Introduction

The functional role of cortical columns has recently come under some scrutiny [Mountcastle, 2003; Rockland and Ichinose, 2004; Horton and Adams, 2005]. We have previously shown that responses in neighboring cells in primary visual cortex exhibit a great deal of heterogeneity when stimulated with natural images [Yen et al., 2007]. In this study, we investigate this issue further by using a 54-channel silicon polytrode [Blanche et al., 2005] to record simultaneously from large numbers of cells in different layers of the primary visual cortex of the anesthetized cat while presenting both natural images and drifting gratings.

Methods

Spike sorting

We sorted the spikes based on a template matching approach. We first identified sets of contiguous active channels, which were channels for which the maximum negative amplitude exceeded four times the standard deviation of the signal. The envelope of the largest negative amplitudes in each contiguous set was then compared to a generic decaying profile found to characterize the signal of a single cell. Those envelopes found to be consistent with single cell signals were then grouped with other similar envelopes to form template clusters. The rest of the signals were then matched against combinations of these profiles using the spatial correlation between the largest negative envelope on all the active channels. Seen below is a schematic of the probe (a) raw, high-pass filtered data and (b) a sample waveform with channel groups identified. To the right are raster plots and ISIs of three cells.

Orientation tuning

We found a total of 492 cells across six sites in one experimental animal, with 209, 209, 76, 146, 121, and 120 cells at each site respectively. The approximate locations of each of the cells are indicated by a dot on the polynode channel with the largest spike amplitude. Blue and red dots indicate tuned and untuned cells respectively. The cells were mostly spread out across the recording probe, but with some inhomogeneity for the different sites. Sites 2, 3, and 7 appeared to capture the largest spread of activity across the polynode. We found a total of 407 (44%) of the cells tuned, with 17, 129, 159, 66, 118, and 64 in sites 1-6 respectively.

Right: The location of the tuned cells, as well as their preferred directions of motion, are shown as dots in the plots for the different sites. The color of the dots denotes the magnitude of tuning, defined as the ratio of the response at the preferred direction to the response at the orthogonral direction. For most of the sites, the tuned cells formed ice-orientation clusters, consistent with those cells belonging to the same cortical column.

Tuning latency

Shown above are plots of spike activity as a function of orientation and time for six cells. The color scale indicates the accumulated number of spikes for each orientation at the given time. The horizontal line indicates the preferred direction and the vertical lines indicate the latency at which that particular direction became preferred. Notice that the cells in the left column exhibited strong orientation selectivity but low direction selectivity. A total of 71/407 (19%) cells exhibited this behavior.

Cross-correlation analysis

Four examples of cross-correlation histograms from our database of cell pairs. All four have peaks located within a lag of ±2 ms, but with very different peak strengths. Also shown is the Gaussian fit to each of the peaks.

Summary

Using novel spike sorting techniques and by comparing the responses of cortical cells to movie and grating stimuli, we found evidence of:

• early onset of orientation tuning
• systematic variation of tuning strength with cell depth, which could indicate the different cortical layers
• sparsely correlated responses within the putative cortical column
• heterogeneity in correlation strength between movie and grating responses in terms of cell distance
• heterogeneity in correlation strength between movie and grating responses for tuned cells.

References