

Edge-Induced Brightness in Humans and Honeybees

Psychophysical and Behavioural Investigations

ABSTRACT

Brightness differences across a contour give rise to illusory brightness effects even in regions a considerable distance from that contour. One example of such an effect is the Craik-O'Brien-Cornsweet Effect (COCE) as shown in Figure i. Although the central regions of successive bars appear alternately bright and dark, they are in fact all of the same intensity, as shown by the intensity profile overlaid on the pattern. In other words, a COCE pattern can appear very similar to a pattern consisting of an alternating series of uniformly luminant bars -- the so-called squarewave pattern (Figure ii).

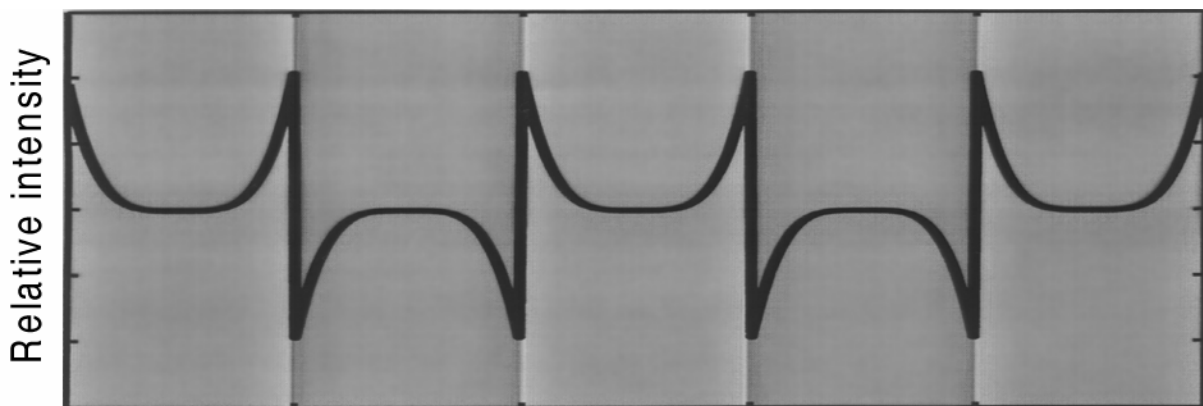


Figure i: A COCE Pattern.

The intensity distribution of a horizontal slice of the COCE pattern has been overlaid on the pattern. Note that despite the apparent differences in the brightness of the central regions of successive bars, the intensity of these regions is the same for every bar.

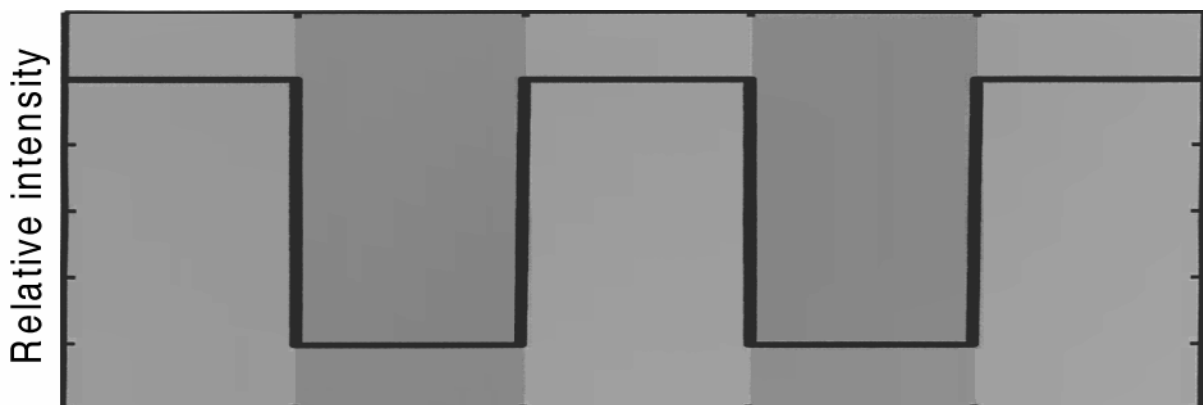


Figure ii: A Squarewave Pattern

The perceived similarity of such patterns can be explained in terms of the spatial filtering that is known to occur in the retina, which emphasises edges and suppresses information on shallow intensity gradients. Thus, the COCE and squarewave patterns appear similar because they produce similar responses from the retina. Retinal filtering explains why the patterns look alike, but it does not explain why they look the way that they do. How do the edges of the bars of the patterns induce brightness effects within the bars?

One hypothesis put forward to explain the illusory brightness in COCE patterns is that a later stage of the visual system is hardwired to compensate for retinal filtering: it assumes by default that the retinal output must have arisen from a squarewave pattern because this is most often the correct interpretation of this type of retinal output. A second hypothesis proposes that there is a dynamic filling-in process whereby brightness information spreads laterally in the cortex, from the edges of each pattern bar to its middle. The perceived brightness of each point in the visual field is thus represented by the activity of the corresponding point in the cortical representation. The perceived brightness of the pattern is then determined by the activity pattern in the cortical map.

The psychophysical experiments reported here were designed to distinguish between these two hypotheses. They used COCE grating patterns for which each edge was contrast-reversed sinusoidally over time at frequencies of up to 22 Hz. At low frequencies, each reversal of the polarity of the edge contrast led to a reversal in the perceived brightness of the bars: each light bar became dark and each dark bar became light. The two hypotheses described above make different predictions as to how the strength of this effect should depend upon the spatial frequency of the grating and the temporal frequency of the contrast reversal.

The results are consistent with the existence of a dynamic filling-in process in the human visual cortex and inconsistent with the hypothesis that the COCE results from the visual system defaulting to the percept of uniform regions in the absence of information to the contrary. The estimates calculated for the velocity of propagation of brightness information range from 125 to 230 mm/sec. Such velocities are similar to physiological measurements of the propagation velocity of epileptiform discharges in visual cortex.

Another set of experiments tested for an effect in honeybees (*Apis mellifera*) analogous to the COCE in humans. The results suggest that honeybees are able to discriminate between patterns based on differences in edge polarity, but are insensitive to gradual luminance gradients. The results of the honeybee experiments parallel the apparent similarity of COCE and squarewave patterns to human observers.