A summary of honeybee colour vision

(As published in recent papers and the CABI book; 2019).

In the study of the bees' vision of colour, first the emission spectrum of each of the standard coloured commercial papers in local sunlight was measured. The result for each paper was multiplied at each wavelength by the spectral sensitivity of each of the three types of receptor cell, which had been measured with a microelectrode. Each ommatidium usually contains one receptor cell optimally sensitive to ultraviolet (UV) one to blue, and six to green light. As shown first by Mathilde Hertz (J. Exp. Biol. 16, 1-8. 1939; and Naturwissenschaften 25, 492. 1939), and many others although they were unaware of it, UV inhibits the detection of white and therefore of blue, so that trichromatic colour vision is impossible. The receptor with peak in the blue detects areas, where the blue content is summed, and the average height of blue can be learned. Bee vision of areas is monochromatic in blue, but each colour has a different content of blue, as compared to the background of green.

Six receptor cells with maximum sensitivity to green light feed into neurons of the lamina that detect green contrast only, excluding the tonic part of the signal. The bee is able to learn green modulation which is equal to the total of (length of edge multiplied by the contrast at each piece of the edge) so that pattern is lost. Similarly, blue contrast at edges is summed to give a blue modulation signal. Green modulation inhibits blue modulation; therefore, vision of edges is usually monochromatic in green. There are no receptors for black or white, and no achromatic vision of black or white patterns.

All signals at this level have the spatial resolution of the retinal array, but in each case, the signals of each kind are summed over large areas of the eye to maximize sensitivity in certain responses. This summation has no effect on detection of a striped grating, but interferes with pattern discrimination.

Bees detect the horizontal position of green modulation, and are able to use this to measure width of a vertical bar, the separation between

two bars, or the asymmetry of green modulation in the horizontal plane.

Edge detectors are very short, only three ommatidia wide on the retina, and are not strung together to signal long edges. Instead, the bee takes an average of the orientation within quite large areas, so that equal lengths of edge at right angles cancel to give zero orientation. Bees also detect a circle of edges, and can learn the position of the centre.

Bees readily detect coincidences between the responses of feature detectors, especially the polarity of blue relative to a vertical green edge or a landmark of green modulation. Cues with polarity indicate a direction or a turning point, like a signpost, as opposed to a symmetrical cue, which is more likely to indicate a destination, like a shop-sign.