Modelling long-range interactions across the visual field in stereo correspondence

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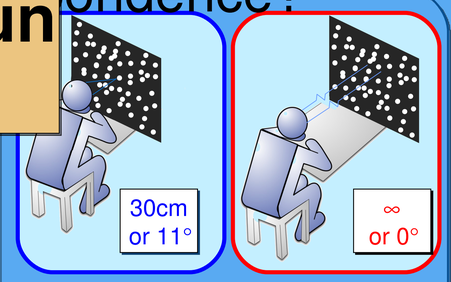
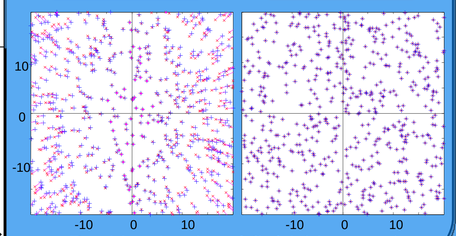
Question – How to explain the influence of the visual periphery on stereo correspondence?

Background

Stereo correspondence means matching up image features between left and right eyes – especially challenging in random-dot patterns.



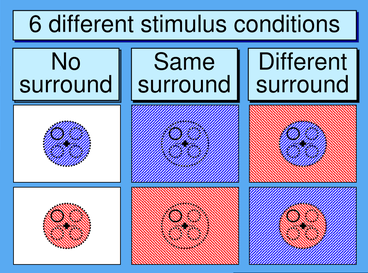
Horizontal disparity depends on object depth, but vertical disparity depends on viewing distance (vergence angle)⇒

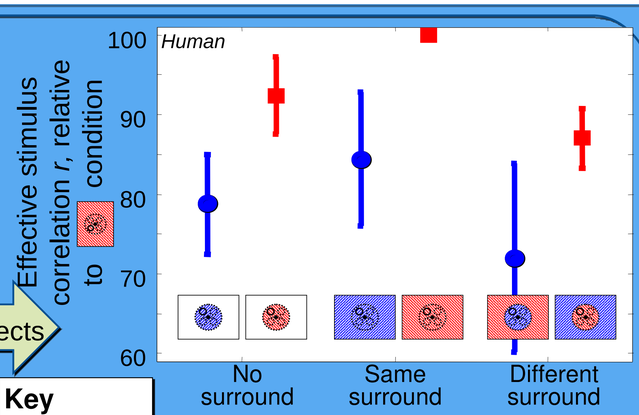


Recent

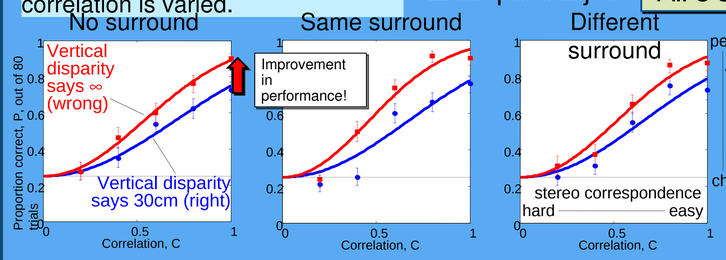
Stereo correspondence is easier for distant viewing.

Task: Which quadrant has the disparate disk? Vertical disparity specifies either 30cm or ∞ viewing distance; physical viewing distance always 30cm. Interocular correlation is varied.





Example subject | All 8 subjects

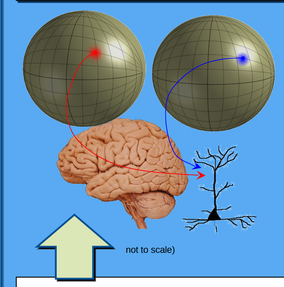


Each curve fit with Weibull, $P = ¼ + ¾ (1-\exp[-(rC)^{\kappa}])$. κ same for all conditions; r quantifies performance on stereo correspondence.

Key

1. **Performance is always better when vertical disparity indicates ∞ viewing, not physical 30cm.**
2. **Performance is better when the stimulus extends beyond 20⁰ – though target disk only from 10-18°.**
3. **Performance is worse when the vertical disparity field is internally inconsistent.**

Neuronal substrate?



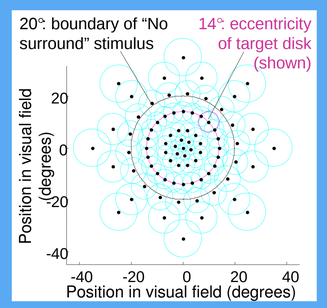
V1 neurons tuned for distant viewing, i.e. with RFs at same elevation.

Long-range cooperative interactions across the visual field in achieving stereo correspondence

Model

Simulate activity of 33,048 energy-model complex cells.

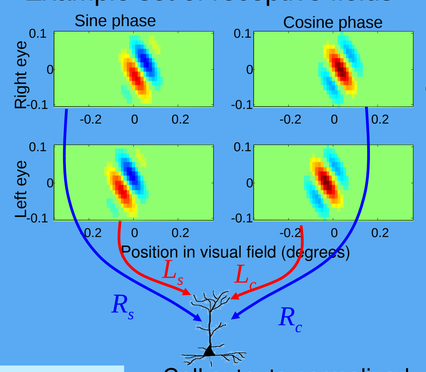
, total of 81 RF locations in the visual field (see figure).
408 complex cells at each RF location:
6 spatial scales: RF sizes 0.05° to 1.6° at fovea (SF 7 to 0.2cpd), rising linearly with eccentricity to 0.4°-12.8° at 35° eccentricity.
4 orientations: 0°, 45°, 90°, 135°.
17 horizontal disparities from -0.5° to +0.5° in steps of 0.0625°.



⇑ Dots show RF centres; cyan rings mark SD of

1. Phillipson & Read, *Eur J Neurosci* 2010
2. Read, *PLoS Comp Biol* 2010: 6(4)

Example set of receptive fields



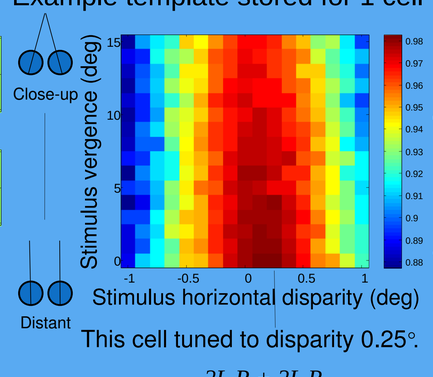
Cell outputs normalized stereo energy: a measure of local cross-correlation.

Templates

Assume the visual system has stored the mean response to different horizontal & vertical disparities (vergences).

For the model, store mean response to 1000 random-dot stereograms, with uniform disparity across the whole retina, for different disparities and vergences.

Example template stored for 1 cell



This cell tuned to disparity 0.25°.

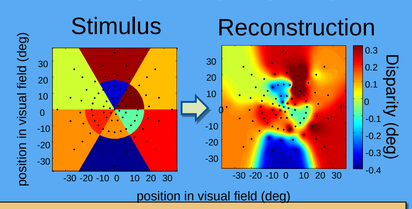
$$E = \frac{2L_cR_c + 2L_sR_s}{L_c^2+R_c^2+L_s^2+R_s^2}$$

Local decoding

Estimate horizontal disparity and vergence at each of 81 locations by seeing which template best matches the current response of the 408 cells centered on that

Neurons are tuned to a range of horizontal disparities but only zero vergence / vertical disparity. Structure of population activity means vertical disparity / vergence can still be decoded[2] (last year's COSYNE poster!).

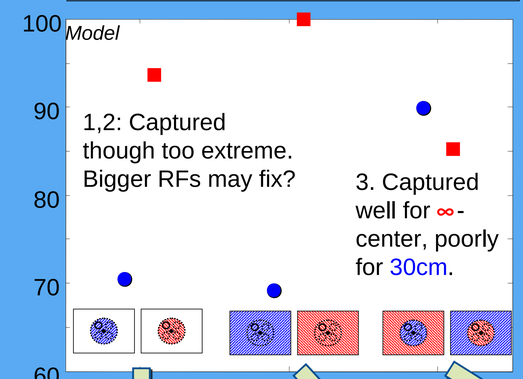
Example disparity map



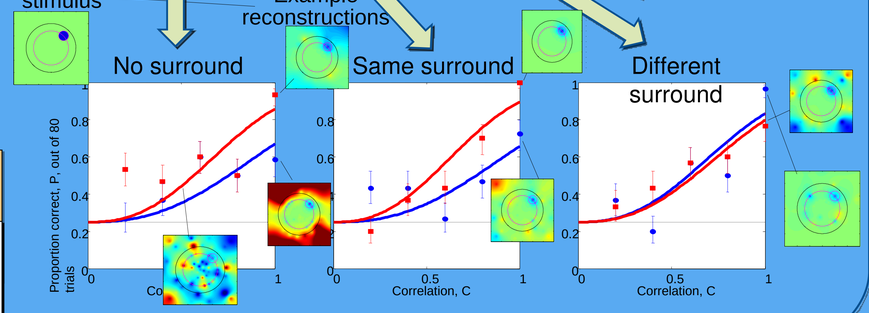
Task decision

Average the 20 disparity estimates from each quadrant . Take disk to be in quadrant with minimum mean.

Results



Example stimulus | Example reconstructions



Answer

Neurons tuned to zero vergence ensure better performance at ∞ viewing. Surprisingly, increase in RF size with eccentricity largely explains the effect of the periphery >20°. A template-based model with purely local stereo correspondence captures performance fairly well, *without* long-range cooperative interactions.

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