Characterizing neural processing in foveal and parafoveal primary visual cortex
Felix Bartsch¹, Bruce G. Cumming², Daniel A. Buts¹

1) Department of Biology and Program in Neuroscience and Cognitive Science, University of Maryland, College Park, MD USA
2) Laboratory of Sensorimotor Research, National Eye Institute, National Institutes of Health, Bethesda, MD USA

Introduction

- Foveal V1 neurons are seldom studied, primarily due to difficulty measuring and controlling eye position with sufficient accuracy given the small size of foveal receptive fields.
- While the center-of-gaze is highly significant behaviorally and kinematically over-represented in V1, it is expected (though not known) that studies of V1 properties in the parafovea [e.g., 1, 2] should generalize to the fovea.

How does visual processing compare between foveal and parafoveal V1?

Are there differences beyond receptive field scaling?
- Here, we use the Nonlinear Input Model [3], an LNLN cascade, to measure properties of V1 neurons in awake macaques across eccentricities between 0.4 and 16 degrees.
- We use model-based eye-tracking sensitive to ~1 arcmin [4] to allow precise measurements of receptive field properties and validate model-based measurements with model-independent measures.

Methods

Electrophysiology: Recordings came from two macaques using 24-electrode linear arrays (50 µm spacing, 106 ± 100s) or a 36-electrode plane Utah array (400 µm spacing, 40 × 40). Animals performed a fixation task to obtain a liquid reward upon completion of each 4-second trial.

Stimuli: Uncorrelated random bar patterns (100 ms) were presented binocularly on CRIT monitors, with each pattern lasting 10ms. The bars were oriented close to the cell’s preferred orientation. Most experiments were presented at zero disparity, but experiments at ±4 degrees eccentricity involved a different dataset where binocular stimuli were presented at randomly selected disparities.

Model-based eye tracking [4]
- We used the units simultaneously recorded in each experiment to infer the precise position of the eye from moment-to-moment. By integrating probabilistic eye position information over a population of simultaneously recorded neurons, we can infer eye position with roughly 1 arcmin accuracy.

Receptive field width depends on filter width and spatial scatter
- RF width was measured by averaging the spatial profile of all filters, weighted by each filter’s contribution to the model prediction. Scale bar = 0.2 deg.

Electromagnetic stimulation (EMS) and eye-tracking measurements with ~1 arcmin/deg accuracy

High spatial frequency tuning in parafovea
- We estimated spatial and temporal frequency tuning of each cell by computing the 2DFFT for each subunit, and taking an average across subunits, weighted by the response of each subunit to the stimulus.

Spatial scatter at high eccentricities affects responses to gratings
- To compare our results to previous studies, we simulate our model’s responses to grating stimuli. This spatial scatter of individual processing elements can explain the increase in RF size with eccentricity.

Models correctly predict SF tuning
- Models predict SF tuning with the NIM architecture [1]. Stimuli: reward upon completion of each 4-second trial.

Scattered inputs generate envelope tuning
- These sensitive measurements across eccentricity rely on a high-resolution model-based eye-tracking algorithm [4].

Conclusions

- Model-based measures of V1 tuning provide high-resolution information about the selectivity of V1 receptive fields.
- The increase in RF size with eccentricity is explained by two factors: (1) the increasing width of individual processing elements; and (2) the increasing spatial scatter of these units. This suggests that parafoveal neurons may be able to resolve higher resolution inputs than previously expected.
- This spatial scatter of individual processing elements can result in selectivity to low frequencies in the context of drift-and-grating stimuli, particularly in the fovea [1].

- These sensitive measurements across eccentricity rely on a high-resolution model-based eye-tracking algorithm [4].

References


Necessity of model-based eye-tracking [4]

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