Notes and Comment

On the disparity gradient limit for binocular fusion

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Recently, Burt and Julesz (1980) have measured the limits of single versus double vision (diplopia) in binocular stereopsis. They found that the extent of the fusional limits is not fixed spatially and argued that a limit on the disparity gradient, rather than the absolute disparity magnitude usually associated with the notion of Panum's fusional area, is the critical factor when two or more objects occur near each other in the (cyclopean) visual field. Their main result was that fusion was never observed when the disparity gradient (defined as the ratio of disparity difference and angular separation as shown in Figure 1) exceeded a critical value of approximately 1. They concluded that this invariant limit captures the role of object interaction in binocular fusion. Despite some criticism (Krol, 1982; Krol & van de Grind, 1980), the concept of limiting disparity gradient would seem to have a rather secure basis in a geometrical analysis of the binocular viewing situation (Kass, 1984; Terzopoulos, 1984) and is currently being used as a major theoretical construct in at least one computational approach to binocular stereomatching (Pollard, Mayhew, & Frisby, 1984).

We have found, however, that fusion and single vision can be achieved in situations in which the disparity gradient exceeds, by a factor of 2 to 3, the critical value reported by Burt and Julesz (1980). As a demonstration, compare the displays in Figure 2. In general, our experiments revealed that when the context consisted of dots of the same contrast polarity, the limiting disparity gradient (0.96 ± 0.2) was close to the previously reported values. When one of the interacting dots was larger than the other (by a factor of 2) the gradient was elevated to 1.4 ± 0.23 (see also Braddick, 1979). When the interacting dots had opposite contrast polarity and one of the dots was larger than the other, the critical value increased to 2.1 ± 0.3 ; that is, the gradient below which single vision was experienced increased and larger disparity differences could be tolerated for a given object separation.¹

Rather than questioning the concept of limiting disparity gradient, our results may be suggesting that the notion of a purely geometrically defined gradient is not satisfactory. Object properties other than mutual separation seem to participate in the interaction context. Burt and

Figure 1. The geometry of two-dot stereogram used to generate the stimuli in our experiments (and Figure 2). x denotes objects in the left image, + denotes objects in the right image. The disparity gradient, $\nabla d = \Delta d/R = (d_1 - d_2)/R$, is defined as the ratio between the disparity difference of the two interacting objects and their cyclopean separation.

Julesz (1980) themselves may have hinted at such dependency when they noted that "nearby objects warp the fusional space." It is suggestive to speculate that the amount of "warping" is directly proportional to the magnitude of the "similarity" between the nearby interacting objects, that is, less similar objects interact less. It is known that the stereomatching system only detects the disparity of similarly oriented "edges" with the same contrast sign, whereas the "edges" with opposite contrast sign are never paired (Julesz, 1971). A similar situation arises in motion (Anstis, 1980) and other domains (Glass & Perez, 1973; Prazdny, 1984) in which the perceptual organization relies heavily on a form of correlation-like analysis. In this sense at least, two objects with opposite contrast polarity are the most dissimilar and should interact the least. Such a general strategy seems to point to a system relying on some "coherence" properties of the world. Conceptually, two nearby "objects" are either similar, in which case they should interact with each other because they possibly contain information about the same "event" (e.g., surface), or dissimilar, in which case they may be informationally orthogonal and should not interact at all (at least not initially) because they potentially carry information about different world "events" (Prazdny, in press).

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Figure 2. Limiting disparity gradient increases with the dissimilarity of the interacting objects. The separation of rows and columns is sufficiently large so that main interactions critical to fusion occur only within pairs of objects. The displays were generated by repeating the basic design shown in Figure 1, and increasing the cyclopean distance between the objects across the rows. The gradient (from bottom to top) is 5, 3.33, 2.5, 2, 1.67, 1.43 and 1.25.

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NOTE

1. The psychophysics was performed on a high-resolution CRT using free fusion and stereograms similar to displays in Figure 2. Three experienced observers (with normal stereo vision) participated in the experiments. The subjects simply pointed to the first row on which diplopia occurred, that is, a row on which dot pairs seemed to appear as triple images. The viewing distance was 50 cm.

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