supplementary information

Supplementary Information for "Dissociation between hand motion and population vectors from neural activity in motor cortex"
Nature, V413, 161

Methods and Additional Notes

Preferred Direction of a cell. The activity of cells from monkeys a and b (39% of total sample) were recorded for 8 targets that were not symmetrically-distributed in space (target directions = 45, 67.5, 90, 180, 247.5, 270, 305, 327.5E). The standard approach (*trigonometric method*) to define the directionality of a cell[1] could not be used with these cells so we used techniques to describe planar objects (*plate method*) to identify the directionality of these cells**.** For each block of trials, vectors were constructed for each movement oriented with movement direction and scaled by cell discharge in polar space. The tips of adjacent vectors were connected by a curved line with a distance coordinate that varied linearly in magnitude in polar space between the two vector tips. Each pair of adjacent vectors and adjoining curved line was then treated as a three-sided planar object and we computed its relative area and centroid. Similar measures were made for each pair of adjacent vectors creating a total of eight objects. The total area and its centroid was then found across all eight objects. The position of the centroid relative to the origin served as a measure of the cell=s directionality for each block of trials.

In order to test the validity of this plate method, the activity of 38 neurons was recorded for movements to 16 targets symmetrically distributed in space (every 22.5E). The PD of each cell computed using the trigonometric method from neural activity recorded for movements to all 16 targets was used as a baseline measure of the cell=s directionality. Table S1 shows the absolute mean error in the PDs for the different methods (trigonometric and plate) and the different target groups (16, 8 symmetric and 8 non-symmetric targets). The absolute mean error in the PD of cells using the 8 non-symmetric was 10.2E and only 2 neurons showed errors greater than the bin-size used to group the PD of cells in Fig. 2 (22.5E). Therefore, directional tuning of 95% of the cells sampled was within one bin-width of its actual tuning. Such small differences cannot account for the non-uniform distribution of preferred directions displayed in Figure 2.

Relationship between cell modulation and PD. Figure S1a illustrates a polar plot of the mean cell modulation relative to movement direction. Cell modulation was defined as the highest mean discharge rate prior to and during movement (reaction time plus movement time) measured for any movement direction minus the lowest mean discharge rate for any movement direction. There was a wide range in the modulation of neural activity across the cell sample (mean ∀ sd = 25.8 ∀ 16.4 spikes/s). The modulation of activity for cells with PDs within ∀ 22.5E of a given movement direction were averaged to define mean cell modulation for that direction. Thick and thin lines denote mean∀sd, respectively. Figure S1b illustrates relationship between peak joint power and mean cell modulation for the 16 movement directions. Note that there is no systematic variation in mean cell modulation and either movement direction nor peak joint power.

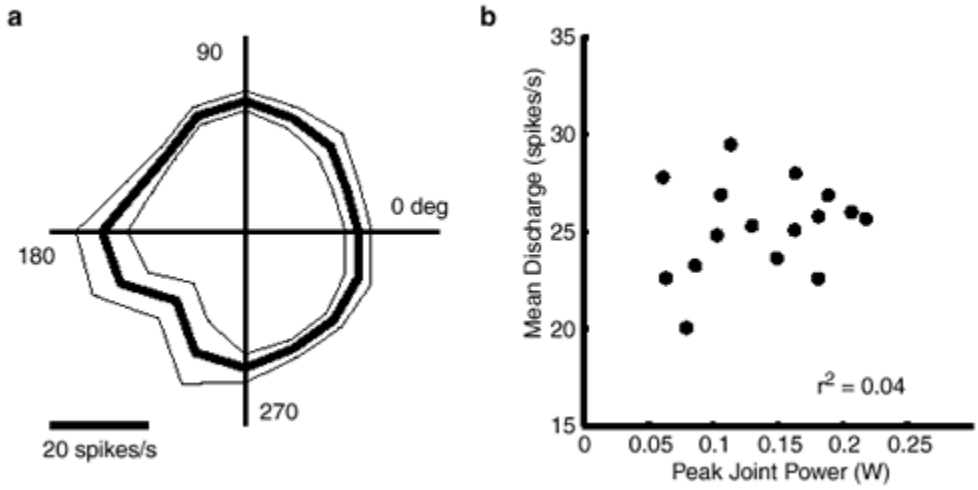

Figure S1

Estimate of the Population Vector. In order to estimate the activity of each cell for movements to all 16 targets, we used a unimodal von Mises function[2] with four parameters (X_1-X_4) to model the discharge rate (S) of a cell from the 8 different directions of movement based on,

$$S = X_4 + X_3 * \exp(X_2 * \cos(D-X_1)) \quad (1)$$

where D is movement direction in Cartesian space and X_1 was pre-set to the cell=s preferred direction.

As a control, PVs were re-computed using the actual discharge rate of the cells for the five movement directions in which activity was recorded in all 214 cells. In all cases, these population vectors were statistically different from the actual direction of hand motion ($p<0.01$, bootstrap technique). Table 2 illustrates the difference between the direction of hand movement and population vectors based on von Mises tuning functions and based on the actual cell discharge rates for the five movement directions. Note the similar sign and magnitude of the errors between the two approaches.

References

1. Scott, S. H. & Kalaska, J. F. Reaching movements with similar hand paths but different arm orientations. I. Activity of individual cells in motor cortex. *J. Neurophysiol.* **77**, 826–852 (1997).

2. Batschelet, E. Mathematics in Biology: Circular Statistics in Biology (Academic, London, 1981).

Table S1 Errors in the directional tuning of cells.

	Trigonometric Method mean ± sd (deg)	Plate Method mean ± sd (deg)
16 symmetric	?	4.4 ± 5.6
8 symmetric	5.8 ± 8.2	8.3 ± 11.1
8 non-symmetric	?	10.2 ± 16.9

Table S2 Population vector errors.

		VECTOR ERRORS	
Target Direction (deg)	Movement Direction (deg)	Von Mises (deg)	Actual Discharge (deg)
45	45.8	18.9	29.5
90	95.8	9.8	12.0
180	182.6	-20.9	-27.0
270	265.5	17.9	19.7
315	311.9	-8.3	-10.3