Attention to Objects and Perceptual Organization

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Jeremy Wolfe, Harvard U.

OBJECTIVE

Information overload impacts technological and biological systems. Example: Surveillance (but really *anything*}

Solution: Selective attention, i.e. sequential selection and processing of the most relevant information only

Our approach: Use mechanisms of perceptual organization to structure sensory input and guide attention according to primate neural representations

Different from other attentional approaches: organize sensory scene not by spatial relationships (pixels) but by perceptual (proto-)objects

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Sparsity (in space and time!)

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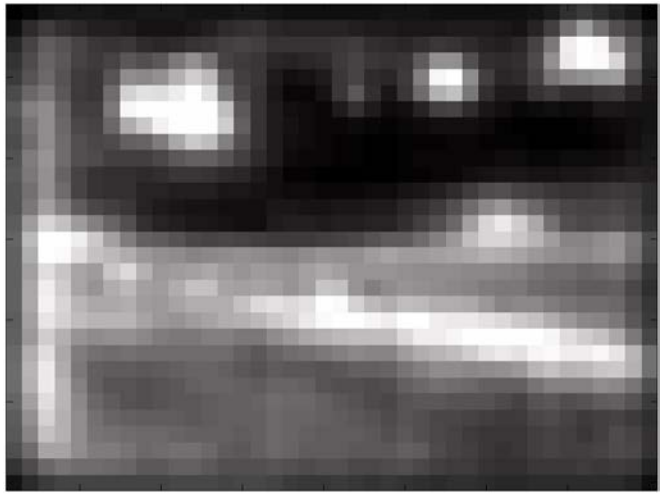
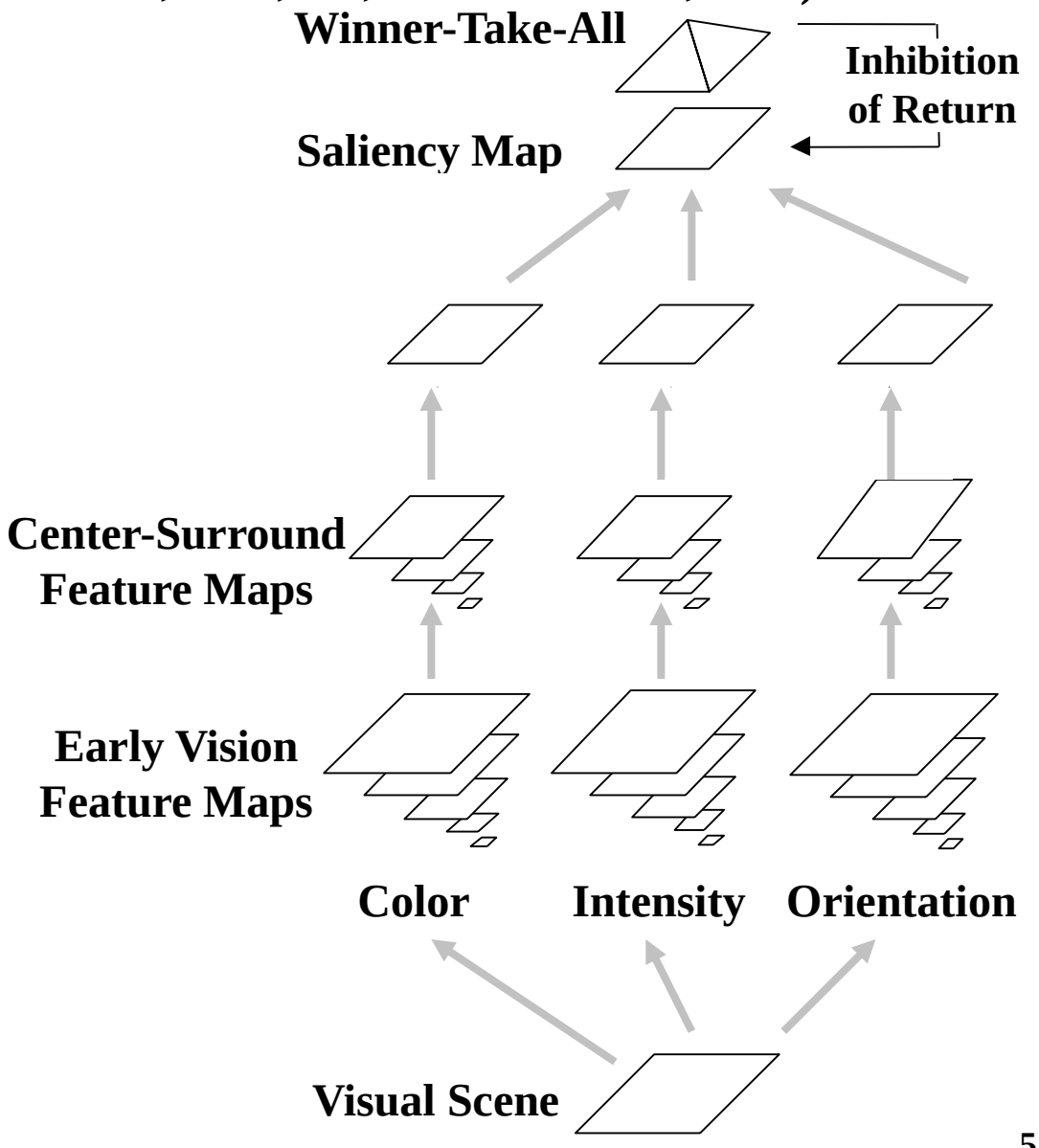
Classical approach: Saliency map

(Koch & Ullman, 1985; Niebur & Koch, 1996; Itti, Koch & Niebur, 1998)

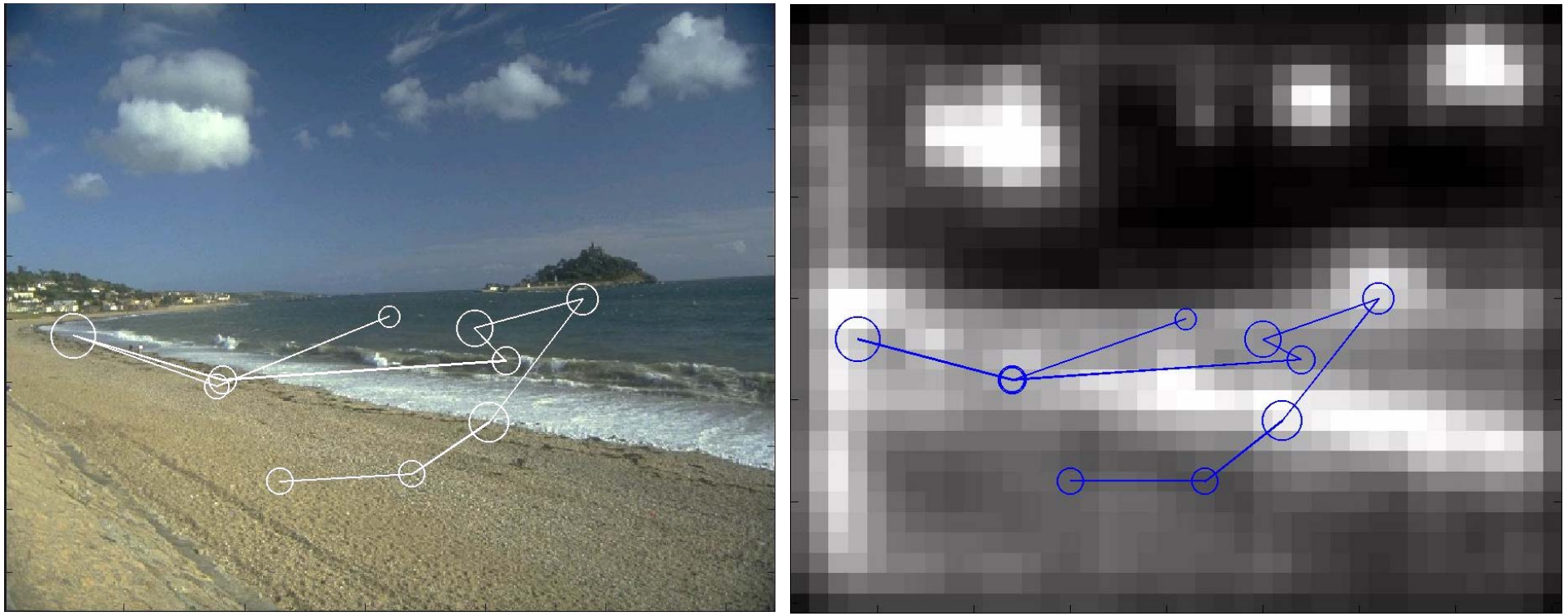


Saliency Map

Visual Scene



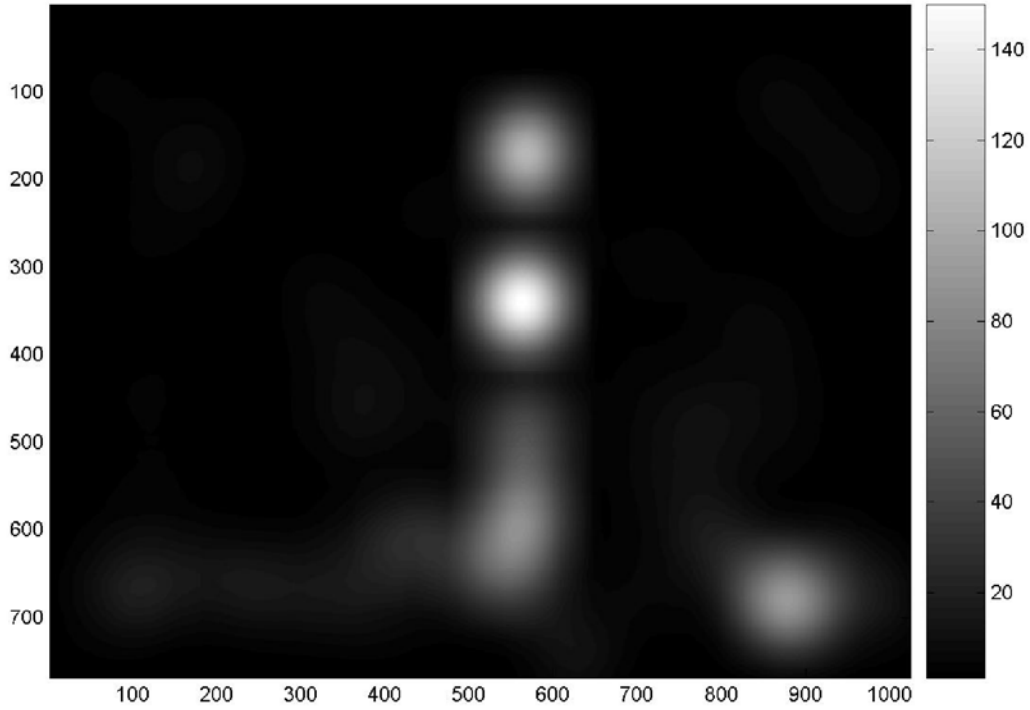
Saliency map is predictive of eye movements



Parkhurst et al, Vision Research 2002

Interest Maps

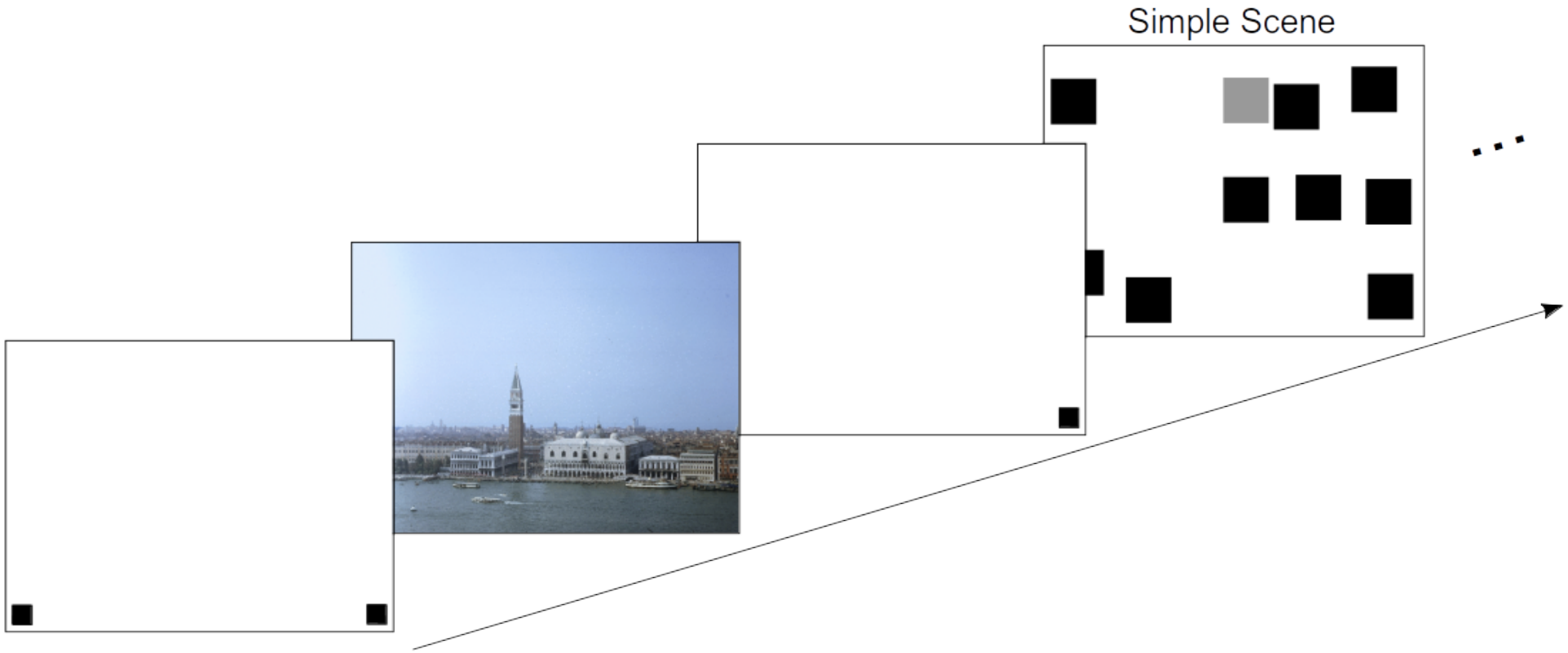
Conscious selection of “5 most interesting points”
15 images from database of 100 natural scenes
874 participants



Interest is highly correlated with fixations and with saliency map

Maschiochi et al, J. Vision 2009

Tap Maps

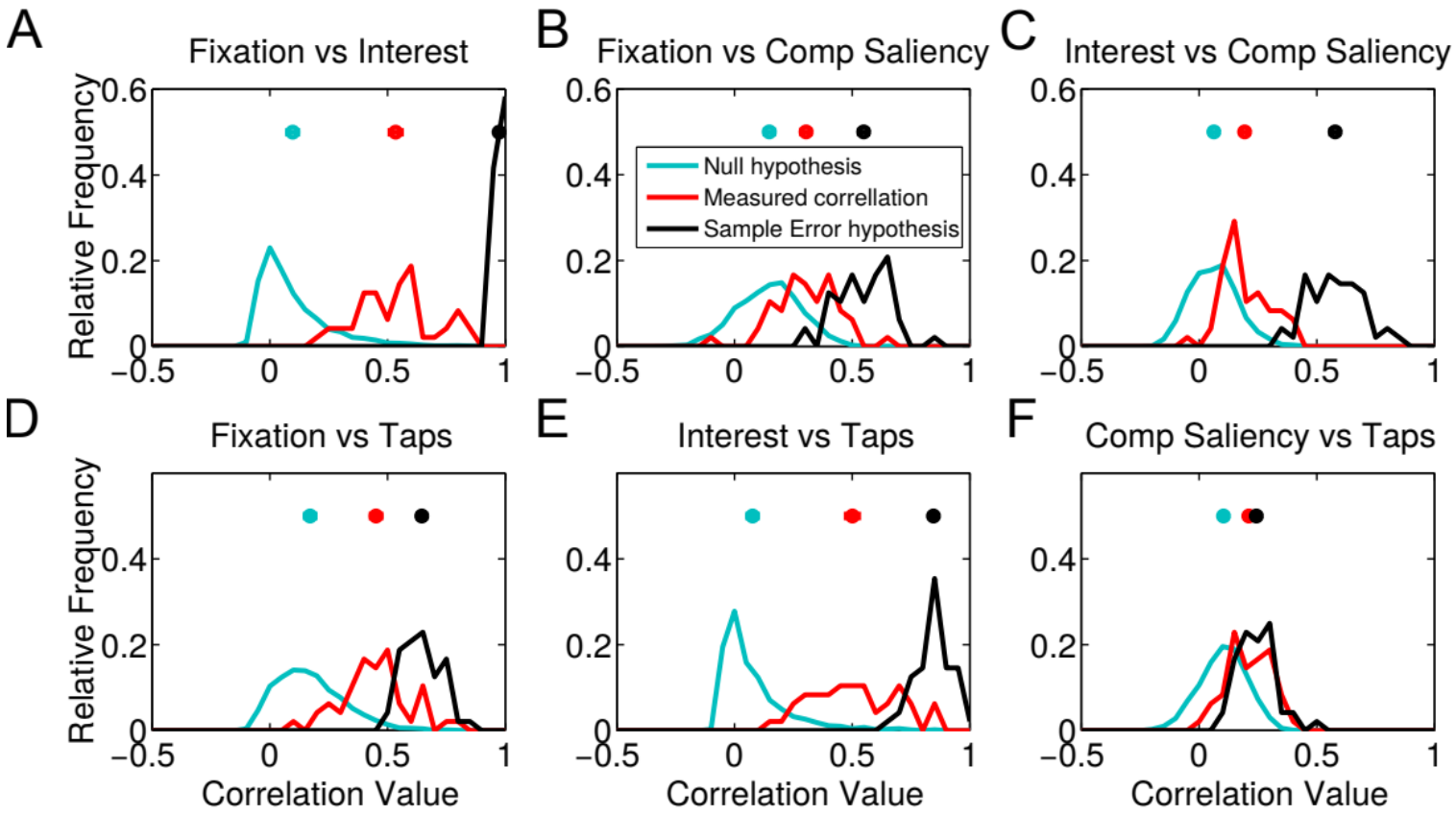


“Tap at the first location you look at!”

Minimize top-down influences

Jeck et al, Vision Research 2017

Tap Maps



Result: Taps are highly significantly correlated with

- **Fixations**
- **Interest**
- **Computational Saliency**

Jeck et al, Vision Research

Saliency map: Limitations

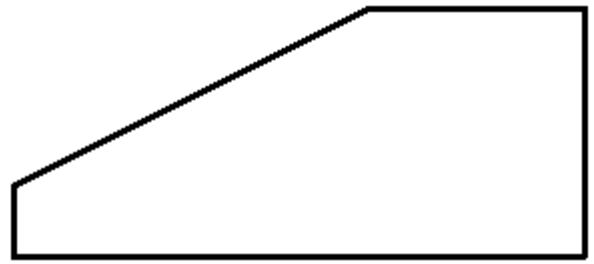
Very successful but

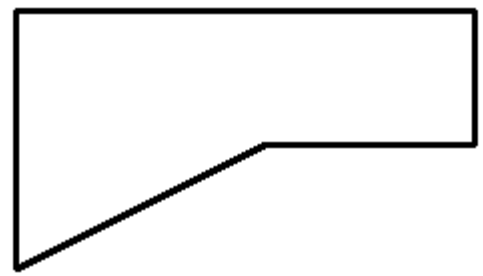
- **Fundamental elements are 'pixels' (~RGC activity) while biological attention operates on perceptual objects**

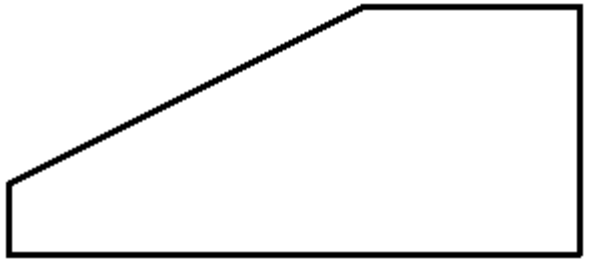
How do we add the notion of *objects*?

Not trivial!

Rubin, N. Nature Neuroscience (2001)







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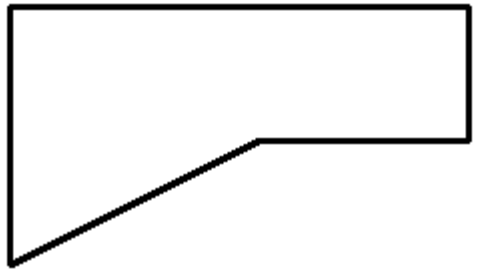
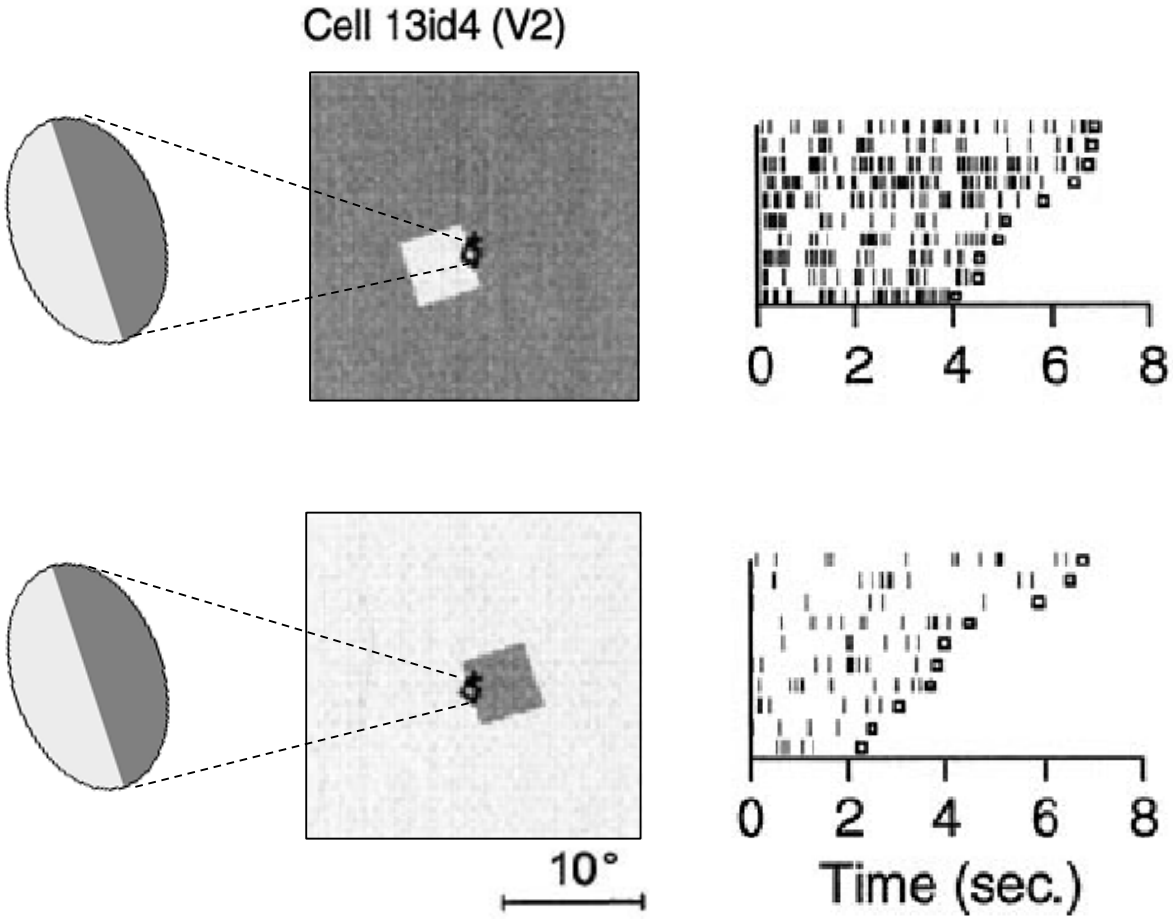


bg

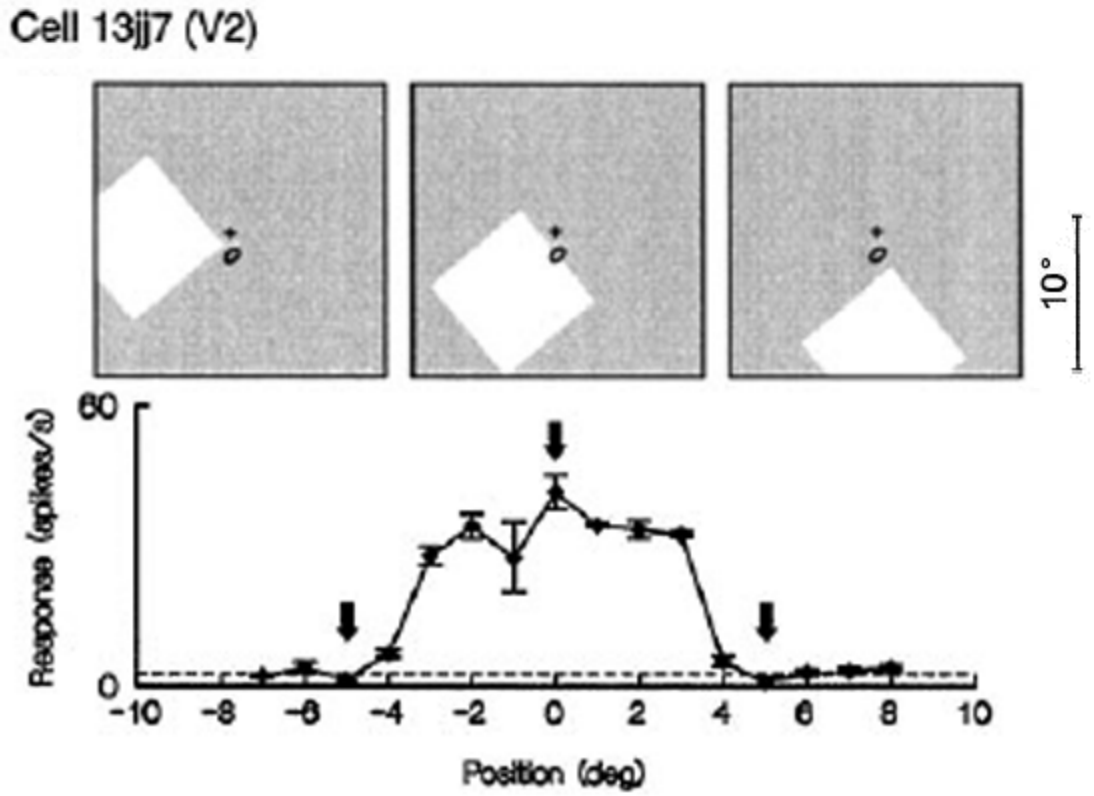
Neuronal representation of image context in visual cortex

Border Ownership Coding In Primate Extrastriate Cortex



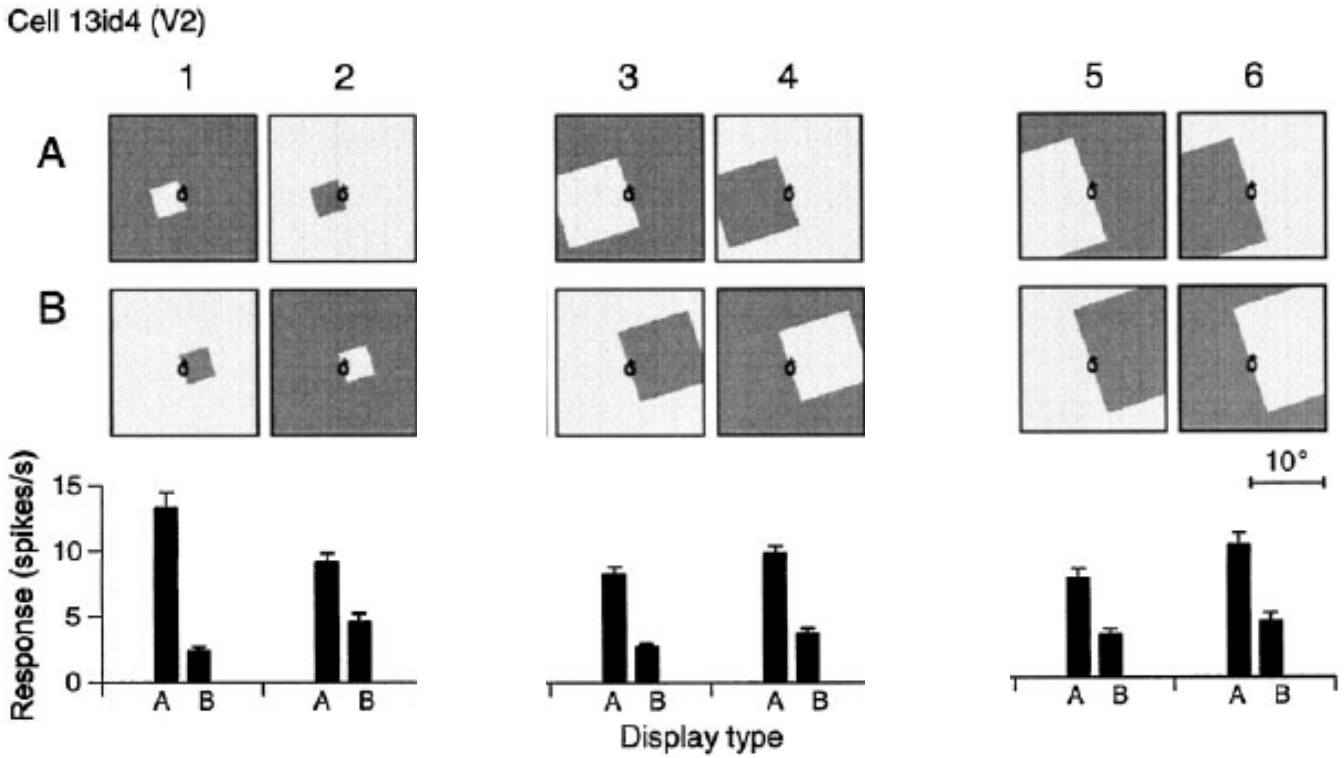
Zhou, H., H. S. Friedman, and R. von der Heydt. "Coding of border ownership in monkey visual cortex." J.Neurosci. 20.17 (2000): 6594-611.

Receptive Fields in V2 are Small



Zhou, H., H. S. Friedman, and R. von der Heydt. "Coding of border ownership in monkey visual cortex." J.Neurosci. 20.17 (2000): 6594-611.

Contrast invariance, size-invariance



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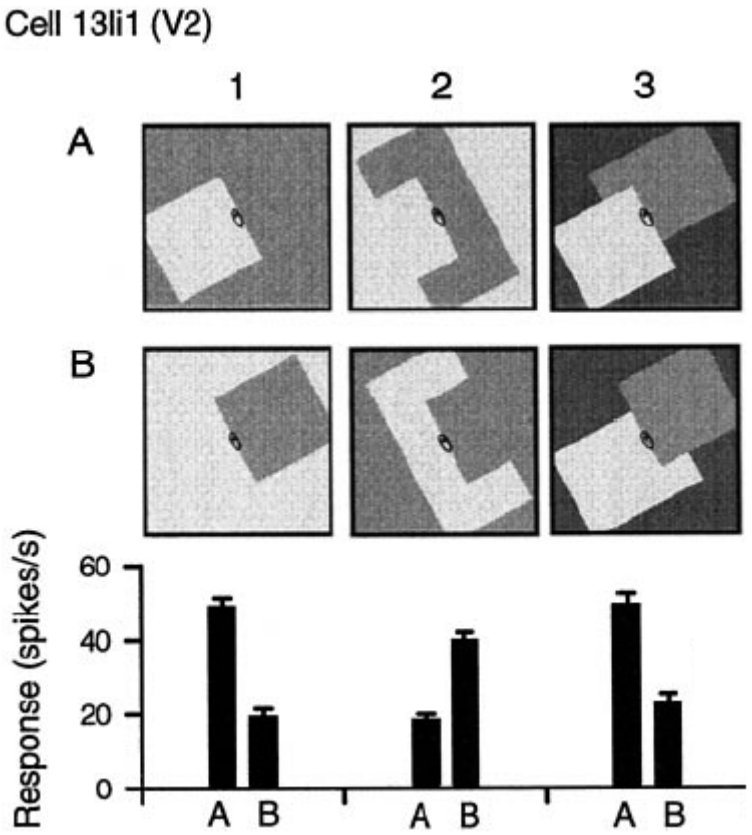
Access to a Variety of Cues



Consistent results are obtained with different features: contrast, outline figures, disparity, ...

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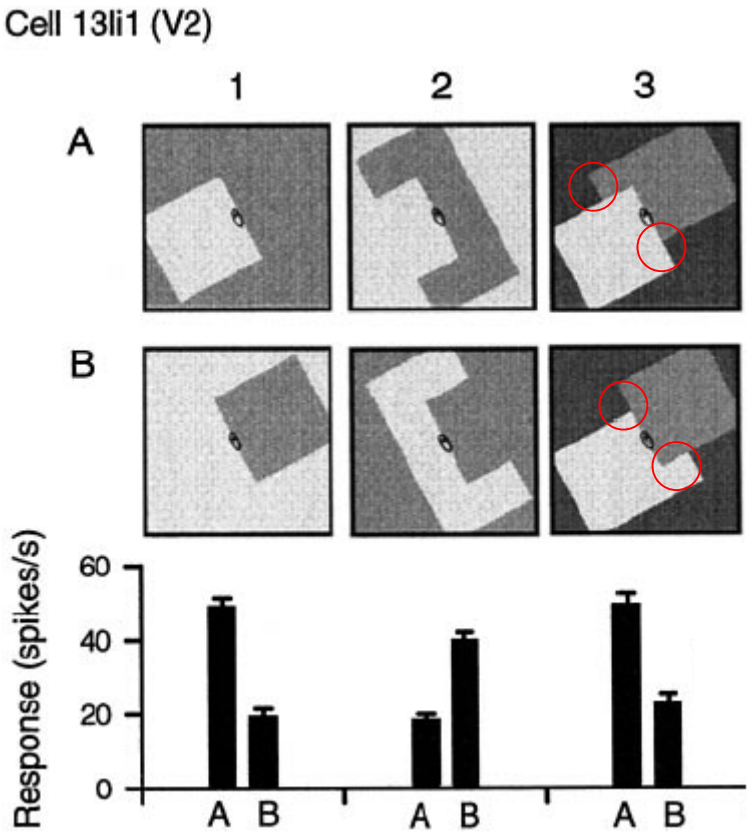

All pixels identical except in outlined areas

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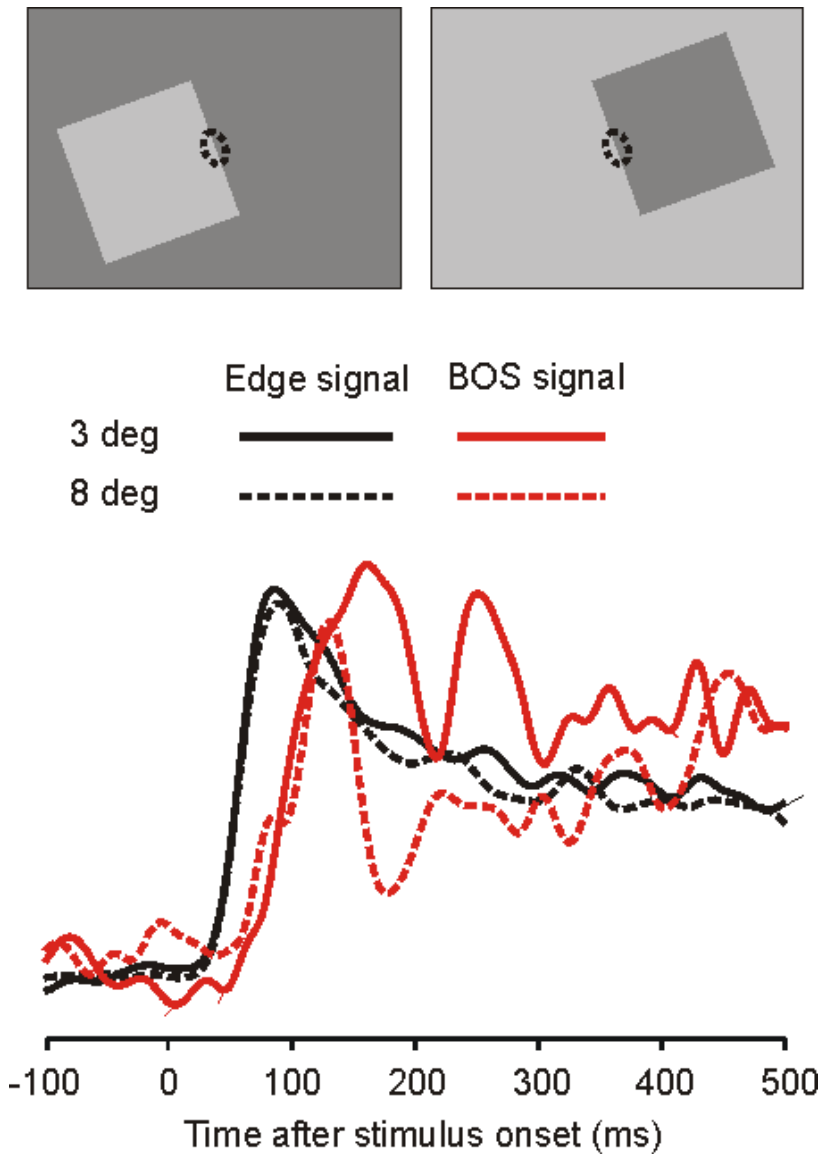
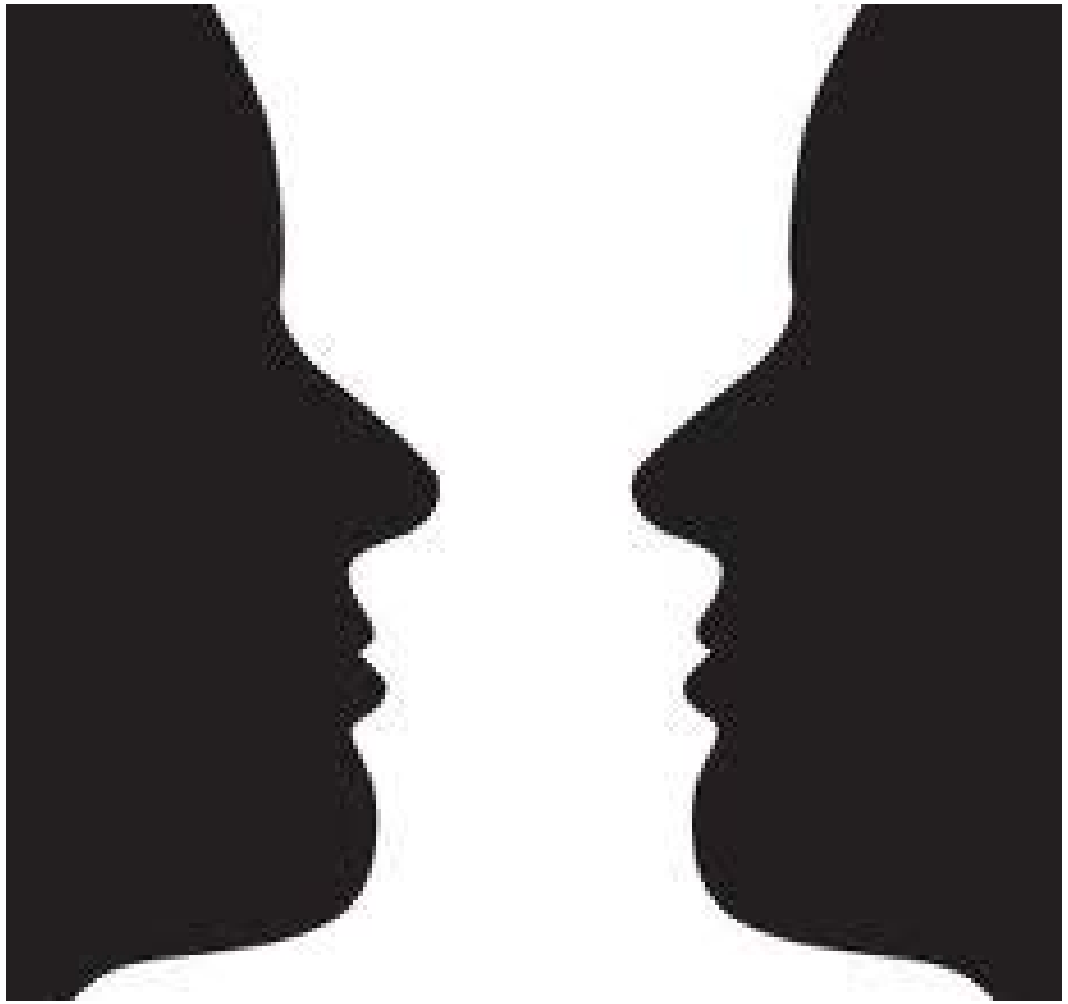
Response Latency



Zhou et al 2000

Vase/Face

(E. Rubin 1915)

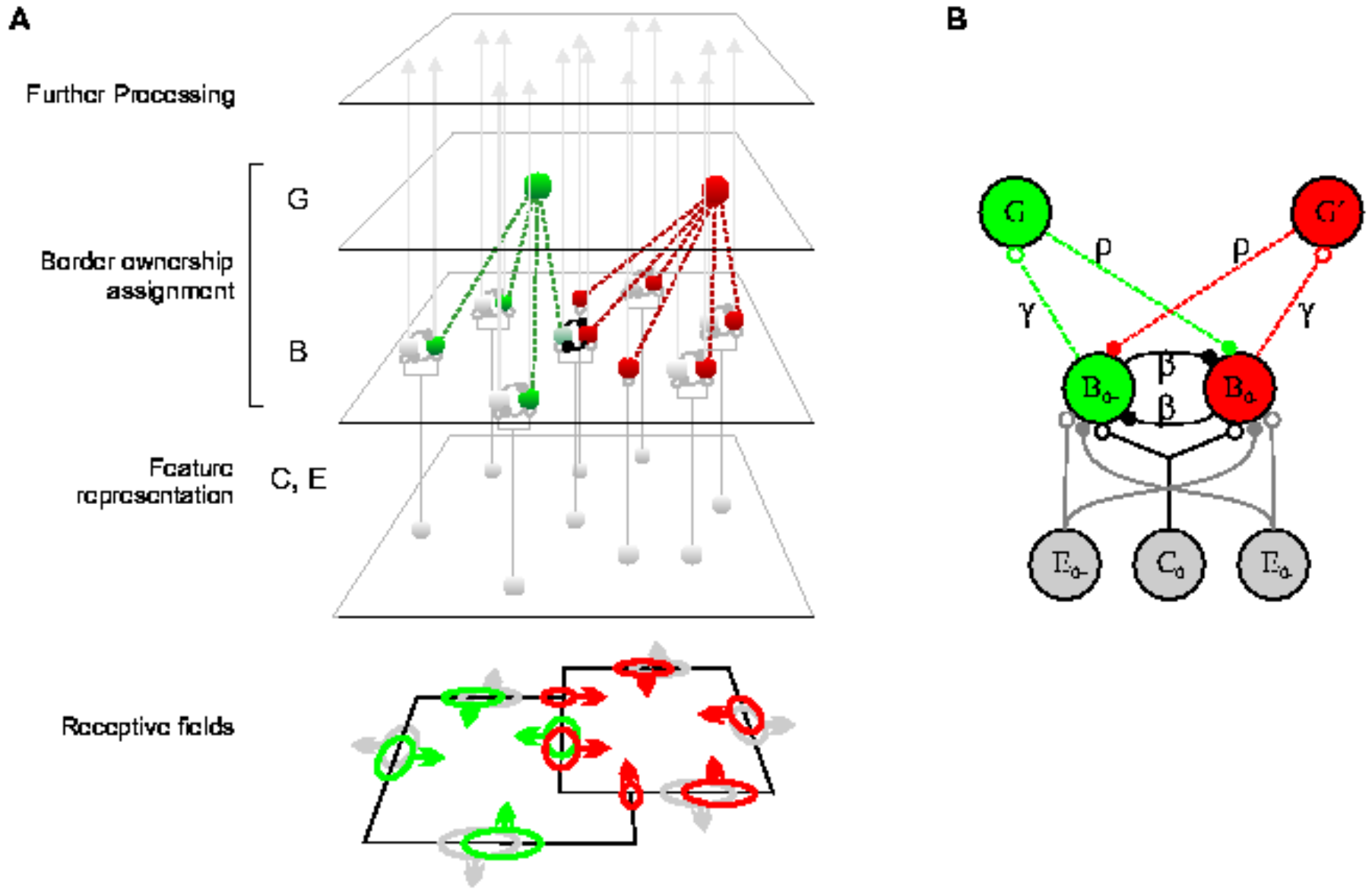


Border ownership is mutually exclusive

Model Design Considerations

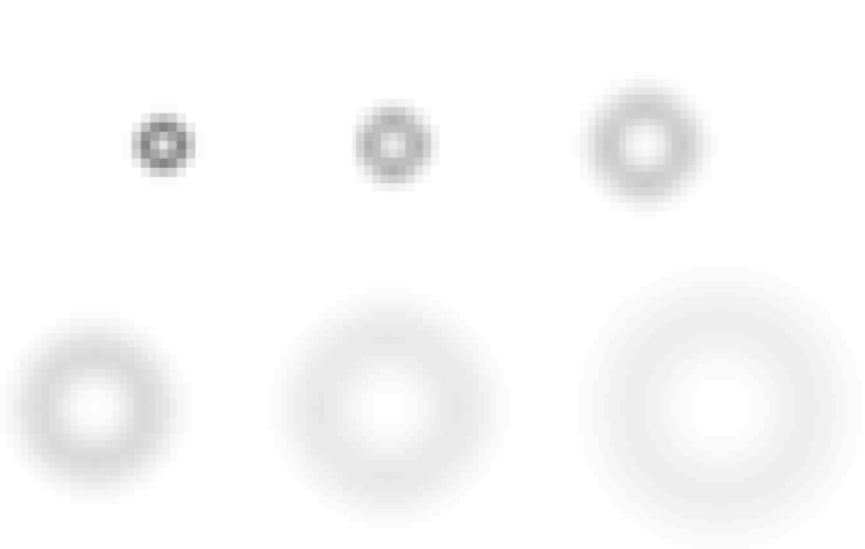
- **Edges of objects may be owned on either of their two sides**
- **Border ownership cells respond preferentially for a single side of ownership**
- **Border ownership cells have broad access to image context with short, fixed latencies (this rules out models based on horizontal connections)**
- **Determination of border ownership occurs independently of high-level functions such as object recognition**

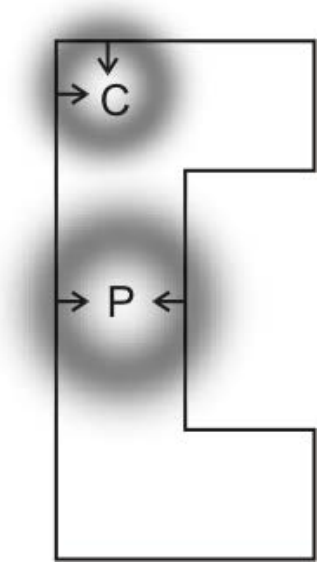
Model Architecture



Craft et al J. Neurophysiol 2007

Grouping Cells: Multi-scale annulus-shaped receptive fields provide proximity grouping and convexity preference

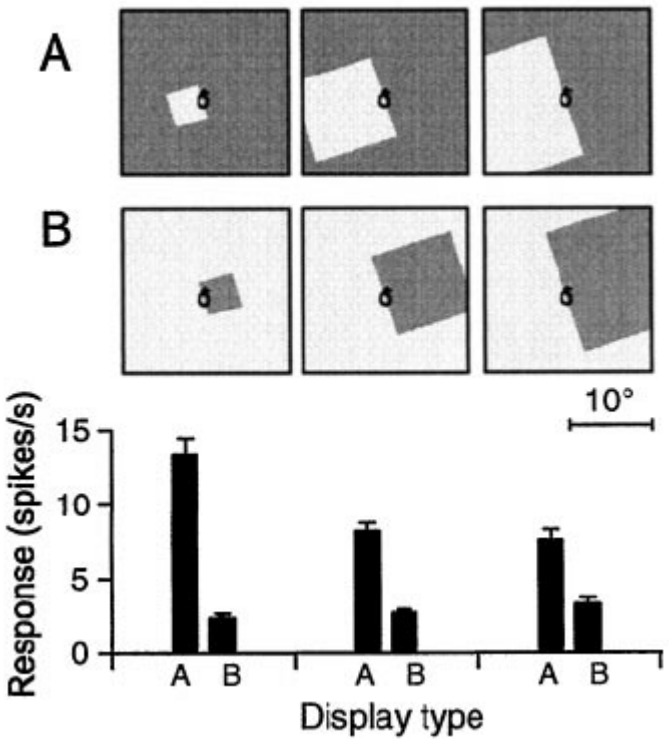




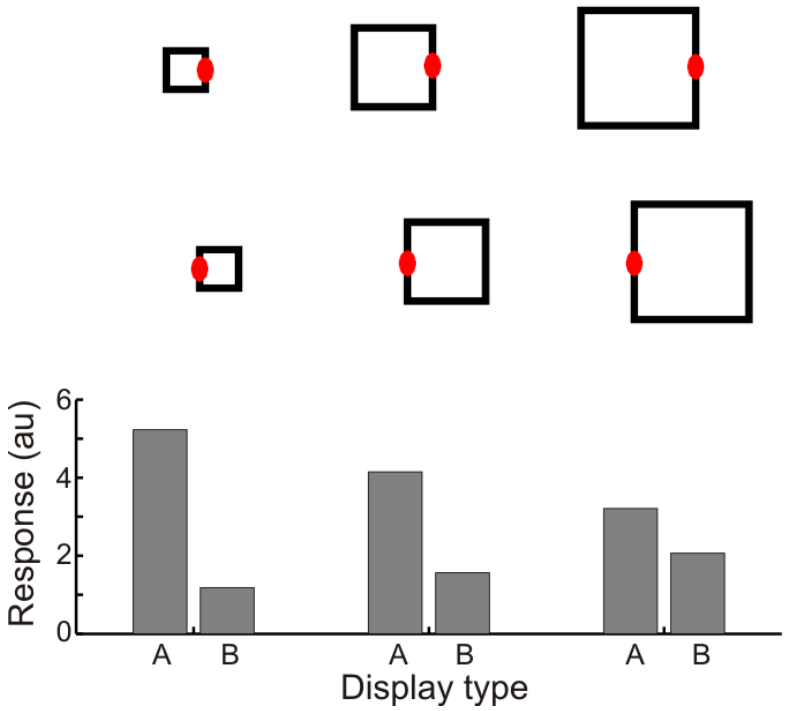
fuzziness = robustness

Model Results: Size Invariance

Cell 13id4 (V2)

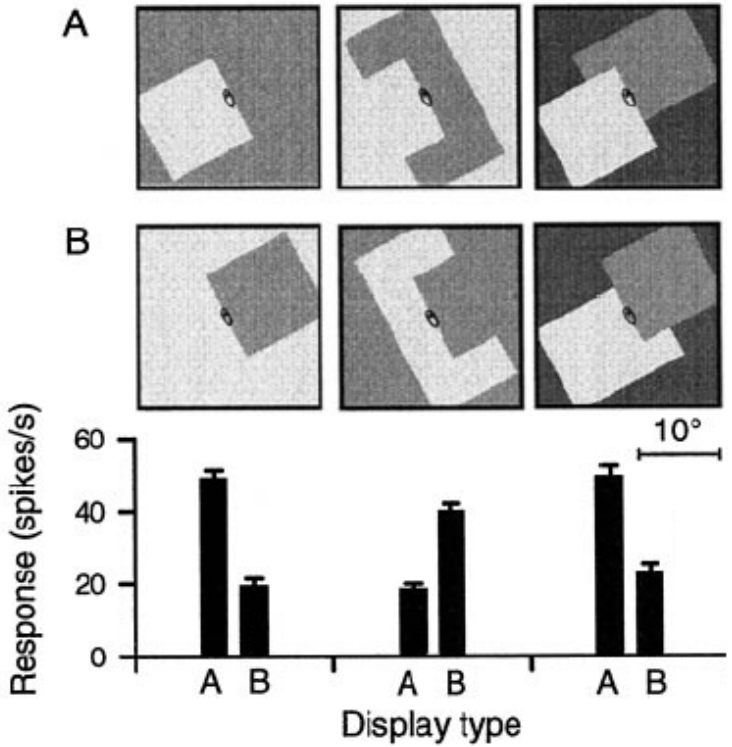


Model



Model Results:
Consistency Across Shapes

Cell 13li1 (V2)



Model