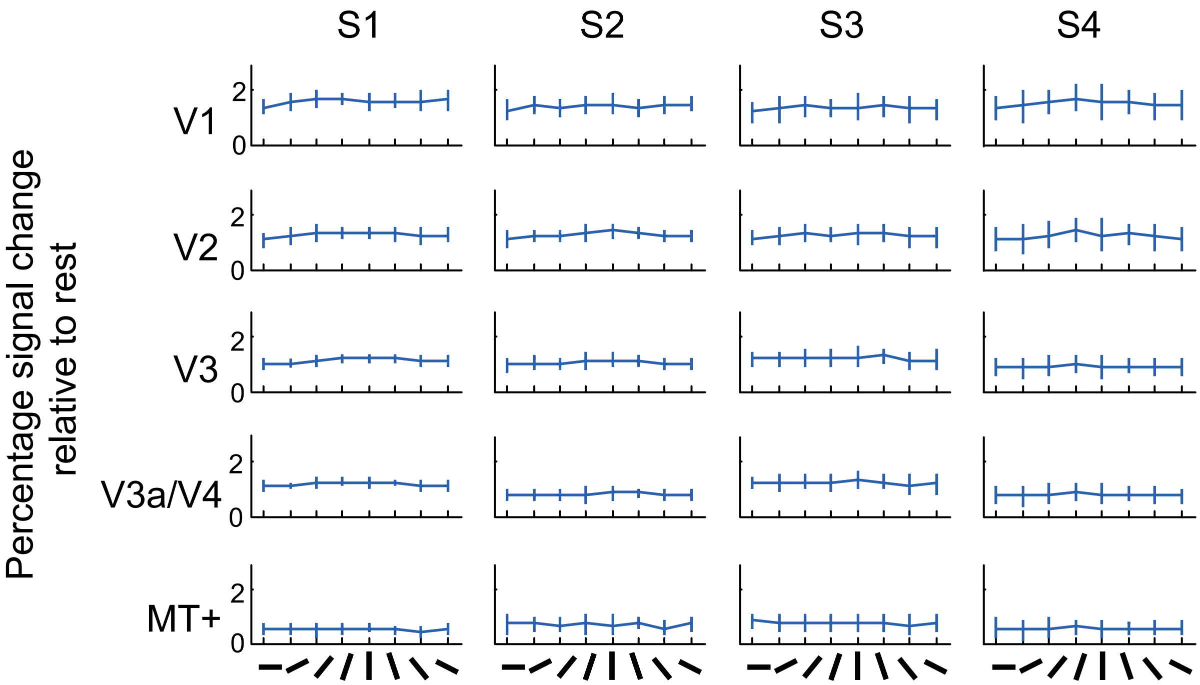
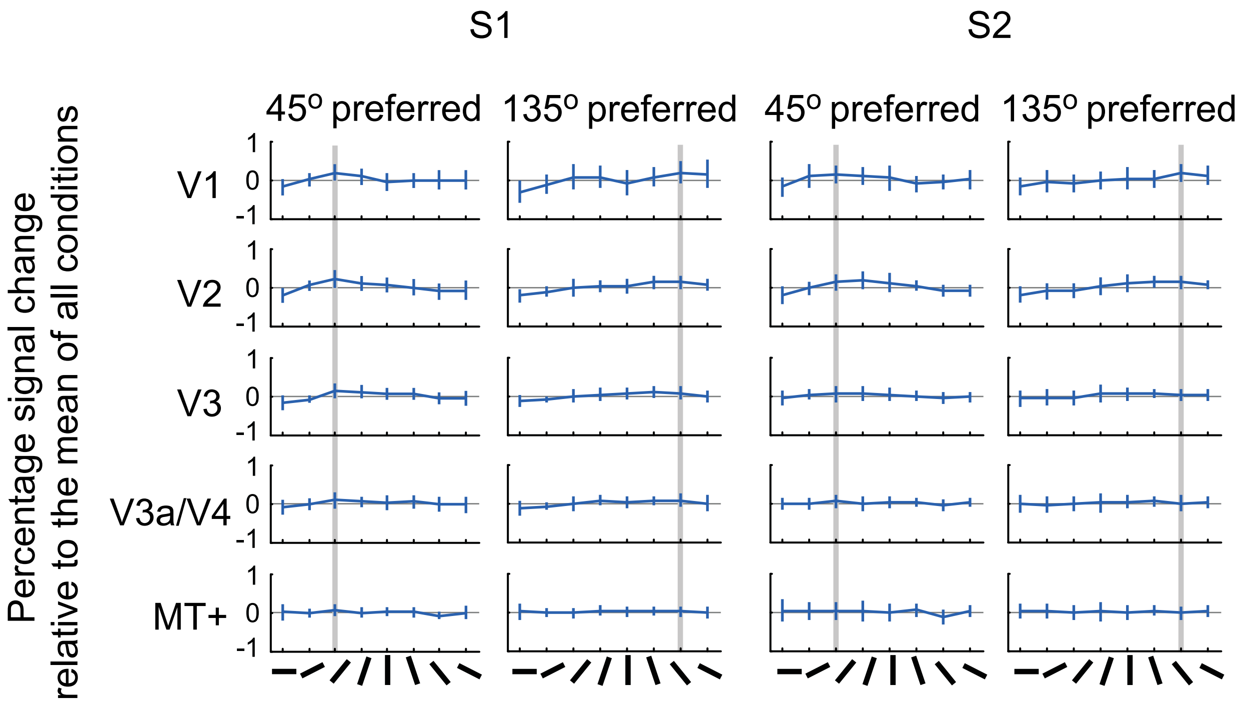
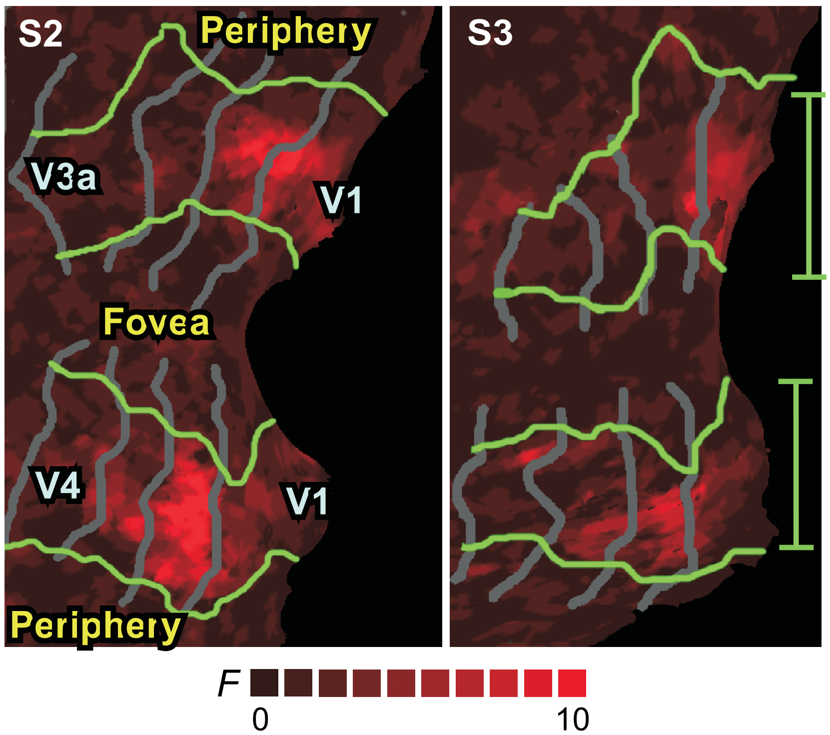


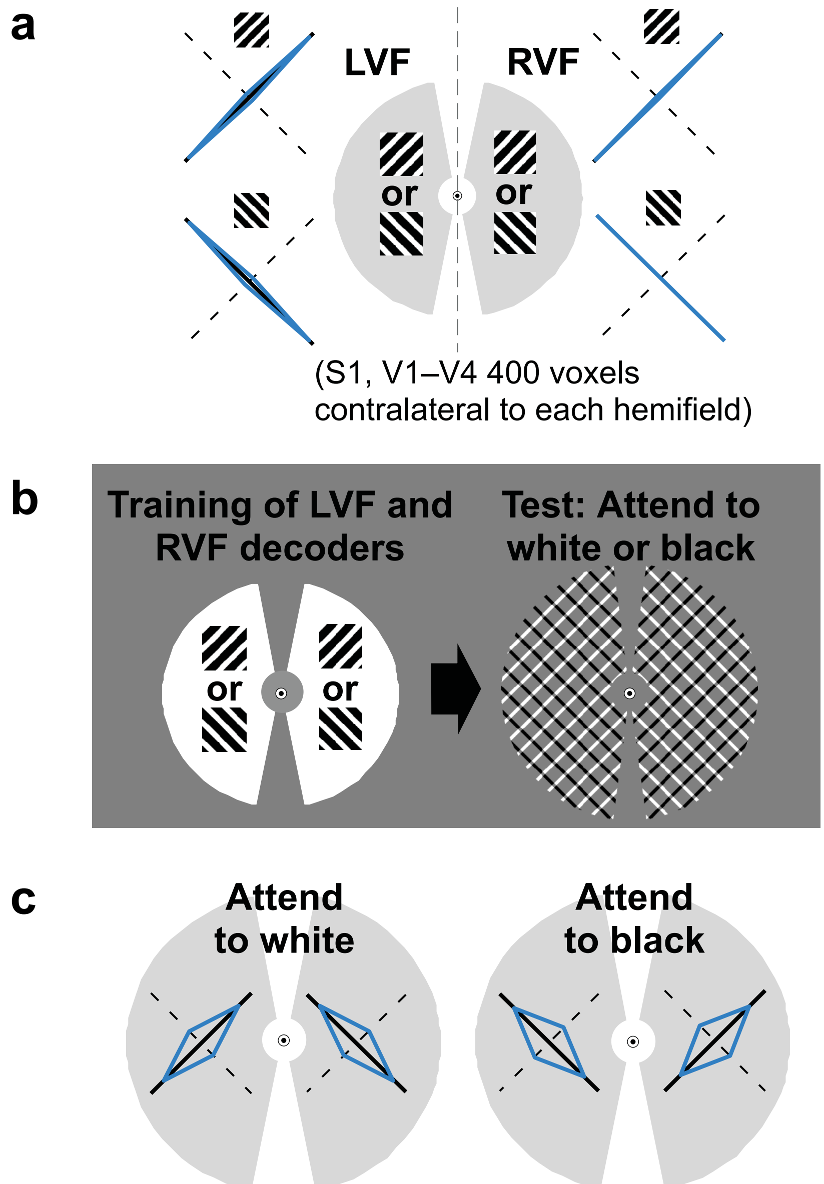

**Supplementary Figure 1.** Average fMRI responses to orientations for each visual area. Response amplitudes indicate the percent change in MRI signal intensity, relative to the rest condition, after averaging across the 200 most active voxels in each visual area (100 voxels for MT+). Error bars indicate standard deviations across stimulus trials. Orientation responses were generally flat, showing weak orientation selectivity. Our data did not show larger responses for horizontal or vertical orientations than for oblique orientations (the oblique effect; Furmanski & Engel, 2000). The lack of an oblique effect in our data may be due to differences in stimulus parameters or visual field location. Overall response amplitudes across all orientations were largest in V1, and generally declined in progressively higher visual areas.




**Supplementary Figure 2.** Average fMRI responses for voxels with the same orientation preference, shown by visual area. Data from two subjects are shown for voxels that prefer 45° and 135° orientations. In each visual area, there were roughly equal numbers of voxels with preferences for each of the eight orientations. The sets of voxels show small response peaks around their preferred orientations in early visual areas (V1 and V2). However, the selectivity is much weaker than that obtained with a weighted sum of all voxels in a given visual area (**Fig. 1b**). Percent signal change in MRI intensity was calculated relative to the mean intensity across all orientation conditions for each run, and averaged across all voxels with the same orientation preference. Error bars indicate standard deviations.




**Supplementary Figure 3.** Map of differential responses to eight orientations. *F*-values were calculated for each voxel using analysis of variance to measure differences in response amplitude across orientation conditions, and plotted on the cortical surface of left V1–V4 for two subjects. Green lines indicate the borders of the voxels used for the decoding analysis, which consisted of the 200 most-responsive voxels in each visual area, as identified by the visual field localizer. Because the visual field localizer covered a smaller area than the orientation gratings (radial dimensions of 2–9° and 1.5–10°, respectively), the cortical region receiving visual input extended somewhat beyond the region marked by the green lines. High *F*-values, indicative of differential orientation responses, were largely confined within the stimulated region of V1 and V2. Note that *F*-values greater than 5.3 are required to infer statistically reliable differences in orientation preference ($P < 0.05$, Bonferroni-corrected for multiple comparisons).




**Supplementary Figure 4.** Split-display experiments. **(a)** Independent decoding of stimulus orientations. The display was split into left and right halves; gratings presented simultaneously in each hemifield could vary independently in orientation (45° or 135°; four possible combinations). Polar plots depict cross-validation results for each hemifield and orientation (S1, 400 voxels from V1–V4 contralateral to each hemifield). The two subjects tested both showed near perfect orientation decoding performance based on ensemble activity from voxels in corresponding regions of the contralateral visual cortex (96.5% and 95.7% correct for S1 and S2, respectively; chance level, 50%). In contrast, if decoders were trained using voxels ipsilateral to each hemifield, then performance fell to near-chance levels (55.1% and 55.9% correct for S1 and S2, respectively). Global bias effects, such as eye movements, cannot account for the accuracy and retinotopic specificity of this orientation decoding performance. **(b, c)** Independent decoding of attended orientations. **(b)** Two decoders were trained as in **(a)**, and then used to predict the attended orientation for the plaid pattern shown in the contralateral hemifield. The plaid was composed of superimposed black and white gratings, and the combination of color and orientation was independently chosen in each hemifield (four possible combinations) for each 16-s stimulus trial. Subjects were instructed to attend to either the white gratings or the black gratings in both hemifields, and had to report which of the attended gratings, left or right, was of greater width. Thus, they had to pay attention to orientations that were independently chosen for each hemifield. **(c)** Performance for independent decoding of attended orientations. The decoding responses are plotted for the stimulus combination shown in **(b)** (S1, 400 voxels from V1–V4 for each hemifield). Attention significantly biased decoded orientations toward the attended orientations in each hemifield ($P < 0.005$, Chi-square test; 72.5% and 78.9% correct for S1 and S2, respectively; chance level, 50%).