Supplementary Figure 1

Pre-recording behavioral performance.

Performance is shown for the last seven days of training prior to neuronal recordings for the DMS and DMC tasks. (a) The monkeys’ average DMS performance (proportion reported as non-match) is shown as a function of sample-test difference. The gray line is a sigmoid curve fit to the behavioral data. Dashed black line indicates chance performance. Error bars indicate SEM for sample-test differences that were presented on more than one session. The circular points show behavioral performance for sample-test differences tested in only one session. The mean number of presentations per sample-test difference was 127 per session. (b) The monkeys’ average DMC performance is shown as a function of sample direction. Colors correspond to the two categories and the green dashed lines correspond to the category boundary. Dashed black line indicates chance performance. Error bars indicate SEM.
Supplementary Figure 2

DMS training behavioral performance.

The monkeys’ DMS performance leading up to DMS recordings is shown as a function of training session for Monkey D (a) and Monkey H (b). The level of behavioral performance is depicted by plotting the sample-test difference at which the monkey would perform at 75% accuracy, as estimated by a sigmoid curve \((1+1/(1+e^{-(x-a)/b}))\) fit to the average performance for the sample-test differences tested in each session. The first 21 (Monkey D) and 20 (Monkey H) motion-DMS training sessions were excluded because performance on 180° sample-test differences was lower than the performance threshold (as the monkey was not yet reliably differentiating between 180° non-matches).
Supplementary Figure 3

Single-neuron measures of direction and category classification.

The average time-course of direction and category selectivity for individual neurons measured by the rDSI (a) and rCTI (b) during DMS (pink curve) and DMC (green curve) tasks. The three dashed, vertical lines represent the start of the sample epoch, the end of the sample epoch, and the end of the delay epoch, respectively. Gray and black bars represent times at which classification accuracy was significantly different between the populations recorded during the two tasks (Wilcoxon rank-sum test, gray, P<0.05, black, P<0.01). Only cells that were direction selective during the sample or delay periods were used from each population. (c-f) Distributions of neurons’ rDSI (c,d) and rCTI (e,f) values during the sample (c,e) and delay (d,f) periods for direction selective cells during the indicated task epoch. Thick dashed lines indicate mean values across the population of direction selective cells during the DMS (pink) or DMC (green) tasks (rDSI, Sample: DMS µ=0.16, DMC µ=0.13; rCTI, Sample: DMS µ=0.0015, DMC µ=0.0093; rDSI, Delay: DMS µ=0.044, DMC µ=0.038; rCTI, Delay: DMS µ=3.9x10^-4, DMC µ=0.049; ***P<0.001).
Supplementary Figure 4

Temporal stability of direction encoding in LIP.

Similar to Figure 5c, the stability of direction encoding in LIP neurons was determined by training the classifier at one time point (y axis) and testing at a second time point (x axis). Classification accuracy is indicated by the color at each x-y coordinate. (a) Direction classification accuracy during the DMS task was above chance during the sample epoch, and near chance during the delay epoch. Classification values were approximately equal for most training and test times during the sample, indicating that direction encoding was mostly stable during this epoch. (b) Direction classification accuracy during the DMC task was also above chance during the sample epoch, and near chance during the delay epoch. Similar to (a), direction encoding was mostly stable during the sample epoch.
Supplementary Figure 5

Mid-training DMC behavioral performance.

(a) The monkeys’ average DMC performance is shown as a function of sample direction. Colors correspond to the two categories and the green dashed lines correspond to the category boundary. The dashed black line indicates chance performance. Error bars indicate standard error of mean (SEM).

(b–e) The monkeys’ average DMC performance during mid-training DMC (cyan) and fully-trained DMC (green) recordings is shown as a function of sample-test difference for match trials (b,c) and nonmatch trials (d,e) where sample directions were 22.5° (b,d) or 67.5° (c,e) from the boundary. Dashed black line indicates chance performance. Error bars indicate SEM.
Supplementary Figure 6

Example LIP neurons and population-level direction and category classification during the mid-training DMC task. 

(a,b) Average activity evoked by 8 sample directions for two LIP neurons from the mid-training DMC task. Different traces indicate different sample directions and are colored according to their direction and category membership. The three dashed, vertical lines represent the start of the sample epoch, the end of the sample epoch, and the end of the delay epoch, respectively. Dark blue and dark red traces indicate sample directions near the middle of categories 1 and 2, respectively, while light blue and light red traces indicate sample directions near the category boundary. Both cells shown were direction and/or category selective during the sample period (one-way ANOVA, P<0.01). Neither cell was direction selective during the delay period. (c,d) The time course of direction and category selectivity in LIP during the mid-training DMC task was determined by computing classification accuracy as a function of time relative to sample onset using the (c) sample direction classifier and (d) sample category classifier. Error bars indicate SEM. The light and dark colored bars at the top of the figures indicate times at which classification accuracy was significantly above chance (light, P<0.05, dark, P<0.01, bootstrap).
Supplementary Figure 7

Monkeys Q and W DMS behavioral performance.

The monkeys' average DMS performance is shown as a function of sample direction. The chance level of performance in the DMS task is 50%. Error bars indicate SEM.
Supplementary Figure 8

Temporal stability of direction encoding in PPC.

Similar to Figure 5c, the stability of direction encoding in PPC was determined by training the classifier at one time point (y axis) and testing at a second time point (x axis). Classification accuracy is indicated by color at each x-y coordinate. Direction classification accuracy in PPC was above chance during the sample period and near chance during the delay period. Classification accuracy was above chance only near the diagonal, indicating mostly dynamic direction encoding.
### Supplementary Table 1

**Supplementary Table 1. Training sessions for DMS, mid-training DMC, and fully-trained DMC tasks.** The number of training sessions leading up to neuronal recordings during the DMS, mid-training DMC, and fully-trained DMC tasks are shown for each monkey. Training sessions on color and image DMS (prior to motion DMS training) and training sessions on motion DMS after DMS recordings (but prior to DMC training) are also shown.

<table>
<thead>
<tr>
<th></th>
<th>Monkey D</th>
<th>Monkey H</th>
</tr>
</thead>
<tbody>
<tr>
<td>Color/Image DMS</td>
<td>72</td>
<td>31</td>
</tr>
<tr>
<td>Motion DMS</td>
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<tr>
<td>Fully-Trained DMC</td>
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<td>65</td>
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