A case of achromatopsia

“The ‘wrongness’ of everything was disturbing, even disgusting... he turned increasingly to black and white foods – to black olives and white rice, black coffee and yoghurt. These at least appeared relatively normal, whereas most foods, normally coloured, now appeared horribly abnormal.”

He confused many things – grey and yellow socks, red and green peppers, mustard and mayonnaise. He could no longer see clouds, since they were indistinguishable from the apparently pale-grey sky.


Spectral Properties of Light

The Visible Spectrum

- Visible wavelengths extend from about 400 to 700 nm

Perceptual Colour Space

- Descriptions of colour use three attributes:
  - Hue
  - Saturation
  - Brightness
- Note opponent colours:
  - Red vs. green
  - Blue vs. yellow

Subtractive Colour Mixture

- Mixing different dyes or pigments
- Each dye or pigment absorbs certain wavelengths and reflects others
- The colour we see is determined by the wavelengths not absorbed by any of the dyes or pigments
- Subtractive mixture has great practical value, but is not useful as a tool for developing colour theories because it is too unpredictable.

Additive Colour Mixture

- Adding or combining different light sources
- Wavelengths of each source reach the photoreceptors
- An everyday example is the colours seen on TV and computer displays.
Additive Mixture: Metamers

- Metamers are pairs of light containing different wavelengths that appear identical.
- A test colour containing a single wavelength can be matched subjectively to another colour containing a mixture of ‘primary’ wavelengths at different intensities.
- Eg. (red+green) primaries subjectively match a yellow test.
- Normal observers require no more than three primaries to match any test colour.

Explaining Metamerism

Metamers appear identical because they create the same pattern of firing in the three types of cone receptors in the retina.
Metamerism supports the ‘trichromatic’ theory of colour vision

Trichromacy

- First proposed in 1777 by Palmer, and later advocated Thomas Young in 1802 and von Helmholtz in 1867.
- It proposed three kinds of colour ‘fibre’, responsive to blue, green, and red.
- Perceived colour is determined by the pattern of activation across the three fibres.

Dual-Process Theory

- Note the discrepancy between opponent colours in perceptual colour space, and retinal trichromacy.
- Hurvich and Jameson (1957) proposed that both trichromacy and opponency theories were correct, but applied to different stages of visual processing.
- An initial trichromatic stage provides the input for a second, opponent-process stage.
- Hurvich and Jameson explained many phenomena with this theory, and later physiological experiments supported the theory

Colour Interactions

- Colour matching succeeds only against a neutral background, in the absence of prior adaptation.
- Context, either spatial or temporal, is known to influence colour.
**Colour Contrast**

- The appearance of one colour is changed when it is surrounded by another colour.
- A colour surrounded by its complement tends to appear reduced in saturation.
- Neutral colours tend to adopt a hue that is complementary to the hue of the surrounding colour.

**Colour Adaptation**

- Exposure of an area of the retina to a specific colour results in a loss in sensitivity to that colour.
- This is functionally equivalent to making the same area of retina more sensitive to the complementary colour.

**Origin of Colour Interactions**

- Contrast and adaptation can be explained using triads of cone responses.
- The hue of a surface is determined by a comparison of its response triad with the response triad of the contextual colour.

**Explaining colour contrast**

- The colour of the green disc depends on relative cone responses to the disc and the background.

**Explaining colour adaptation**

- Adaptation alters relative cone response
Colour Constancy

• What is the functional significance of contrast and adaptation effects?
• Light reaching the eye from surfaces depends jointly on the spectral properties of the illuminant, and the spectral reflectance of each surface.
• Spectral reflectance is an inherent property of a surface.
• Contrast and adaptation serve to remove the effect of the illuminant and extract information about surface reflectance.

Colour Constancy

• The hue of an object remains constant despite changes in the wavelength of the illuminating light.
• Films have no constancy mechanisms, so colours change according to lighting.

Colour Constancy

• The ratio of responses across cone types remains stable despite changes in the properties of the illuminating light.
• Comparisons of cone excitation ratios therefore provide information on surface reflectance.

Incidence of Colour Defects

<table>
<thead>
<tr>
<th>Deficiency</th>
<th>% Prevalence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protanomaly (L)</td>
<td>1.73</td>
</tr>
<tr>
<td>Deuteranomaly (M)</td>
<td>4.78</td>
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<tr>
<td>Protanopia (L)</td>
<td>0.81</td>
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<tr>
<td>Deuteranopia (M)</td>
<td>0.48</td>
</tr>
<tr>
<td>Tritanopia (S)</td>
<td>0.45</td>
</tr>
<tr>
<td>Monochromatism (no cones)</td>
<td>0.3</td>
</tr>
</tbody>
</table>

Testing Colour Deficiency

• Reported number depends on colour deficiency.
### Origin of Colour Defects

- Colour deficiency occurs mainly in males (9%) rather than females (0.5%).
- It is genetically transmitted.
- The relevant recessive genes are located on the X (sex-linked) chromosome.
- Females have two X (one from each parent), males have X from mother, Y from father.
- Males inherit the anomaly if the single X chromosome from the mother carries the trait.
- Females are affected only if they receive a variant X chromosome from both parents.
- Prevalence varies markedly between racial groups, with Caucasians showing higher incidence than other groups.