bands and sensitivity to unsensed phenomena. These properties are integral to human vision. At present, human vision is far more sophisticated than we can hope to achieve with a computer vision system. Infrared guided-missile vision systems can actually have difficulty in distinguishing between a bird at 100 m and a plane at 10 km. Poor birds! (Lucky plane?) Human vision can handle this with ease.

1.3.2 The neural system

Neural signals provided by the eye are essentially the transformed response of the wavelength dependent receptors, the cones and the rods. One *model* is to combine these transformed signals by addition, as illustrated in Figure **1.5**. The response is transformed by a logarithmic function, mirroring the known response of the eye. This is then multiplied by a weighting factor that controls the contribution of a particular sensor. This can be arranged to allow a combination of responses from a particular region. The weighting factors can be chosen to afford particular filtering properties. For example, in *lateral inhibition*, the weights for the centre sensors are much greater than the weights for those at the extreme. This allows the response of the centre sensors to dominate the combined response given by addition. If the weights in one half are chosen to be negative, whilst those in the other half are positive, then the output will show detection of contrast (change in brightness), given by the differencing action of the weighting functions.

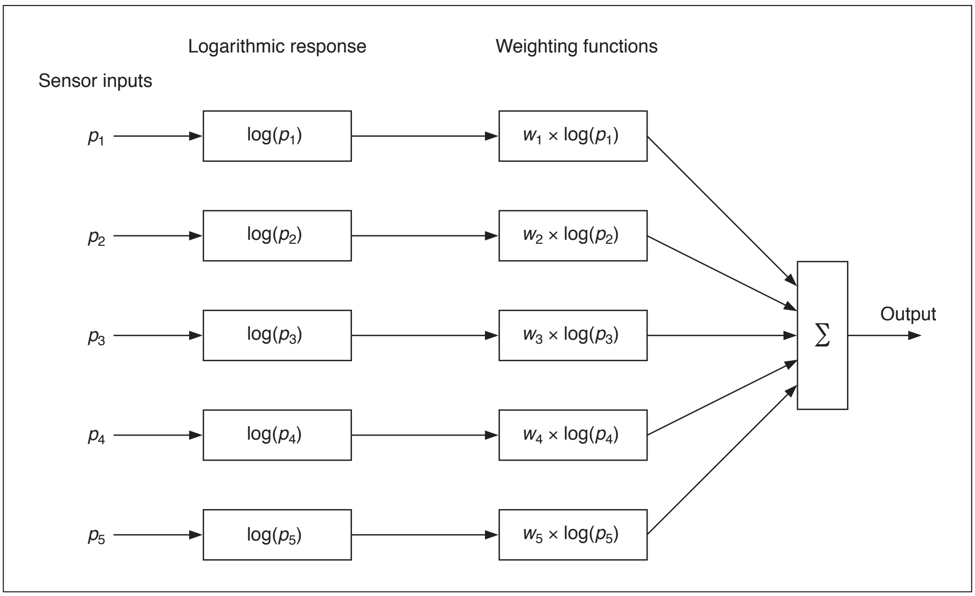

Figure 1.5 Neural processing

The signals from the cones can be combined in a manner that reflects *chrominance* (*colour*) and *luminance* (*brightness*). This can be achieved by subtraction of logarithmic functions, which is then equivalent to taking the logarithm of their ratio. This allows measures of chrominance to be obtained. In this manner, the signals derived from the sensors are combined prior to transmission through the optic nerve. This is an experimental model, since there are many ways possible to combine the different signals together. For further information on retinal neural networks, see Ratliff (1965); an alternative study of neural processing can be found in Overington (1992).

1.3.3 Processing

The neural signals are then transmitted to two areas of the brain for further processing. These areas are the *associative cortex*, where *links* between objects are made, and the *occipital cortex*, where *patterns* are processed. It is naturally difficult to determine precisely what happens in this region of the brain. To date, there have been no volunteers for detailed study of their brain's function (though progress with new imaging modalities such as Positive Emission Tomography or Electrical Impedance Tomography will doubtless help). For this reason, there are only psychological models to suggest how this region of the brain operates.

It is well known that one function of the eye is to use edges, or *boundaries*, of objects. We can easily read the word in Figure **1.6**(a), this is achieved by filling in the missing boundaries in the knowledge that the pattern most likely represents a printed word. But we can infer more about this image; there is a suggestion of illumination, causing shadows to appear in unlit areas. If the light source is bright, then the image will be washed out, causing the disappearance of the boundaries which are interpolated by our eyes. So there is more than just physical response, there is also knowledge, including prior knowledge of solid geometry. This situation is illustrated in Figure **1.6**(b) that could represent three 'Pacmen' about to collide, or a white triangle placed on top of three black circles. Either situation is possible.

Figure 1.6 How human vision uses edges

It is also possible to deceive the eye, primarily by imposing a scene that it has not been trained to handle. In the famous *Zollner illusion*, Figure **1.7**(a), the bars appear to be *slanted*, whereas in reality they are *vertical* (check this by placing a pen between the lines): the small crossbars mislead your eye into perceiving the vertical bars as slanting. In the *Ebbinghaus illusion*, Figure **1.7**(b), the inner circle appears to be *larger* when surrounded by *small* circles, than it appears when surrounded by larger circles.

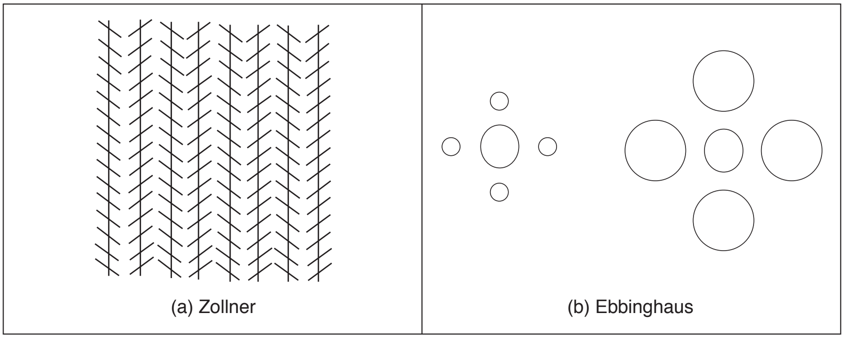

Figure 1.7 Static illusions

There are dynamic illusions too: you can always impress children with the 'see my wobbly pencil' trick. Just hold the pencil loosely between your fingers then, to whoops of childish glee, when the pencil is shaken up and down, the solid pencil will appear to bend. *Benham's disk*, Figure **1.8**, shows how hard it is to model vision accurately. If you make up a version of this disk into a spinner (push a matchstick through the centre) and spin it anti-clockwise, you do not see three dark rings, you will see three *coloured* ones. The outside one will appear to be *red*, the middle one a sort of *green*, and the inner one will appear deep *blue*. (This can depend greatly on lighting – and contrast between the black and white on the disk. If the colours are not clear, try it in a different place, with different lighting.) You can appear to explain this when you notice that the red colours are associated with the long lines, and the blue with short lines. But this is from physics, not psychology. Now spin the disk clockwise. The order of the colours reverses: *red* is associated with the *short* lines (inside), and *blue* with the *long* lines (outside). So the argument from physics is clearly incorrect, since red is now associated with short lines not long ones, revealing the need for psychological explanation of the eyes' function. This is not colour perception, see Armstrong (1991) for an interesting (and interactive!) study of colour theory and perception.

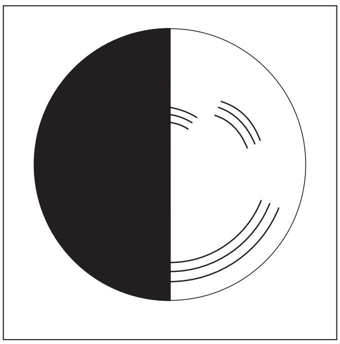

Figure 1.8 Benham's disk

Naturally, there are many texts on human vision. Marr's seminal text (Marr, 1982) is a computational investigation into human vision and visual perception, investigating it from