Position-specific heterogeneity of orientation pooling in curvature tuned neurons of macaque area V4

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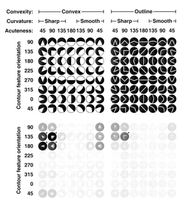
Introduction

Previous studies (Pasupathy & Connor, 1999; 2001) have shown that neurons in macaque visual area V4 are involved in the processing of shapes of intermediate complexity and are sensitive to curvature.

We sought to examine the mechanisms that endow V4 neurons with their shape-selective properties

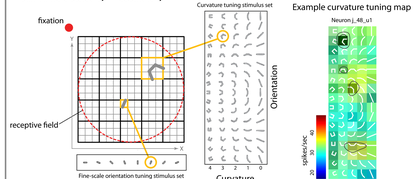
While we replicate the main findings of the earlier studies, we find that curvature-tuned V4 neurons exhibit a surprising degree of spatial variation in their curvature preference.

This complex pattern of selectivity can be fit with a model in which fine-scale orientation tuning maps are pooled to account for spatially varying curvature tuning.



Methods

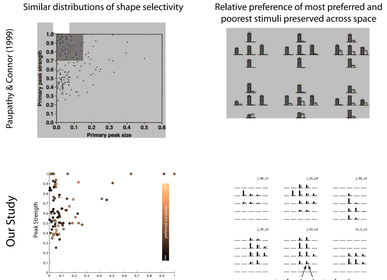
We recorded from 81 isolated units and 78 multi-units in area V4 of 2 awake behaving macaques. Stimuli were presented in a fast reverse correlation sequence (16 ms duration, Poisson distributed delay between stimuli) while the animals maintained fixation for 4 seconds. "C" shaped stimuli were presented on a 5x5 grid centered on the receptive field, while oriented bars were presented on a finer 15x15 grid. A pseudo-random sequence from the combined stimulus sets was presented on each trial. Stimuli were scaled by RF eccentricity.



Replication of prior study

Similar distributions of shape selectivity

Relative preference of most preferred and poorest stimuli preserved across space



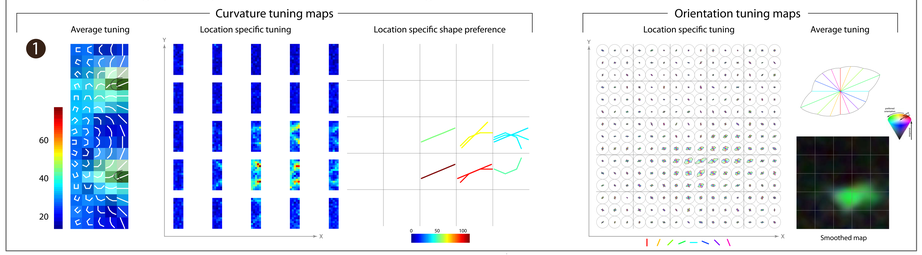
Though we do replicate Pasupathy & Connor's findings using their metrics, a finer-grained analysis reveals spatially varying shape preference for curvature tuned neurons.

1 Example Neurons

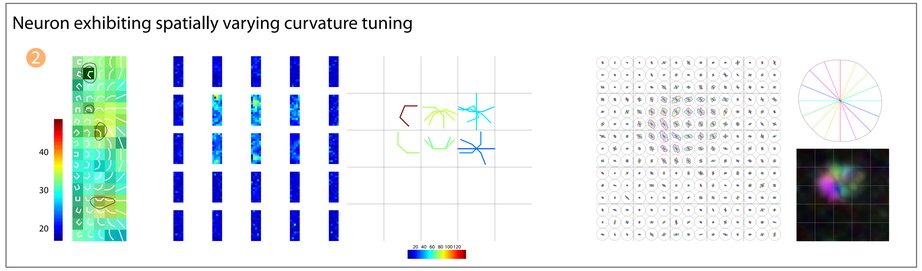
Spatial invariance is more limited for curvature-tuned than orientation-tuned neurons

On a finer scale, curvature tuned neurons exhibit local variation in orientation tuning

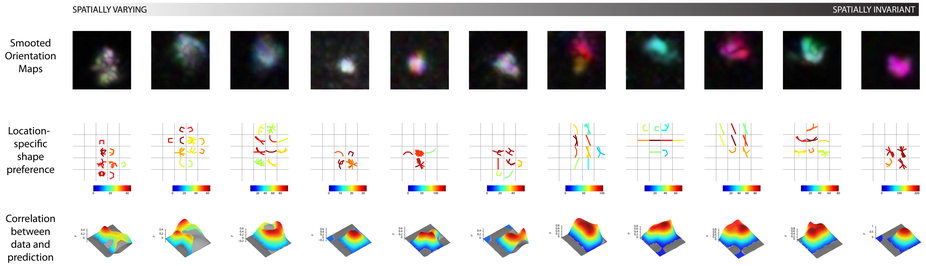
Neuron exhibiting spatially invariant orientation tuning



Neuron exhibiting spatially varying curvature tuning

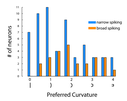


Other examples:

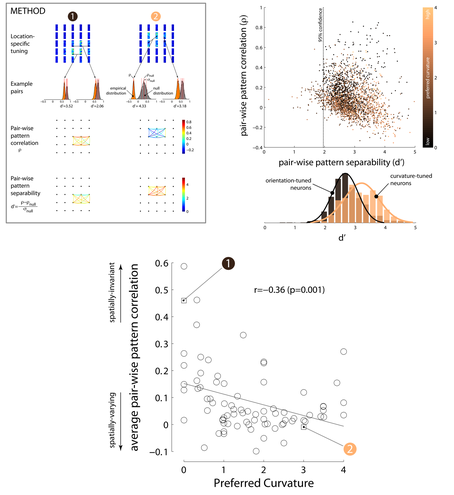


2 Population Statistics

V4 neurons exhibit a broad range of curvature tuning

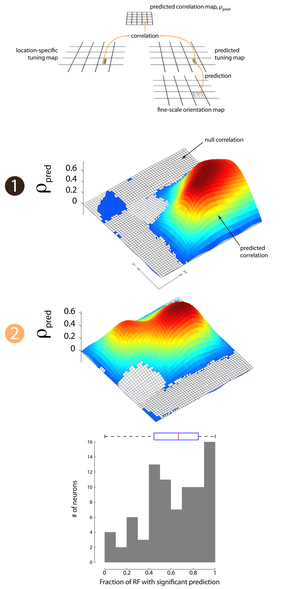


Neurons with preference for higher curvature have spatially varying tuning across RF sub-units



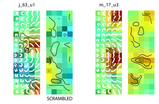
3 Pooling Model

Curvature- and orientation-tuning are predicted by a weighted average of fine scale orientation tuning

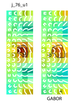


4 Control

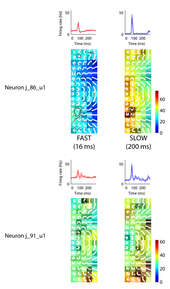
Scrambled stimuli do not elicit tuned responses



Gabor stimuli elicit identical tuning



Stimulus duration does not change shape selectivity



Conclusions

We find that curvature tuned cells in area V4 exhibit considerable spatial variation in curvature preference.

At a finer scale, curvature tuned neurons exhibit local variation in orientation tuning.

In contrast, orientation tuned neurons are spatially invariant and have homogenous fine-scale orientation tuning maps

Patterns of fine-scale orientation tuning maps suggest a strong inheritence of V1 orientation maps.

A weighted-average model of fine-scale orientation tuning predicts curvature- and orientation-tuning.

References:

1. Pasupathy, A. & Connor, C.E. Responses to Contour Features in Macaque Area V4. *J Neurophysiology* **82**(5), 2490-502 (1999)
2. Pasupathy, A. & Connor, C.E. Shape Representation in Area V4: Position-Specific Tuning for Boundary Conformation. *J Neurophysiology* **86**(5), 2505-19 (2001)
3. Mitchell, J.F., Sundberg, K.A. & Reynolds, J.H. Differential Attention-Dependent Response Modulation across Cell Classes in Macaque Visual Area V4. *Neuron* **55**(1) 131-41 (2007)

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