Additional information accompanying the paper:

“Distortions of visuotopic map match orientation singularities in primary visual cortex”,
by Aniruddha Das and Charles D. Gilbert

The primary finding in the published paper is that the map of visual space on the primary visual cortex (of cat) is not smooth; rather, the map shows strong local inhomogeneities that match the local inhomogeneities of the map of orientation on cortex, such that the rate of movement of RFs across cortex is largely linearly proportional to the rate of change of orientation. In Fig. 1 we reproduce Fig. 2a and 2b of our published paper, to show our main findings and to compare with the results of other tests and simulations reported below. The data from the specific experiments used for the illustrated Monte Carlo simulations (Fig 3 and 4) are highlighted. The slopes of the regression lines are tabulated in Table 1, along with the results from the various simulations (a partial reproduction of Table 1 of our published paper).

The data reported in the paper were tested using a number of statistical tests, and the primary findings were tested against null hypotheses that were simulated using Monte Carlo techniques. The salient numerical results obtained through such tests and simulations are cited in the published paper. Further details of the statistical tests and Monte Carlo simulations, including figures, are provided below.

I: Check for bias in the measurement of cortical position:

We checked whether the linear relationship between rate of RF movement & rate of change of orientation could be an artefact of systematic errors in cortical position. For example one possible source of systematic errors is as follows: in our measurements we could have systematically overestimated cortical separations that gave small orientation (or RF) shifts because the cortical separations were too small to be accurately measured. By the same token we could have underestimated separations that gave large orientation shifts. Such systematic errors would have artefactually stretched the clustered rates of RF movement and orientation change along the diagonal (Fig 1b) leading to an apparent linear relationship between the two. Any such systematic errors should would also lead, however, to correlations between cortical separation and measured orientation shift, or measured RF shift. In Fig 2a and Fig 2b we show orientation shift and RF shift, respectively, as functions of the inter-site cortical distance separating of the corresponding pair of recording sites. The values of $R^2$ in the two plots came to 0.09 and 0.06 for the Δ orientation & Δ RF scatter plots respectively. Clearly these quantities are not correlated with inter-site distance, indicating that there is no systematic bias in our selection of recording sites.

II: Monte Carlo simulations: to show that our finding, of inhomogeneity in cortical magnification correlated with inhomogeneity in the orientation map, cannot be accounted for by a smooth visuotopic map with some additional scatter.
We tested the results of individual experiments (over small cortical regions of about 1 - 2 mm in size) against the null hypothesis that RF clustering could be the result of a linear, locally homogeneous map from cortical co-ordinates to visual space, + some random scatter. For each experiment, we first obtained the best fit for the linear map factor with a least-squares method. We calculated the linear transformation (rotation + magnification) from the cortical coordinates to the experimentally obtained RF centers that minimized the sum of squares of residual “scatter”. We then used this best fit linear map factor and the RMS of this residual minimal scatter for the Monte Carlo simulations. We kept the set of cortical positions fixed and generated sets of RF positions = linear map + random scatter, with the scatter chosen from a 2D Gaussian probability distribution of RMS = RMS minimal scatter. For each such set of RF positions generated, we performed the same set of calculations (change in RF centre vs. change in orientation) for the same pairs of cortical sites as in the experimental situation. The results of such calculations, pooled together for 4 experiments, are shown in Fig. 3. The simulated RF shifts show little correlation with the corresponding orientation changes and display none of the trends apparent in the real data. The regression slopes and correlation coefficients obtained from the simulated data (Table 1) make it highly improbable (prob. < 10^-7) that our results could be accounted for by a linear visuotopic map with added scatter.

III: Monte Carlo simulations: to show that our results are robust against uncertainties in electrode position or RF scatter.

We estimated the influence on our results of uncertainties in cortical & RF position using a Monte Carlo simulation that added scatter to our real data. The scatter of cortical position was chosen from a gaussian distribution of diameter 50 microns around the experimentally obtained value. The scatter in RF centre position was chosen from a gaussian of diameter = 0.2 X (RF diameter), a value obtained from our measurements (see below). The results of the simulation, pooled over 4 experiments, are shown in Fig 4. The regression lines through the simulated data gave slopes and correlation coefficients similar to those obtained from the real data (Table 1).

IV: Measuring and controlling for scatter in RF position and size:

By using stringent controls for eye movement, with eye rings glued to sclera and with a reference electrode to monitor residual eye movements, we find that there is negligible scatter in RF size or position (in the upper cortical layers, where we restricted our measurements). In four experiments we specifically measured the scatter in (multi unit) RF position and size down vertical penetrations. With stabilized eyes and fixed reference electrodes, we plotted the boundaries of RFs encountered at 50 to 70 micron intervals from the surface down to 500 microns. At each cortical site, the position scatter was measured = RMS of the distance of RF centres from the mean RF centre. RF sizes were defined = (RF diagonal / 1.414). Scatter in RF position and standard deviation in RF size were normalized by the mean RF size at each cortical site. Over 24 penetrations in 4 experiments and all eccentricities available on the exposed Area 17 (0° -> 10°), we obtained the following results:

RF position scatter: = 0.108 X (mean RF size)
RF size: standard deviation = 0.09 X (mean RF size)
We have used these values for our paper and in the Monte Carlo simulations of scatter.

These values for RF scatter might appear surprisingly small when compared with values in the literature (this had been done most carefully in the monkey, *e.g.* Hubel & Wiesel 1974). We believe, however, that the pattern of the much larger RF scatter obtained by earlier investigators is suggestive of eye movement. (See, for example, Fig. 7 of Hubel & Wiesel ‘74).

**V: A comparison between the optically mapped and hand mapped values of RF orientation:** For the quantitative analysis we used RF orientation values mapped by hand. In each experiment the difference between hand-mapped and optically imaged orientations was typically ~ 10°, ± 10° (1 std. dev.). Since our calculations involved orientation differences the effect of this small shift between hand-mapped and optically-imaged orientations was even less significant. This is evident, for example, in Fig 5 where we compare numerical results obtained with hand-mapped values, with those obtained using optically imaged values of orientation, for 2 experiments.

**References**


<table>
<thead>
<tr>
<th>Rate of RF Movement, (fractions of RF diameters per 100 μm cortex) vs Rate of Change of Orientation (degrees / 100 μm cortex)</th>
<th>Shift in RF (fractions of RF diameters) vs. Change in Orientation (degrees)</th>
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</thead>
<tbody>
<tr>
<td>Slope (± SE)</td>
<td>R²</td>
</tr>
<tr>
<td>Real Data</td>
<td>0.0110 (± 0.000066)</td>
</tr>
<tr>
<td>Monte Carlo simulation 1: (Linear map + scatter)</td>
<td>0.002 (± 0.00034)</td>
</tr>
<tr>
<td>Monte Carlo simulation 2: (Real data + scatter)</td>
<td>0.0119 (± 0.0002)</td>
</tr>
</tbody>
</table>

Table 1: Slopes and correlation coefficients for real data (Fig. 1), and for the two Monte Carlo simulations (Fig 3, 4).
Website Fig 1: Primary findings of the paper.
A: Rate of RF movement across cortex is linearly proportional to the rate of change of orientation;
B: For pairs of RFs recorded from nearby sites, the jump in RF position is proportional to the change in orientation preference.
Data from the particular experiments used as the basis for the Monte Carlo simulations in Fig 3, 4 are indicated by special symbols (Slopes and correlation coefficients in Table 1)
Website Fig 2: Orientation Changes and RF Shifts Show No Correlation With Inter-Site Distance.
A: Scatter plot of orientation shift vs. inter-site distance on cortex.
B: Scatter plot of RF shift vs. inter-site distance on cortex.
(See text for correlation coefficients)
Website Fig 3: Simulation of Null Hypothesis, Linear Map + Scatter.
A, B: Data from Monte Carlo simulation based on null hypothesis, plotted as in Fig.1A, B
(Slopes and correlation coefficients in Table 1)
Website Fig 4: Simulated Effect of Measurement Uncertainty on Results. A, B: Data from Monte Carlo simulation adding realistic scatter to experimental results, plotted as in Fig.1A, B. (Slopes and correlation coefficients in Table 1)
Website Fig 5: Results Obtained with Hand-Mapped Orientation Values Match Closely Those Obtained With Orientations Read Off Optical Image: Results from 2 experiments, in upper and lower rows respectively, analysed as in Fig 1A (left column) and Fig 1B (right column).

Key:  
+ hand-mapped data 
♦ optical image data