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  Second Order Motion

2.0 Andy Smith (Psych, Royal Holloway College, University of London) "Second order motion" (5 July 1996)

2.1 The processing of visual motion involves some kind of correlation of retinal patterns of luminance across time. Motion detection can operate on the raw information present in the optic nerve, or even within the retina itself in some species. Motion extracted from luminance variations has therefore been described as first order motion. But it turns out that the sequential retinal appearance of other features, not just luminance variations, can also result in the sensation of motion. Because this form of motion cannot be deduced directly from the information of the optic nerve but involves a broader view, a further stage of processing, this type of motion has been described as second order motion.

One type of second-order motion is created by having a screen divided up into black and white areas. For each black/white border, there is a contrast, that is a difference between the black and white areas. This can be greater or smaller and can be arranged to always be around the same mean (average of the black and white areas involved). By having features (eg, vertical stripes) defined in terms of variations of this contrast and then moving those features (while keeping the actual black/white borders in the same place - or perhaps moving them around randomly), you have an example of second-order motion. In this case contrast-defined, second-order motion.

2.2 Is second-order motion detected by a special system?

YES because there are profound differences between what first and second order motion can do. Thus second-order motion does not stimulate optokinetic eye movements, for example.

YES because you can't add first and second order components and deduce the perceptual direction of motion whereas you can add two first order components together.

NO because maybe second-order motion perception results from first-order artefacts that creep into either the experimental presentation or the brain's processing of even some of the most carefully constructed 'pure second order' stimuli. For example, a non-stochastic distribution of the dots in an image (or sample points by the brain) would lead to a mean luminance change across the image (or in the representation of mean luminance) so you could detect it with a first- order detection system.

So which is it?

2.3 Exp. 1. If there is a non-stochastic distribution then any effect should be proportional to pixel size. The pixels are the areas of black/white areas. Oops! It is! Thresholds get smaller for bigger pixels.

2.4 Exp. 2. ... But only for a static carrier. The carrier is those black/white edges. If the carrier is dynamic (the black/white pattern changes randomly) then it doesn't matter how big the pixels are.

Conclusion: static images might have first- and second-order components. First-order components might be accidently introduced in the distribution of black/white areas. That is by the presence of clumps of black or white areas and thus variations in the mean luminance across the screen.

2.5 Exp. 3. Varying the amplitude of the contrast modulation (that is the amplitude of the signal that is actually moving) would produce a big effect if there was some kind of global distortion: for example a saturation at high values that might introduce some (centrally created) apparent luminance changes. But no effect of varying this modulation, suggesting this potential source of non-linear distortion is not a worry.

2.6.1 Exp. 4a. If the static noise (the black/white areas) has first-order components because of clumping, then high-pass filtering (high-spatial frequencies filtered out) should get rid of it. It does....

2.6.2 Exp. 4b ... But high-pass filtering does not affect contrast-related features (because they are much lower frequency in these displays). It doesn't.

Conclusion: don't use a static carrier. No problem. The problem is that other people have! Eg. some of the leaders in this business such as Chubb and Sperling and Lu. Oops! So some of their results become questionable. And when repeated by Smith et al., some of their findings turn out not to be completely reliable.

2.7 For example Lu and Sperling 1995 report that first- and second-order systems have similar sensitivities to temporal frequency. However, their 'second-order' stimuli probably had first-order components (so no wonder they had the same sensitivities!). And when Smith et al. repeated these experiments with DYNAMIC carriers they find that first and second order sensitivities to temporal frequency are indeed quite different!

2.8 Another example is that various people (including Smith before he saw the - artefactual - light) suggested that second-order sensitivity fell off as you go into the periphery at about the same rate as first-order sensitivity. Actually it turns that when you do it right, it still does!! But it needn't have done!

2.9 Conclusion: First and Second order motion processing systems are probably distinct. You have to be dead careful when designing stimuli to be sure you are presenting what you think you are presenting, not only to the eyes, but to each stage of the visual (or perhaps any sensory) pathway. Watch out for those Jabberwocky non-linearities!

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