- Friday, August 1, 1997
  First and Second-Order Cues to Orientation

1.1 Here are the minutes for the YORKVIS meeting which took place on Friday Aug 1st 1997. Although it was the Friday of an August long weekend we had 23 attendees.

1.2 At the present time we have no speakers scheduled. I would like to invite all members of this list to volunteer to come and give a seminar. Post-docs and graduate students are particularly encouraged. You could do half a seminar if you liked.... Good dates would be the first Fridays of the month: Oct 3rd, Nov 7th, Dec 5th but any Friday morning is OK (except I am away 4-22 Sept).

1.3 The summary below is being posted on the web page at the same time as I am sending it out now. The web page version has cool pics and links to other related talks and sites.

2.0 This meeting was by Steve Dakin, a Brit from Montreal. We have had talks about second- order cues for motion (Andy Smith) and second-order cues for depth (Laurie Wilcox) and this talk was about second-order cues for orientation.

2.1 One way to generate a second-order oriented stimulus is to take a first order sine wave at say, orientation 45 degs from vertical. This will be the carrier. Modulate the grating's contrast by a vertical grating. This produces a clear vertical grating with the vertical stripes alternating between vertical rows of black and white elongated blobs, orientated at the carrier frequency (high contrast part) and a grey bar (low contrast part). Which looks like this (figure courtesy of Steve Dakin):

A modification is to modulate the contrast of the carrier not with another 1D grating, but by a 2D Gaussian. This Gaussian can then be elongated to provide an oriented, contrast-defined, second-order feature.

2.2 In common with other second-order defined visual properties, the visibility is probably not due to a distortion in the stimulus itself since its visibility does not go up with the magnitude of the components on the screen.

2.3 A powerful model that DOES predict this effect is a filter-rectify-filter model. The arguments against this happening in the brain are that it would use a lot of filters and that it would be TOO good. In real life the second order grating shown above in 2.1 actually appears tilted towards the carrier (pretty convincing, isn't it? Use a pencil to show that it is really vertical!).

3.0 In order to see how independent the mechanisms for 1st and 2nd were, Steve looked for sub-threshold summation. He set up orientated Gabor patches of ordinary gratings (see Laurie Wilcox's talk to see some pictures and a basic description of how you make these patches).

FIG 2 CAPTION

(a,b) Shows patches with fixed vertical carriers, windowed by Gabor envelopes of 90 deg and 92.5 deg respectively. The tilt of the envelope is difficult to detect. (c,d) Shows stimuli with 92.5 deg envelopes and a (c) 0.2 deg and (d) 0.4 deg cue added to the carrier. Detection of envelope tilt in (d) is more apparent than (b). (e,f) Illustrates the control condition; a horizontal carrier windowed by envelopes of (e) 90 deg and (f) 92.5 deg. (Figure and caption provided by Steve Dakin)

The Gabor was the 'envelope' or '2nd order aspect' and the grating was the carrier or 1st order aspect. Was the threshold for detecting tilts of the Gabor lowered by having sub-threshold tilts of the carrier at the same time? Far from helping the detection task it turned out that detecting the tilt from vertical of the Gabor envelope (2nd) in the presence of a vertical grating (1st) was actually more difficult than when the grating was at a far-away orientation (a control condition). As the orientation of the grating (1st) tilted from vertical in the same direction as the tilt of the Gabor hat was to be detected, it did indeed improve performance from this worsened level, but performance never got better than the control level. These observations were interpreted as interference (by the vertical grating) which got less as the grating was tilted away from the testing zone. They were not compatible with sub-threshold summation over the range tested.

3.1 The presence of a tilt in one system (1st or 2nd) not only made tilt in the other system (2nd or 1st) easier to detect (than when the other system was not tilted), but also altered the perception of the orientation detected by the other system. This is demonstrated in this picture:

FIGURE 3 CAPTION

(a-d) shows Gabors composed of a vertical (90 deg) envelope multiplied by a carrier of orientation (a) 0 deg, (b) 45 deg, (c) 85 deg, and (d) 90 deg. Note the anti-clockwise and clockwise tilting of the envelope in (b) and (c), respectively. (e-g) shows Gabors composed of a vertical carrier multiplied by an envelope of (d) 0 deg, (e) 45 deg and (e) 85 deg. Note the clockwise-tilting of the carrier in (f). Figure and caption provided by Steve Dakin.

When judging the orientation of the patch (envelope, Gabors, 2nd order contrast-defined aspect), if the carrier and envelope were CLOSE together then there was a 'repulsion' effect, further apart and there was an attraction (envelope judged in direction of carrier). When judging the carrier, there was a tendency for the envelope to drag the carrier in the same direction for intermediate values (esp. when they were about 45 degs misaligned). (Some of these effects may be in common with well-known visual illusions such as the Fraser Spiral).

3.2 The effect of the envelope (2nd) on judgements of the orientation of the carrier (1st) were much bigger for lower spatial frequencies of the carrier.

4.0 A simple, regular 'oriented channel (or filter) model' explained all the perceptions of the carrier. In other words, 'second order effects' had an effect in the Fourier domain of these classic oriented filters.

4.1 To explain the more complex attraction/repulsion characteristics of the perception of the envelope, a more complex model involving averaging across all orientations was proposed. This is called the 'isotropic filter' - rectify - filter model since the first stage combines information from all orientations. It needs less filters than the filter-rectify-model (since the first ones are all the same). The model turns out to be a little fussy that the SCALE of the final row of filters is matched to the spatial frequency of the envelope, but then it works fine. I guess this means that a model would have to have an earlier stage that extracted the spatial frequency of the envelope and arranged that the information was passed through the appropriate-scale set of filters.

5.0 The conclusions were (i) that the influences of some of the 'second order effects' of contrast modulation on the perception of the carrier were linear and operated within the Fourier domain. (ii) the influences of the 1st-order carrier on the envelope could not be explained in this way but could be relatively simply and satisfactorily modelled by including an isotropic first stage.

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