICHROMAT (SCHWATRZ, 2004 FIG. 6.1)	Protanomalous abnormal erythrolable (normal peak @565nm) absorption spectrum shifted to shorter λ	Deuteranomalous abnormal chlorable (normal peak @ 535 nm) absorption spectrum shifted to longer λ	Tritanomalous abnormal cyanolabe (normal peak @ 430 nm)
ETIOLOGY USUALLY	Heredity	Heredity	Acquired (rare)

SELECTED READING/REFERENCES

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