Patches and maps in cat area 17

Activation of a single functional modality in feline primary visual cortex (for example, a oriented grating stimulus) provokes a spatially distributed cortical response. Restricted regions of elevated activity appear across the cortex, forming areas which become the **iso-orientation domains** of a map of orientation preference. Are these domains distributed regularly across cortex? We compare the spatial arrangement of active regions with three artificial models with prescribed spatial structure. We find that regions of activity are arranged regularly across cortex approximately in a rough hexagonal grid.

Intrinsic optical imaging

Cats (9 weeks to adult) were anaesthetised and a craniotomy was made, exposing area 17 (primary visual cortex). A set of grating stimuli were presented to the animal, and the cortical surface was recorded using a camera. The absorbance of light is modulated by neural activity, which results in an image identifying active populations of neurons across the cortex. Shown here is a map of the cortical response to a single orientation. Lighter regions of the map indicate populations in visual cortex which respond preferentially to a vertical grating.

Arrangement of active regions

The centres of active regions were located by finding the peaks of the strongest cortical response, and neighbouring peaks were identified. Peaks of activity are indicated by black crosses, and neighbouring active regions are connected by black lines.

Synthetic imaging maps

Artificial maps of the cortical response were generated by sending white spatial noise through a low-pass filter, then mixing with more white noise. "Activity" peaks and neighbours were located as for the optical imaging maps.

Hexagonal grids

The locations of bumps observed in optical imaging maps was compared with points arranged on a hexagonal grid, under the hypothesis that active regions across cortex have a regular spatial organisation. Grids with random origins and orientations were generated, with a nominal vertex spacing of 1100 µm. Points were then shifted in a random direction by up to 450 µm.

Random locations

The arrangement of active regions across cortex could follow a random distribution. We generated uniform random point locations to compare against the arrangement of active regions of cortex observed though optical imaging.

Examples from the four data sets are shown. The border of the visible area of cortex is sl as a white outline, or as a white region. From top to bottom: A map of the cortical respon a single orientation, obtained through optical imaging; a synthetic optical imaging map created by filtering white noise; a set of locations generated by a jittered hexagonal grid; a set of locations placed randomly within the visible area of cortex. Scale bars are 1 mm in all figures.



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The jittered hexagonal grid model was indistinguishable from the measured spatial distribution of cortical activity.

Comparison between models



Discussion

The graphs at top-right and bottomright show the full distributions of inter-

blob angles and distance, respectively, measured for the four data sets. The two artificial data sets (the synthetic imaging maps and the jittered hexagonal grid) are quite similar to the distribution of activity in the cortex, the spatial arrangement of activity blobs is clearly not random.



The imaging techniques used to record maps of cortical function can only reach the superficial layers of cortex. This begs the question of whether functional maps are generated deeper in cortex.

Another regular system exists in the superficial layers, called the superficial patch system; long-distance axonal projections from large populations of superficial pyramidal cells cluster to reveal a semi-regular pattern (figure behind text from Lund 2003; scale bar 1 mm).



The measured distribution of inter-peak distances for active cortical regions is very similar to the inter-patch distance measured under population labelling experiments in the superficial layers. If functional maps are generated through lateral interactions within the superficial layers, the spatial arrangement of functional domains could be expected to be similar to the clustered axonal arborisations of the patch system.

rov-Smirnov test was used to compare istributions. An asterisk indicates that ot be distinguished at 1% significance. es that the distributions are indistinguishance level. A red square indicates that the distributions were significantly different.

Experimental Maps Jittered Hex Grid Synthetic Maps Uniform Random



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