

Putting plaids in perspective

Farell has described¹ a “new view” of the stereo-matching problem. He claimed that occlusion relationships in natural scenes introduce interocular positional shifts in all two-dimensional (2D) directions, which putatively demonstrates that “horizontal disparity is not a reliable cue to depth” in natural scenes. Farell argued that the visual system must therefore search locally in all 2D directions to establish correspondence.

There is both a geometric and a perceptual component to Farell’s claim. The geometric component asserts that occlusion causes corresponding surface regions to be shifted in all 2D directions. However, as the portions of the contour behind Farell’s apertures that cannot be superimposed by a horizontal shift are seen by only one eye^{2,3}, they are not disparities (which by definition require matches). Thus, from a geometric perspective, ‘aperture disparities’ do not exist. The geometric consequence of stereoscopic occlusion is to generate monocular features in addition to horizontal disparity²⁻⁷; it does not generate local disparities in all 2D directions, as Farell claims.

The perceptual component depends on whether the visual system actually computes aperture disparities (even though these would be geometrically incorrect). We have shown that the visual system uses the non-horizontal shifts of contour junctions to decompose contours into corresponding and non-corresponding (monocular) contour segments, which implies that, for most (if not all) occlusion configurations, it does not. This is true even in the pattern used by Farell to demonstrate his ‘aperture disparities’ (Fig. 1).

But as Farell used a very different stimulus, his suggestion that aperture disparities are calculated may stem from this difference. He added two sinusoidal gratings with different orientations to create stereo-

scopic plaid patterns, and introduced disparity by horizontally shifting one grating in one of the binocular images. Depending on the orientations of the two gratings, this manipulation would shift the plaid intersections not just horizontally, but in any 2D direction. Farell found that these stereo plaids appeared in a single-depth plane, consistent with the horizontal disparity of the plaid intersections, rather than splitting into two gratings in depth.

It is unclear how this result relates to aperture disparities, as coherence does not occur for the intersections formed by stereoscopic occlusion junctions^{2,3}. The fact that perceived depth was predicted by the horizontal disparity of the plaid’s intersections indicates that horizontal disparity is sufficient to understand this result.

Farell reasoned that the perceived depth of the plaids could arise from a second stage of stereo processing that integrates the disparities of the 1D components (gratings) into a coherent surface, so he did an adaptation experiment to determine whether the disparities of the plaid’s 1D components could influence a post-adaptation test stimulus. The results provided evidence for facilitation by 1D adapters, but also revealed inhibition by the 2D adapters at the disparity of the test stimulus. Thus, as in previous investigations into this problem^{8,9}, Farell’s results are ambiguous about the nature of the matching primitives used to establish binocular correspondence.

Farell’s claims about stereoscopic occlusion are grounded on an incorrect understanding of stereo-occlusion geometry, so it is not surprising that he was unable to find unambiguous evidence that the visual system contains mechanisms to compute what he has (mis)labelled “aperture disparities”.

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Farell replies — When we look at Anderson’s Fig. 1a, or at just about anything else, we see surfaces and boundaries, contours and intersections, edges and angles. These complex, interpreted image features might well be the stimulus elements that stereo mechanisms analyse to recover depth¹⁻⁴. But are they?

To answer this question, I proposed a two-stage stereo framework beginning with the matching of simple orientated components that are not elements of our conscious experience, but are standard elements of psychophysical and physiological theorizing. In the light of Anderson’s interpretation, in contrast, complex image features such as surfaces, boundaries and intersections become the inputs to perceptual processing, rather than the outcomes of it.

One interpretative difference concerns definitions. In Anderson’s definition, only points on the left and right retinal images that correspond to the same point in 3D space have a disparity. Looking at any stereogram, we see why this objectivist definition, though appropriate when studying optics, can be misleading when studying perception. The left and right halves of a stereogram, being spatially separated, have no point in common, so by this definition stereograms cannot have disparities. This, of course, will not do. But are stereograms not laboratory artifices and therefore weak tests of a classic definition? Even if they were, there are naturalistic Wheatstone viewing conditions in which we see stereoscopic depth from non-veridical matches, such as the ‘double-nail’ and ‘wallpaper’ illusions⁵ — and, I believe, aperture viewing — all of which defy Anderson’s definition.

My Fig. 1 (ref. 6) addressed whether non-veridical matches occur when we look through apertures, which function like stereoscopes to give each eye a view of a different part of the world. If observers do make these non-veridical matches, then stereo correspondence must be a 2D, not a 1D, matching process. These matches can be studied using either depth-coherent patterns (for example, sinewave plaids) or segregated patterns (for example, Fig. 1a and most squarewave plaids; see my Fig. 2 (ref. 6)). But coherent plaids allow us to dissociate easily the disparities of 1D components and 2D features and thereby to isolate stereo-matching primitives, which is why I used them in preference to non-cohering patterns.

As Anderson points out, my Fig. 2 (ref. 6) indicates that depth polarity discrimination depends on the horizontal component of

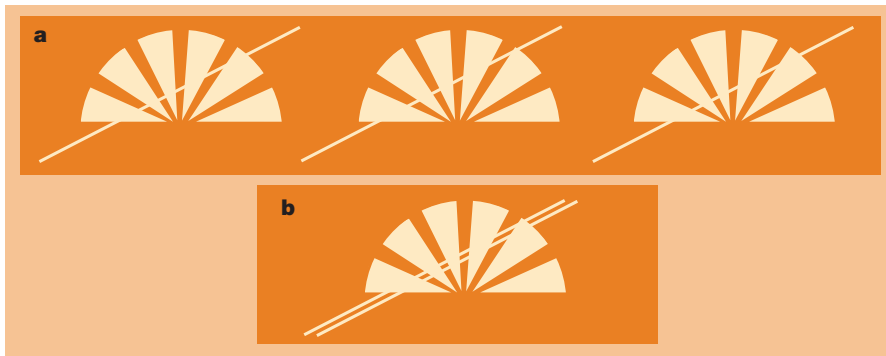


Figure 1 Sunburst stereogram. **a**, A variation of Farell’s stereogram that putatively demonstrates that occlusion geometry can cause disparity to be generated in all 2D directions. Cross-fusers should fuse the left two images, divergers the right two images. When fused, the black contour appears behind the slits in a single-depth plane consistent with the horizontal disparity of the line. **b**, The views of the left and right eye are superimposed so the disparity of the apertures is zero. Although the contour segments within the apertures appear shifted parallel to the aperture boundaries, only portions of the contour that can be superimposed by a horizontal shift are corresponding sections of the contour.

2D feature disparities. And he is right that this result is neutral about whether we match 2D features or 1D components, which is why I ran the adaptation experiment. Anderson infers that there is an ambiguity between some marginal inhibitory effects, which suggest contrast adaptation, and robust facilitatory effects, which imply a component analysis of disparity. Contrast adaptation, which is mostly non-selective for depth⁷, could display a selective component at the depth of visible features. But because the facilitatory effect of disparity adaptation occurs at a different depth, the selective component of contrast adaptation, like masking⁸, must occur after stereo matching. This reinforces a component analysis of disparity. Still, the main result remains the improved performance after adaptation at the components' disparity, which other models do not explain.

As Anderson says, depth coherence is not usually seen between occluding and occluded surfaces, and seems absent from real-world scenes. Coherence is easily dismissed as an illusion, as a failure to segregate the visual world into distinct objects, which could be hazardous if it were more than just a laboratory curiosity. If 1D components are the stereo-matching primitives, we will have to flip this view on its head.

A broadband object in depth contains 1D components with phase disparities that potentially signal an assortment of depths⁸. Visual systems do not process these components as independent stimulus elements, but combine them into visible features, such as surfaces, boundaries, edges and intersections, and combine their disparities into a particular (coherent) depth, just as they combine the components of sinusoidal plaids into 2D features and give them coherent depth. Coherence is the rule and is an integral part of object perception, not exceptional or illusory. Coherence is also compatible with, and necessary for, depth segregation: sets of components that cohere around different phase-congruent disparities will automatically segregate in depth.

My conclusions applied to stereoscopic matching generally, not just to matching in apertures or transparent scenes. As Anderson notes, apertures and other partial occluders typically result in failures to match. I did not examine failures to match, which do not account for the study's empirical findings: depth coherence, depth reversal and disparity adaptation of 1D components.

Elsewhere, Anderson and others have shown that unpaired image regions resulting from partial occlusions do indeed influence perceived depth (see his references). Like other binocular information sources, these unpaired regions ('visibility disparities') can be detected only through a matching process. We must include visibility disparities among the many cues available

from stereo matching, including disparities of spatial frequency and orientation, as well as position or phase, all of which bear on a scene's 3D spatial layout and yet are potentially conflicting. Reliable perception of the third dimension requires that evidence from all these sources be combined at a second-stage site. My study is therefore not incompatible with Anderson's previous work: partial occlusions should fit comfortably into the two-stage framework.

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Nutrition

Effect of vegetables on bone metabolism

Fractures caused by osteoporosis are a major burden to health care¹. Attempts to prevent osteoporosis through diet have had little success: calcium consumed in dairy products has only a small effect on the risk of hip fractures², and soy, a rich source of phytoestrogens that has been proposed as an alternative to oestrogen treatment³, has not yet been shown to be effective in humans. Here we show that a variety of salads, herbs and cooked vegetables that are common in the human diet can alter bone metabolism in rats.

The consumption by rats of onion, for example, increases their bone mass: in male rats fed 1 g dry onion per rat per day for 4 weeks, bone mineral content⁴ increased by $17.7 \pm 6.4\%$ ($P < 0.05$; $n = 6$), mean cortical thickness increased by $14.8 \pm 7.6\%$, and the mineral density of trabecular bone increased by $13.5 \pm 3.1\%$ ($P < 0.05$) relative to controls.

Figure 1 shows that 14 vegetables eaten by humans can significantly inhibit bone resorption in the rat. A mixture of 500 mg each of onion and Italian parsley (Fig. 1, lane 35), and a mixture of lettuce, tomato, cucumber, arrugula (rocket), onion, garlic, wild garlic, common parsley, Italian parsley and dill (100 mg of each daily) significantly

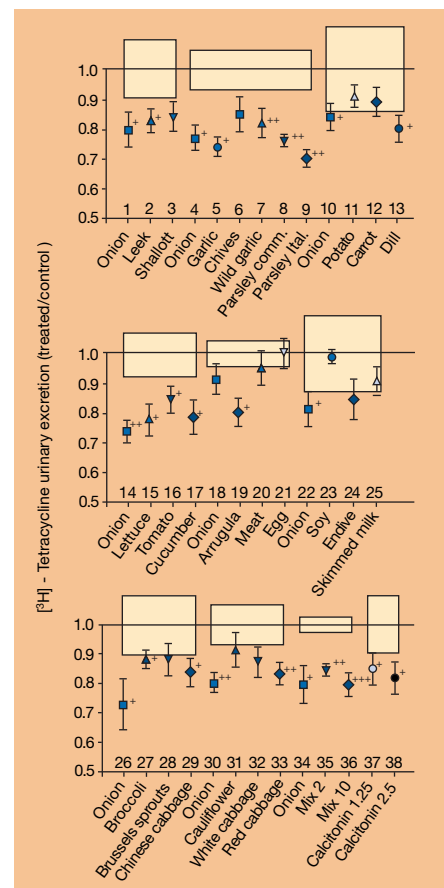


Figure 1 Effect of foodstuffs and the hormone calcitonin on bone resorption as assessed by the urinary excretion of previously administered radiolabelled tetracycline^{9–10}. Data are plotted as the ratio of treated/untreated control (\pm s.e.m.; $n = 5$ per group) over 10 days. The 95% confidence interval of the untreated control groups ($n = 5–6$; 10 experiments) is shaded. Onion was used as a positive control for all foodstuffs. All rats received the same total daily amount of food, including 1 g of the dried test foodstuff. Fresh foods were air- or freeze-dried and ground. Calcitonin was injected daily at doses of 1.25 or 2.5 IU per kg body mass at the optimal time⁹. *Cooked before drying; * $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$. Details of methods and materials can be obtained from R.C.M.

inhibited bone resorption (lane 36), indicating that the effect was additive. There was no inhibition by soybeans at the same dose, or by foodstuffs of animal origin (lanes 20, 21, 25), and even milk powder had no significant effect, despite its 1.29% calcium content. The mean 20% inhibition by 1 g onion per day is slightly higher than the effect of calcitonin at doses (per kg body weight) used to treat postmenopausal osteoporosis⁵ (lanes 37, 38).

Because osteoporosis in humans occurs most frequently in postmenopausal women, we studied the ovariectomized rat^{6,7} as a model. Although bone resorption in these rats increased by $32 \pm 3\%$ ($P < 0.001$) compared with sham-operated animals, this was inhibited by onion (30–1,500 mg per day) in a dose-dependent manner: at the highest dose, resorption decreased by $25 \pm 4\%$ ($P < 0.01$). Onion therefore inhibits