Describe and evaluate research into the nature of visual information processing (e.g. the processing of colour)

Ornstein (1975) describes the eye as 'the most important avenue of personal consciousness' and it's estimated that 80 per cent of the information we receive about the external world reaches us through vision (Dodwell, 1995). Research has focused on vision both as a sensory and a perceptual system. One area of research into the nature of visual information processing centres on the processing of colour.

All light rays entering our eyes from the external environment are brought to a focus at one point on the retina, where an image will be formed. The retina is made up of 120 million rods and 7 million cones used in the processing of that light. The rods are specialised for vision in dim light, including night-time vision, and contain a photosensitive chemical (rhodopsin), which changes structure in response to low levels of illumination. They help us see black, white and intermediate greys (achromatic colour). The cones are specialised for bright light vision, including daylight, and contain iodopsin. They help us see chromatic colour (red, green, blue and so on)

Light can be describe physically by its energy spectrum (intensities at different wavelengths) or phenomenologically by three dimensions: brightness (perceived intensity), hue (perceived colour), and saturation (the purity of hue; how much colour or how much white). Although both hue and saturation are aspects of 'colour', theories of colour vision and its defects are concerned mainly with hue.

Rushton & Campbell (1954; cited in Rushton, 1987) were the first to measure the photosensitive pigments contained within the rods and cones of the living human eye. They applied the familiar observation that a cat's eye will reflect back light shone in it. They found that instead of the *tapetum lucidium* of the cat's eye that reflects back the light, however, humans have a very black surface behind our retinas (the choroid coat), which reflects only very faint light. Rushton and Campbell identified rhodopsin, the photosensitive pigment of the rods, plus red and green pigments. However, they found that insufficient blue light is reflected to measure the blue cone pigment (Rushton, 1987). Rushton and Campbell's findings were also confirmed using living colour-blind participants, who possessed only one of the two pigments measured by them.

There are two opposing theories as to how we process colour, the Young-Helmholtz trichromatic theory and the opponent process theory.

The trichromatic theory (Young, 1801) claims that colour is mediated by three different kinds of cone, each responding to light from a different part of the visible spectrum, blue-sensitive, responsive to short wavelengths; green-sensitive, responsive to medium wavelengths; and red-sensitive cones responsive to long wavelengths. While the sum of the three wavelengths (B+G+R) determines brightness, their ratio or pattern (B:G:R) determines colour.

This theory suggests that every colour (including white) should excite blue, green and red cones in a characteristic set of ratios, such that a mixture of red and green and blue light, adjusted to produce this same set of ratios, should appear white or whatever the initial colour was. Maxwell (1854) found that every colour can be matched by a suitable mixture of blue, green and red 'primaries' (the trichromacy of colour), and this was later confirmed by

Helmholtz (Rushton, 1987). Hence, this theory is often referred to as the Young-Helmholtz trichromatic theory.

Later, Marks *et al*. (1964; cited in Rushton, 1987) used fresh retinas from monkeys and human eyes removed during surgery to measure visual pigments in single cones. They found the blue, green and red sensitive cones, thus supporting the Young-Helmholtz trichromatic theory.

While the Young-Helmholtz theory can explain the effects of mixing colours of different wavelengths, it has difficulty explaining colour blindness and the phenomenon of negative after-images.

The most common form of colour vision defect is the inability to distinguish between red and green. Sufferers are referred to as having dichromatic vision, as they only possess red or green sensitive cone pigments. The next most common deficit is true colour blindness, which involves an absence of any cones at all (monochromatic vision), and the least common form of colour vision deficit is that of yellow-blue blindness.

Negative (or complementary) after-images occur if you look intently at a coloured surface, for example red, and then look at a plain surface. You'll find that you perceive an after-image that is the 'opposite' of the colour you just looked at, which in the case of red would be green.

Both colour blindness and negative after-images can be explained more easily by the opponent process (tetrachromatic) theory (Hering, 1878). This claims that colour analysis depends on the action of two types of detector, each having two modes of response, one signals red or green, the other signals yellow or blue. A third type of detector, black–white, contributes to the perception of brightness and saturation.

Further evidence in support of the opponent process theory comes from DeValois & Jacobs (1984), who suggested that while the retina encodes in terms of three constituent components (a blue–green–red 'component' system: stage one of colour vision), output through the bipolar and ganglion cells and onto the LGN (stage two) becomes recorded in terms of opponent processes. They suggested that there seem to be four kinds of LGN cells: those which increase activity to red light but decrease with green (R+ G-), and similarly for green and red (G+ R-) and blue and yellow (B+ Y-). Still other LGN cells simply respond to black and white (Beaumont, 1988).

According to Harris (1998), both theories are compatible, and neurophysiological evidence exists for both, which has led to the generally held view that a complete theory of colour vision must draw on elements from both theories.