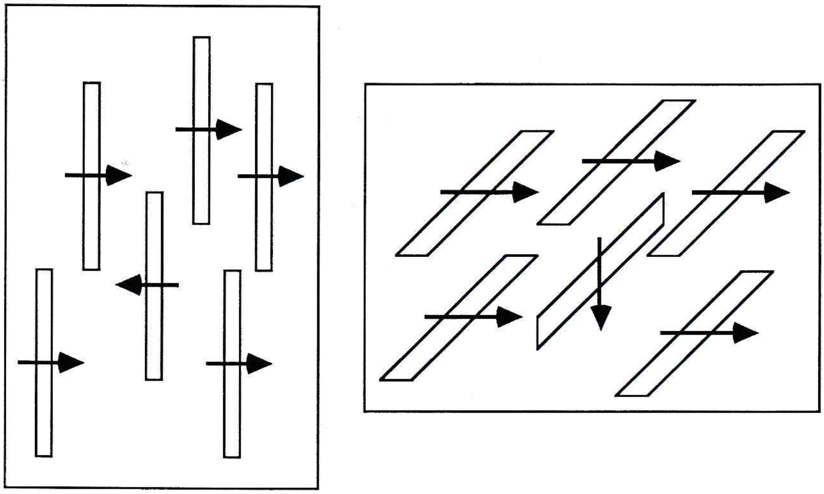

Fig. 10.9. Motion 'pop-out'. (a) Vertical stripes (not shown) move behind stationary vertical slits. Stripes drift to the left behind the 'target' ('odd person out'), but to the right behind the 'distractors' (all the other similar stimuli). Not surprisingly, the target pops out in motion segregation. (b) Oblique stripes (not shown) drift down to the right behind stationary oblique slits. Although motion is in the same direction behind all the slits, the short ends of the slits make the motion appear horizontal behind the distractors but vertical behind the target, which pops out.

still appeared to drift horizontally. When the flicker was confined to the cut ends (Fig. 10.7(d)), so that there were now brightness edges along the sides of the slits, the effects disappeared and the stripes were seen as moving in a direction at right-angles to the long axis of the slit. We attribute this new aperture effect in Fig. 10.7(b) and (c) to brightness-based motion signals from the ends of the stripes as they drift across the tiny ends of the slits. These signals propagate along the whole length of the slit and determine the perceived direction of drift — unless these are countermanded by brightness signals from the long sides of the slits, which would strongly indicate that the stripes are moving parallel to the slits. Thus, signals from the intersections of the stripes with the ends of the slits compete against signals from the whole length of the sides of the slits. If the latter are not removed by the flicker technique they win the competition and the stripes appear to move at right-angles to the axis of the slits. If the brightness edges from the sides are removed, then the signals from the tiny ends win the day and the whole slit appears to drift in a direction parallel to the tiny ends of the slits.

This new form of the aperture effect was enough to give motion segregation. In Fig. 10.9(a) it is not surprising that the leftward-moving target pops out from the rightward-moving distractors. But in Fig. 10.9(b) all the oblique windows contained stripes drifting in the *same* direction, down to the right. The only difference is that the distractors had their ends cut horizontally, so that they appeared to drift horizontally. The target had its ends cut vertically, so that it appeared to drift vertically downwards. The vertical tiny ends on the target slit were enough to make this slit 'pop out' perceptually from the distractor slits. If the brightness edges were not removed, however, this motion segregation collapsed. Note that this segregation is based on perceived motion, not perceived position — that is, upon the apparent dynamic drift of the target window, not on any apparent static displacement of the target, which would not even be noticed, since the windows are positioned randomly.

The new aperture effect could alter perceived size in a kind of dynamic Müller–Lyer illusion. In a conventional Müller–Lyer illusion (Fig. 10.7(e)) the apparent length of a line depends on the orientation of the shorter oblique lines ('fins') at the line ends. When these point out, the vertical line appears longer than when they point in. To generate an analogous dynamic illusion, two slit-shaped windows of the same length had their tops and bottoms cut with opposite bevels (Fig. 10.7(f)). When there were brightness differences at the vertical edges the windows were correctly seen as of the same length, but when the brightnesses were the same, the vertical edges being seen only from movement, the top and bottom of the left-hand window appeared to drift outwards and the top and bottom of the right-hand window appeared to drift inwards, so that overall the left-hand window looked longer than the right-hand window. This is not simply another version of Fig. 10.4 (d). In Fig. 10.4 (d) the expanding or contracting rings altered the apparent size of the circular windows. Here it is not the moving stripes themselves, but rather their intersections with the obliquely cut top and bottom of the windows, that determine the perceived size.

Finally, two directions of motion were combined. This shows that what we found in one dimension is also true in two dimensions. Adelson and Movshon (1982) showed that if two striped patterns are superimposed, moving at right-angles, the result is a plaid or tartan that appears to move diagonally. Imagine a 'negative' window —

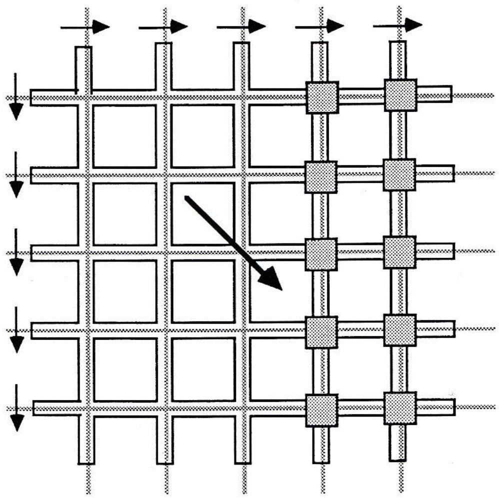

Fig. 10.10. Behind a grid of stationary slits, horizontal stripes drift down behind the horizontal slits and vertical bars drift to the right behind the vertical slits (short arrows). Result: in peripheral vision, the whole display appears to drift down to the right (long arrow). In the right half of the picture, the same oblique drift is perceived even though the grid intersections are occluded.

with panes of opaque glass and transparent horizontal and vertical bars (Fig. 10.10). Behind this negative window there are vertical stripes drifting to the right superimposed on horizontal stripes drifting downwards. When there are brightness differences there is no net impression of diagonal motion, but if a flickering surround is used to remove the brightness edges, the whole field appears to drift down obliquely, especially in peripheral vision. The oblique motion of Adelson and Movshon's plaid has sometimes been attributed to the intersections of the two sets of stripes, which do move obliquely as moiré fringes. However, if the intersections of the stationary window grid are covered up there is still a reasonable impression of a plaid drifting obliquely, again especially in peripheral vision.

Conclusion

A visible edge can be revealed by a discontinuity in almost any visual characteristic — brightness, texture, depth, colour, motion, and so on. Although a single characteristic can represent an edge, as shown in Fig. 10.1, most edges in real life are visible not by brightness alone but by conjunctions of many characteristics. For instance, if a dark-grey textured rock hides part of a distant light-green grassy meadow, the edge is revealed by brightness, colour, texture, and depth. Why does the visual system use multiple sources of information instead of simply relying on the most common one — brightness differences? The reason is probably that it helps to defeat camouflage and increase reliability. Motion edges are particularly useful for breaking camouflage, as prey and predators both know. Colour vision would be of little use to a lion, since the antelopes on which it preys are the same colour as their average surroundings. But prey must move to escape, so lions and other predators are keenly sensitive to motion. The zebra that stands out clamantly in a zoo blends into the background in the wild and a spotted cat is hard to pick out against foliage — until it moves, when motion-defined edges immediately give away its position. This is why the study of kinetic edges is important. The new illusions that we have described may tell us about the neural mechanisms used in extracting these edges.

Consider recognizing objects in the following sequence of pictures: a black and white photocopy, a tone-graded grey photograph, a colour photograph, a black and white cinema film with a fixed camera, and then a similar cinema film with the camera in motion, so giving the relative motion of objects at different distances. Now we can introduce colour, and indeed stereoscopic depth, using two cameras with polaroid glasses. It is remarkable how well artists can convey information with pictures of the most basic kind — black lines on white paper. But it is interesting that the visual system has developed these extremely subtle further processes in visual perception, which evidently must have survival value in the real world. Perhaps the other ways in which edges are delineated and objects are recognized are seldom essential; but — fortunately for the richness of our experience and the possibilities given to artists — they are useful enough to occupy large parts of our brain as a result of the evolutionary pressures that operated on our ancestors.

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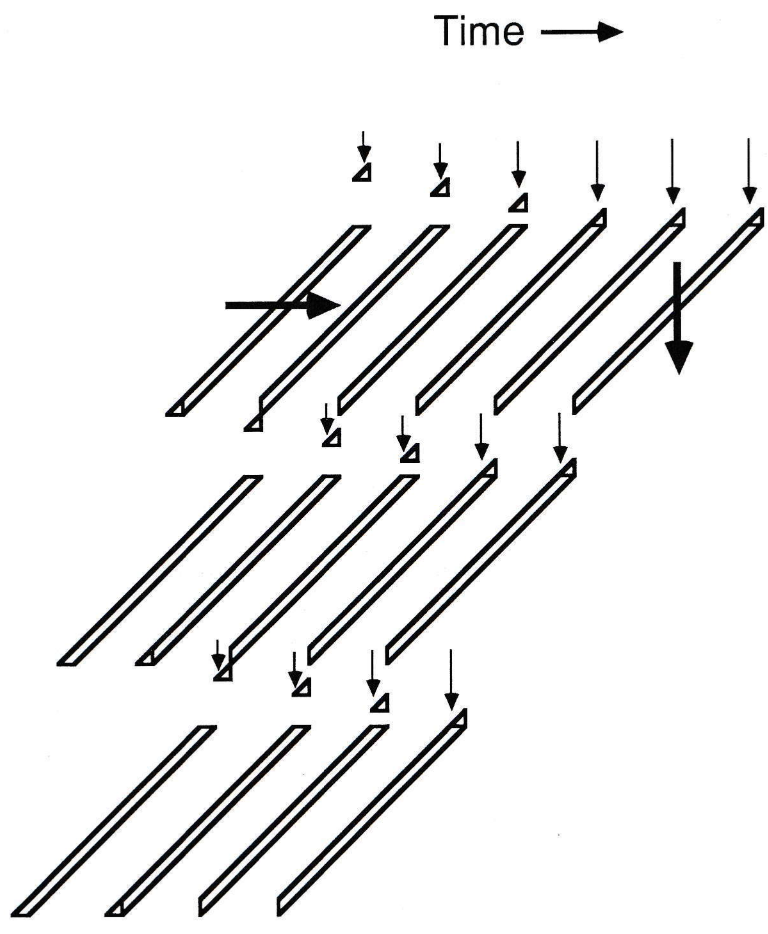

Fig. 10.8. A display of many parallel, oblique stationary slits, behind which oblique stripes (not shown) drift down to the right. Initially the short ends of the slits are cut horizontally, as shown on the left, so that the slits appear to drift horizontally (long horizontal arrow). Then a tiny triangular piece migrates slowly from the bottom of each slit to the top of the slit below. When they arrive they make the slit ends vertical, so that now the slits appear to drift vertically (long vertical arrow).

tally. But if you now make the top and bottom edges of the window slope obliquely, the stripes instantly appear to move obliquely up or down according to the slope of the tiny ends of the window. They appear to be dragged up or down by the tips. This effect is seen only if the brightness differences at the long edges of the window are eliminated. Furthermore, as in the case of the dot pattern, if the average brightness of the stripes is the same as the surround, the entire window appears to drift with the stripes. On the other hand if the brightness difference is introduced the window appears stationary. This phenomenon was demonstrated dramatically by filling the entire screen with oblique slit-shaped windows, all with the same orientation (Fig. 10.8).

The flicker in the surround was manipulated so that it bordered only the sides or only the ends of the slits. Result: it was the sides that were important. When the flicker was confined to the long sides of the slits, removing the luminous edges (Fig. 10.7(c)), the vertically cut slit still appeared to drift vertically and the horizontally cut slit