

Dependence of Receptive Field Properties as a Function of Location in Functional Maps

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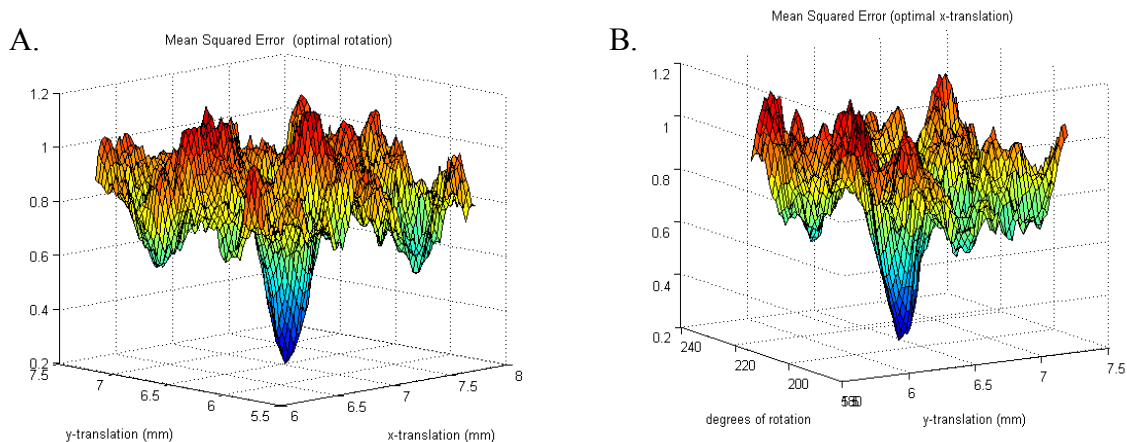
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Receptive field properties in primary visual cortex display a large variability. Much of this variance could be accounted for by inhomogeneities in the local cortical circuitry. Optical imaging of intrinsic signals provides a representation of these local inhomogeneities. The functional map in the vicinity of a cell is a representation of its local architecture, and a cell's properties should thus be correlated with the local structure in these maps. One such property is the degree of orientation selectivity as measured extracellularly. Here we introduce a general method to study how single cell RF properties vary across the orientation map and provide some initial support for the dependence of orientation selectivity on map location.

Method:

The position of our 10x10 electrode array (400 μ m separation) on the cortical surface has 3 degrees of freedom: x-translation, y-translation, and rotation. All of the electrodes with isolated spikes have functionality in correspondence with the underlying functional maps: orientation, ocular dominance, and retinotopy. The goal of the algorithm is to minimize the mean-squared error of this functionality with respect to the positioning variables. For example, the sum of the squared differences between the orientations of the electrodes and the orientations at their respective location in the map, should be minimized when the correct position of the array has been found.

The results of this method from one experiment are shown in Figure 1. Figure 1A shows the mean squared error as a function of x and y translation at the optimum rotation (i.e. a slice at Φ where $e(x,y,\Phi)$ is minimized). Figure B is at the optimal x-translation. There is a pronounced dip in these error plots, which unambiguously corresponds to the location of the array. We performed a very wide search and this peak was the global minimum. Figure 1C shows the resulting location of the array obtained by our algorithm. Figure 1D shows a scatter plot of the orientation preference from the electrophysiology and the orientation map at the determined locations.



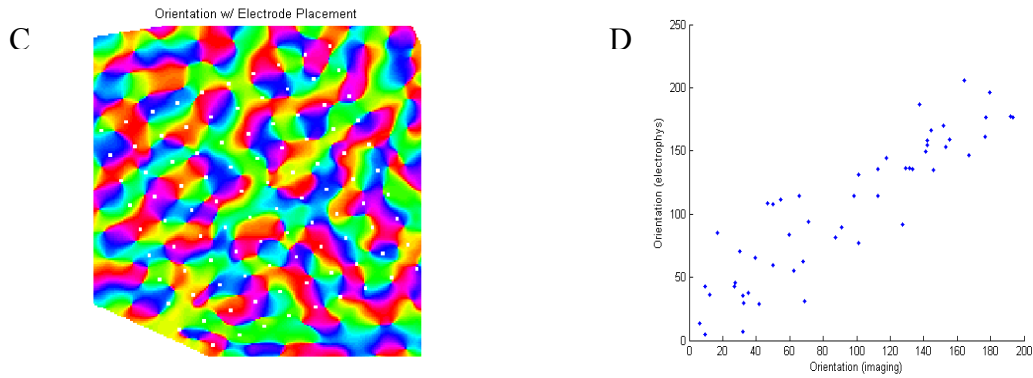


Figure 1: (A) The error function, $e(x,y,\Phi)$, at the slice for optimal rotation, (B) x-translation,. The search is over a fairly large range, and the peak is at an obvious global minimum. This peak corresponds to the location of the array, which is shown in C. The grid of white dots are the determined electrode positions (400 μ m apart). Figure D shows a scatter plot of the orientation preference from the electrophysiology of 52 electrodes vs. the preference in the orientation map at the corresponding locations, as determined in the search. The orientation domain is from 0° to 180°. The axes go beyond 180 because the angular variables have been “unwrapped” to better demonstrate the correlation. We used a correlation coefficient metric for angular variables provided by Mardia '72, which results in $R = 0.52$. It should be noted that using this metric, instead of the error (i.e. maximizing correlation), results in the exact same location of the array in the search.

Results:

Figures 2A and 2B show the Orientation Selectivity Index (OSI) as a function of the OSI in the orientation map. The positive correlations indicate that cells are more sharply tuned in isodomains and more broadly tuned near pinwheel centers.

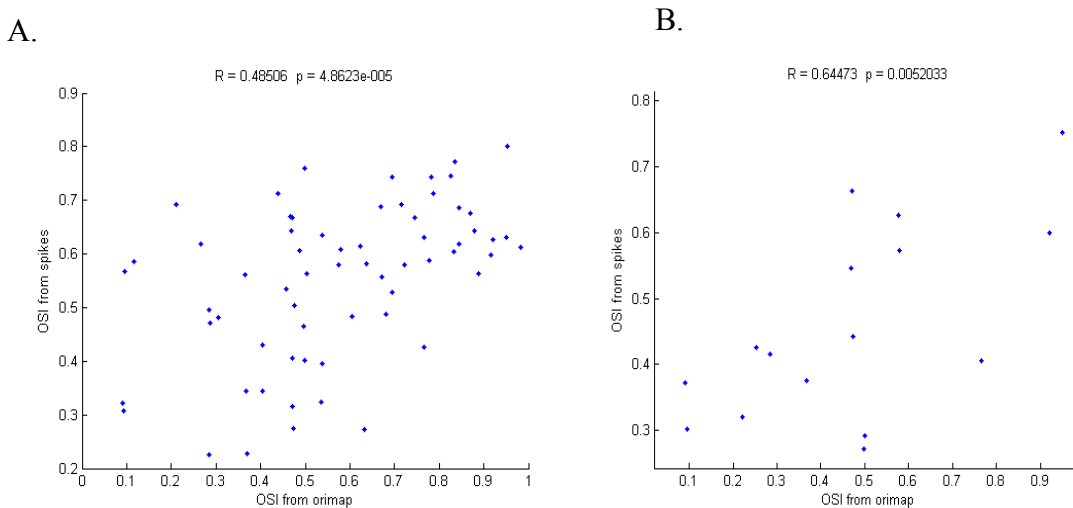


Figure 2: A, Single-unit. B, Multi-Unit

References

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