

H 12: Vision Properties and Effects

Normal light (photopic vision)

At medium and high levels of illumination the three types of cones cells are sensitive to light and the rod cells are insensitive to light. The signals from the three types of cones cells provide full colour vision as well as light/dark perception.

The sensitivity of each of the three types of cone cell acting in isolation was determined by Estevez in 1979 and is shown by Hunt as a plot of relative sensitivity in Figure 1.

The cone cells tend to be connected either

individually or in very small groups to the nerve fibres and as a result photopic vision gives the highest degree of spatial resolution available.

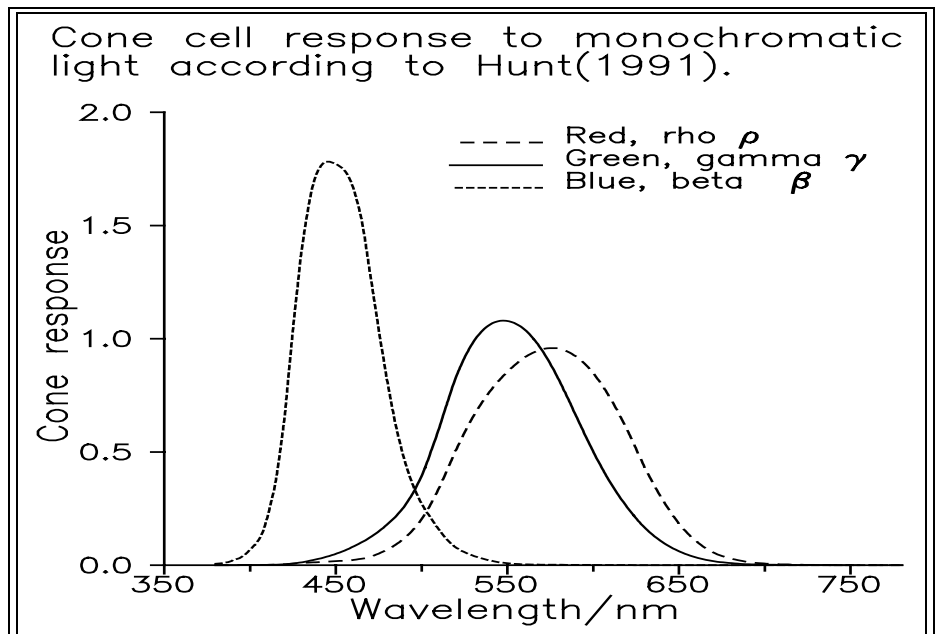


Figure 1: Cone cell response under photopic conditions. The area under each curve is the same

Low light (scotopic vision)

At low levels of illumination the rod type cells are sensitive to light and provide a monochromatic or light/dark perception.

Figure 2 plots the relative response of rods to light at each wavelength in the visible spectrum and shows under scotopic conditions they are most sensitive to light at about 510nm (bluish green) with 1700 lumens/Watt.

The photopic luminous response (cones) is most sensitive at a wavelength of 555nm with a sensitivity of 683 lumens/Watt.

The rod cells are not individually connected to an optic nerve, several cells are connected to one nerve fibre and as a result scotopic vision is lower in spatial resolution than photopic vision.

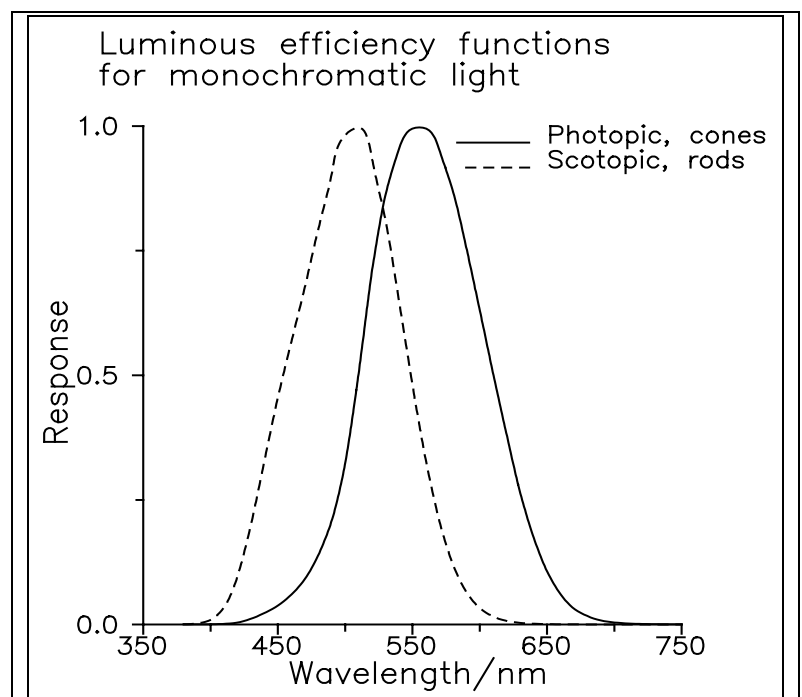


Figure 2: Luminous response of the eye under scotopic conditions and under photopic conditions.

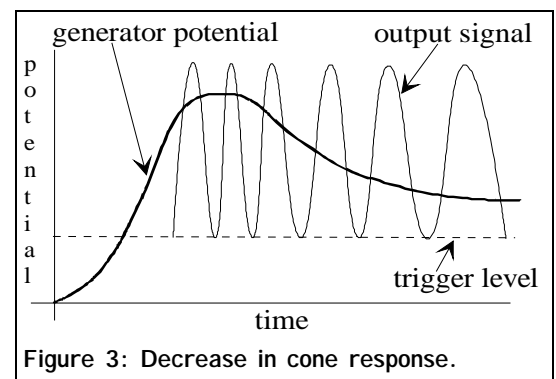
Adaptation of vision

Chromatic adaptation

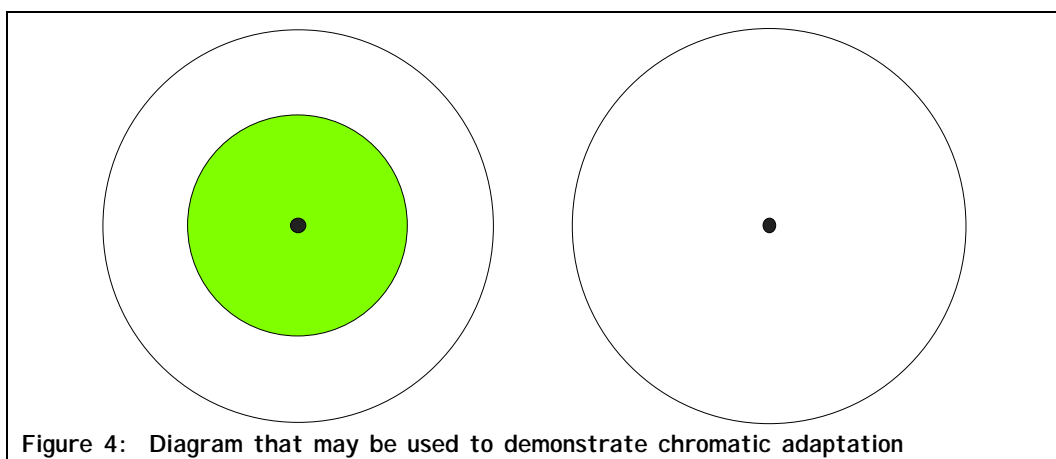
The instantaneous response of the eye to a continuous stimulus is different to that a few seconds later when the retina has become adapted. This process is best understood by first considering the way in which sensing cells operate. A stimulus to the cell generates an electrical potential within the cell termed the generator potential, when this potential exceeds a trigger level an output is generated in the form of a series of pulses. The magnitude of the pulse is constant but the frequency of pulses increases the higher the generator potential is over the trigger level.

The process of adaptation to a constant stimulus is illustrated Figure 3. When a continuous stimulus is applied, the generator potential rises to a peak value and then decreases to lower constant level.

Adaptation has a number of important consequences. The most important is that the response of the retina changes according to the average illumination in the environment. Consequently, a white object is perceived as white under a wide range of illumination conditions. For example, the spectrum of light reflected by a white piece of paper is very different when illuminated by daylight to that under incandescent light, yet the paper is perceived as white under both conditions.



Adaptation can be demonstrated with the aid of Figure 4: Stare, for at least 30 seconds at the green coloured circle on the white piece of paper. The green sensitive cone cells on which the image of the circle falls will become adapted and hence less sensitive. When the gaze is switched to a plain white piece of paper, an after-image of a magenta coloured circle will be visible instantly. Although all three cones are now receiving the same stimulus, the de-sensitised green cones give a lower output than the red or blue sensitive cones. The temporary imbalance gives the impression of a magenta circle. The magenta circle will disappear as the retina adapts to the new image conditions.



Simultaneous contrast

Simultaneous contrast describes one type of effect where the perception of colour of an area of an image is changed by the colour of the neighbouring areas. It arises from the many lateral interconnections between the nerve cells. The interconnections act by inhibiting the signal from one set of cells (group A) when a neighbouring set of cells (group B) are active and vice versa. The net effect is to emphasize boundaries between areas of different colour or lightness. For example, a medium grey stripe on a dark grey background will appear lighter than the same stripe viewed

against a light grey background. Figure 5 illustrates this effect.

The grey vertical stripes in the diagram both have the same reflectance properties, the effect of the neighbouring areas make the appearance of the stripe on the left-hand side different from that on the right hand side. The lightness of the grey is between that of the yellow and of the blue. When the grey is viewed over the lighter, yellow background the grey will appear to be darker than its “true” colour. When it is viewed against the darker, blue background, the grey will appear to be lighter than its “true” colour.

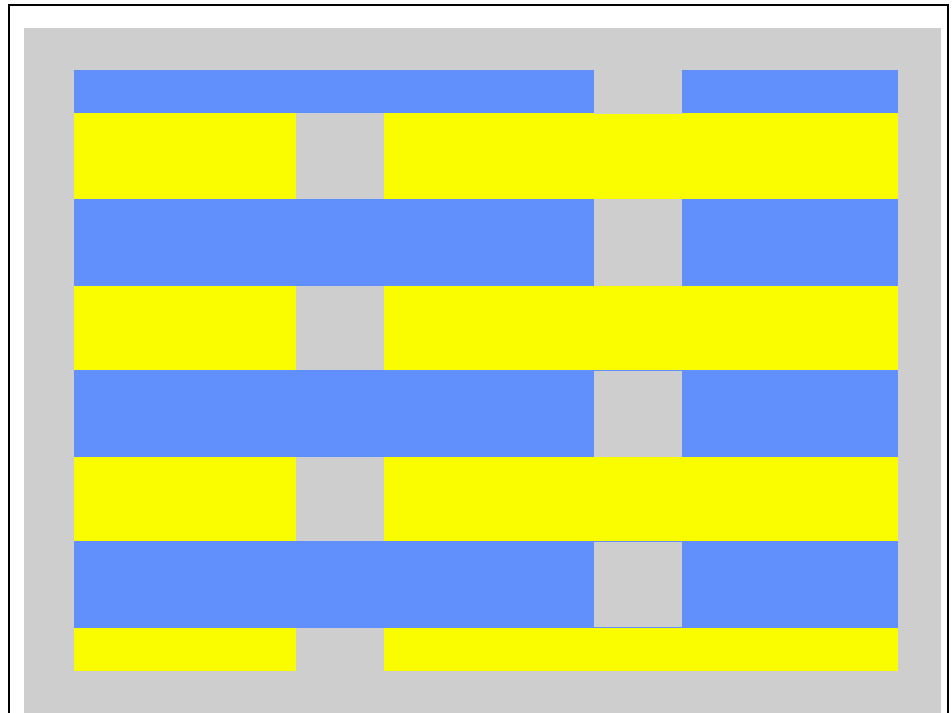


Figure 5: The simultaneous contrast effect. The vertical strips are identical but have different appearance

Receptive field and lateral inhibition

The simultaneous contrast effect arises from the many lateral interconnections between the nerve cells. The interconnections act by inhibiting the signal from a *centre* set of cells (excitatory) when a neighbouring set of *surround* cells (inhibitory) are active and vice versa. The concept is illustrated in Figure 6.

The interconnections between the signals are made by excitatory synapses and inhibitory synapses, as shown in Figure 7.

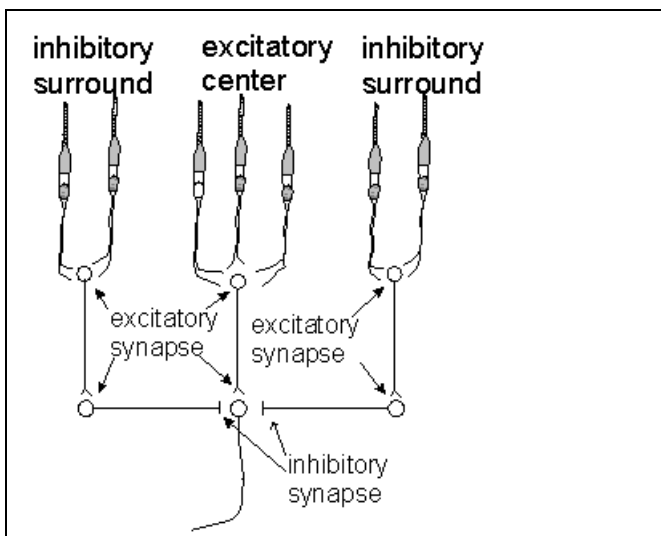


Figure 6: Connections between centre and surround

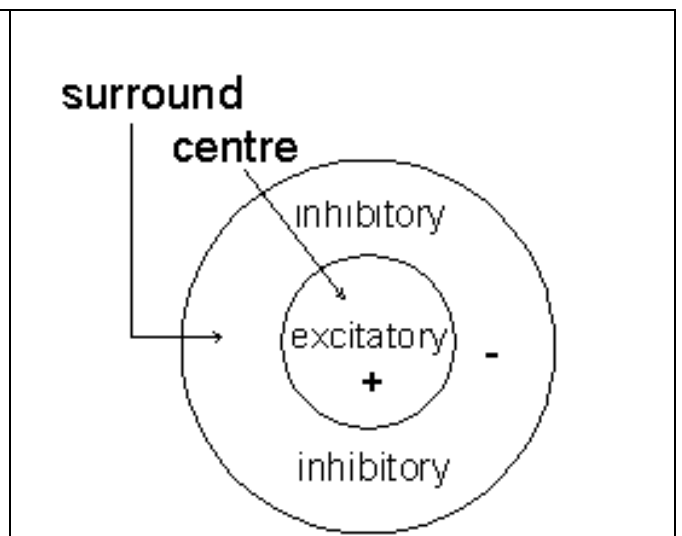


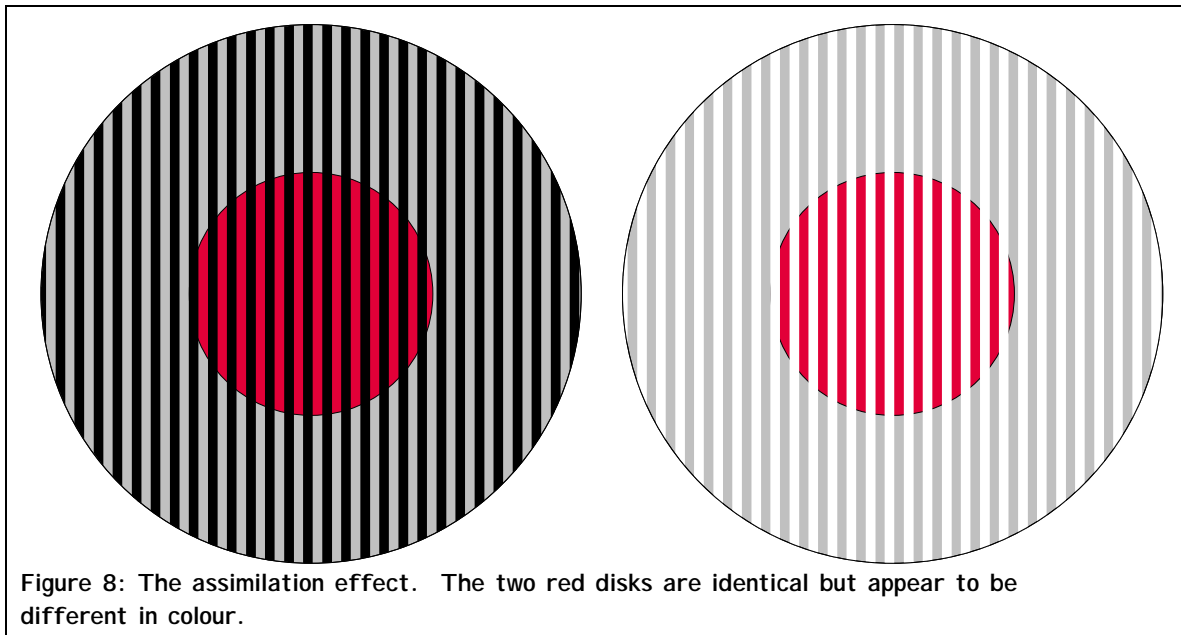
Figure 7: The receptive field

If the receptive field is covered by a uniform section of the image, then the level of suppression of the central signal by the surround could be called “normal”. Now imagine that the image falling on the surround is lighter than the centre, the suppression from the surround will be higher than the uniform image case. As a result, the image from the central elements will appear to be darker than in

the uniform field condition.

Assimilation

Assimilation describes another type of effect where the perception of the colour of an area within an image is changed by the colour of the neighbouring areas. The effect is illustrated in Figure 8, where the same shade of red disk is covered by a grid of black lines (LHS) and by a grid of white lines (RHS). The LHS disk appears to be darker than the RHS disk. The appearance of the disk is changed by the nature of the overlapping grid and it has assimilated, or taken on, some of the characteristics of the grid. The black line grid makes the disk appear darker, the white line grid makes the disk appear lighter.



Ideal viewing conditions

From the structure of the eye it is clear that several viewing conditions must be controlled in order to establish reliable assessments of the colours of objects.

- The level of illumination must be sufficient to produce photopic (cone) vision.
- The field of view must be controlled so that the image produced by the lens falls on roughly the same area of the retina.
- The nature of the background against which the sample is viewed must be controlled. A medium bluish grey (smoky) is to be preferred.

Number of colours

Under ideal viewing conditions a normal observer can distinguish about 3 to 4 million separate colours. These are colours that can be seen as just visibly different from each other.