Representations of scene statistics in the primary visual cortex for inferring binocular disparity

Jason M. Samonds
Object Identification

**Ideally**

**Reality**
V1 perspective of incoming visual information

Noise and background add uncertainty
Uncertainty in corresponding features between the eyes

left eye

right eye

percept

stereo correspondence problem
Current understanding of neural mechanisms

Ohzawa et al., Science (1990)
Current understanding of neural mechanisms

Chen & Qian, Neural Comp. (2004)
Current understanding of neural mechanisms

Computer vision solutions

Computer vision solutions: sharing information
Depth changes gradually with respect to objects

Cooperative Computation of Stereo Disparity

Marr & Poggio, Science (1976)
Translating the algorithm to neural circuits

- **Near**
- **Zero**
- **Far**

Disparity

Left Image (1D Example)

Visual Field Location 1

Visual Field Location 2

Right Image
Recording & Stimulation

Samonds et al., J Neurosci (2009)
Recording & Stimulation

Samonds et al., (2011a,b)
Quantifying interactions

Samonds et al., J Neurosci (2009)
Evidence of disparity-dependent neuronal interactions

Disparity Tuning Similarity ($r_{\text{disp}}$)

RF Distance (°)

$n = 63$ Pairs

$r = 0.32$

$p = 0.01$

Samonds et al., J Neurosci (2009)
Evidence of disparity-dependent neuronal interactions

Samonds et al., J Neurosci (2009)
Binocular disparity tuning sharpens over time

Samonds et al., J Neurosci (2009)
Are the cross-correlation results and sharpening related?

Samonds et al., (in preparation)
Measure sharpening with skewness

\[ \gamma_1 = \frac{\mu_3}{\sigma^3} = \frac{\frac{1}{N} \sum_{d=1}^{N} (f(d) - \bar{f})^3}{\left( \sqrt{\frac{1}{N} \sum_{d=1}^{N} (f(d) - \bar{f})^2} \right)^3} \]

- skewness >> 0
- skewness = 0
- skewness << 0

Samonds et al., (in preparation)
Measure sharpening with skewness

\[
\text{skewness} = 0.5 \quad \text{skewness} = 2.0
\]

Samonds et al., (in preparation)
Model replicates sharpening over time

Samonds et al., (in preparation)
Model predicts greater sharpening with larger stimuli

Samonds et al., (in preparation)
Model predicts greater sharpening with larger stimuli

Samonds et al., (in preparation)
Model predicts greater sharpening with larger stimuli

Samonds et al., (in preparation)
Model predicts reduced sharpening for anti-correlated DRDS

Samonds et al., (in preparation)
Model predicts reduced sharpening for anti-correlated DRDS

Samonds et al., (in preparation)
Depth changes gradually vertically/horizontally

Li, Samonds, and Lee (in preparation)
Disparity correlation depends on orientation

Li, Samonds, and Lee (in preparation)
Disparity correlation depends on orientation

Li, Samonds, and Lee (in preparation)
Spike correlation depends on orientation between RFs

Li, Samonds, and Lee (in preparation)
Intensity and depth are negatively correlated

Samonds et al., (2011)
Intensity and depth are negatively correlated

Samonds et al., (2011)
Measuring intensity and depth in V1

Samonds et al., (2011)
Relative luminance and binocular disparity are negatively correlated

Samonds et al., (2011)
Relative luminance and binocular disparity are negatively correlated. Samonds et al., (2011)
Relative luminance and binocular disparity are negatively correlated.
Stereo computation is difficult because in any given visual scene, there are many similar features, which create ambiguity for matching corresponding features registered by the two eyes.

Using cross-correlation analysis, examining disparity tuning changes over time, and using a network model, we show that disparity-tuned neurons in the primary visual cortex (V1) have organized recurrent connectivity.

The organization matches predictions based on the statistics about spatial relationships found in 3D natural scenes.

Relative luminance and disparity tuning are correlated also matching predictions based on the statistics found in 3D natural scenes.
Conclusion

The organization of the recurrent connectivity and the correlation between tuning in V1 both represent expected statistical trends found in 3D natural scenes and could be used by the visual system for inferring binocular disparity.
Thank you for your attention!

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