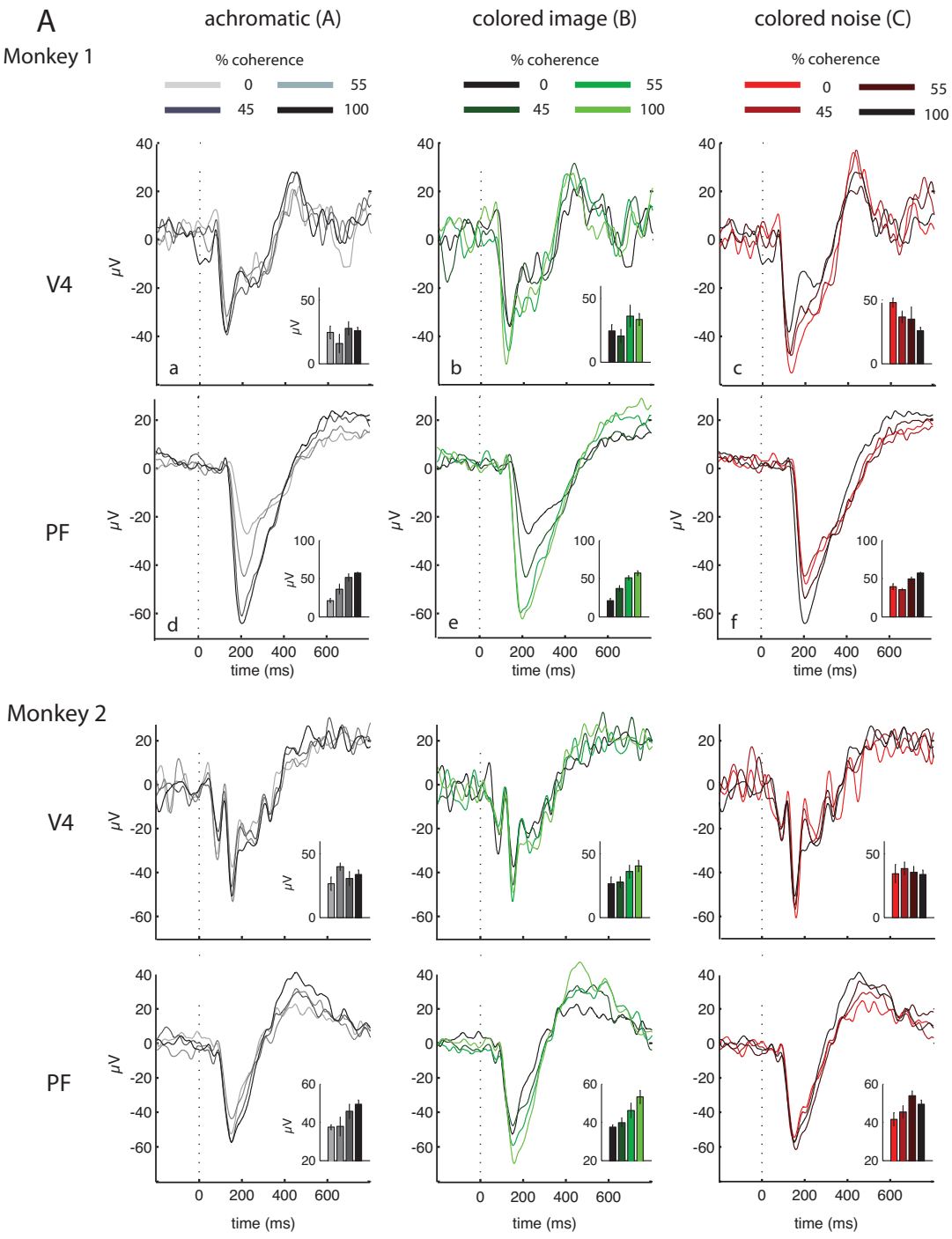
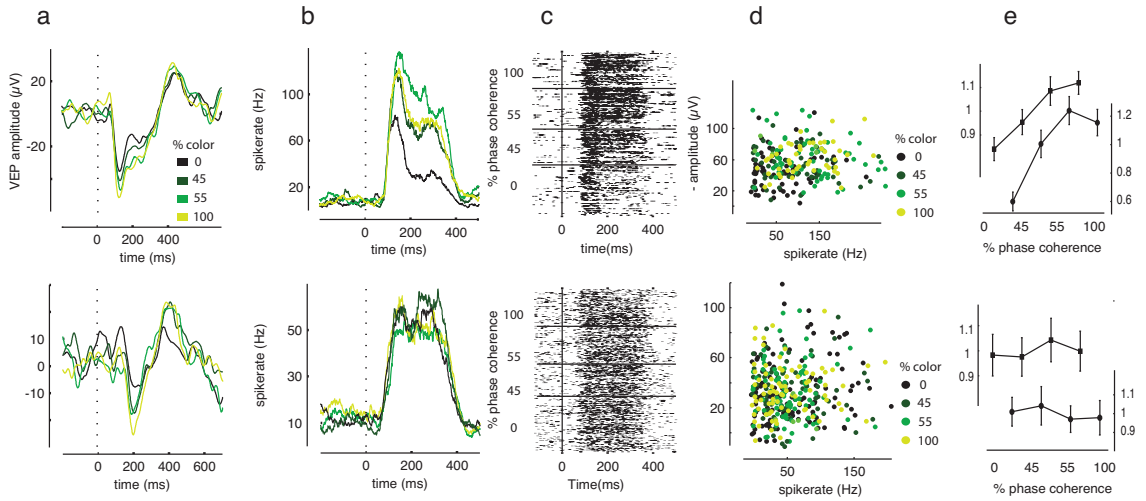
Supplementary Figures

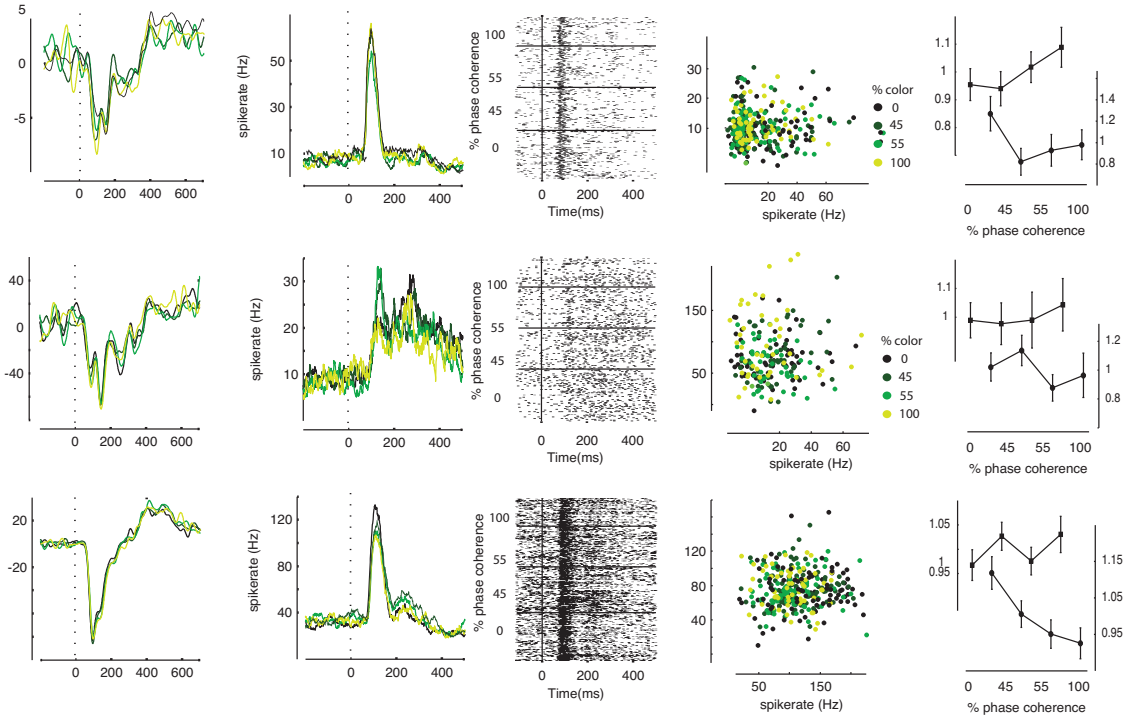


Supplementary Figure 1. Additional representative examples of single LFP sites and their visual evoked potentials (VEPs) for the different stimulus conditions. In monkey 1 (panel A) and monkey 2 (panel B) for sites recorded in V4 and PF cortex. In V4 color leads to a systematic increases in the VEP, whereas luminance based shape does not. In PF cortex VEP amplitude increases with increasing levels of coherence similarly for the different color conditions.

A. Monkey 1

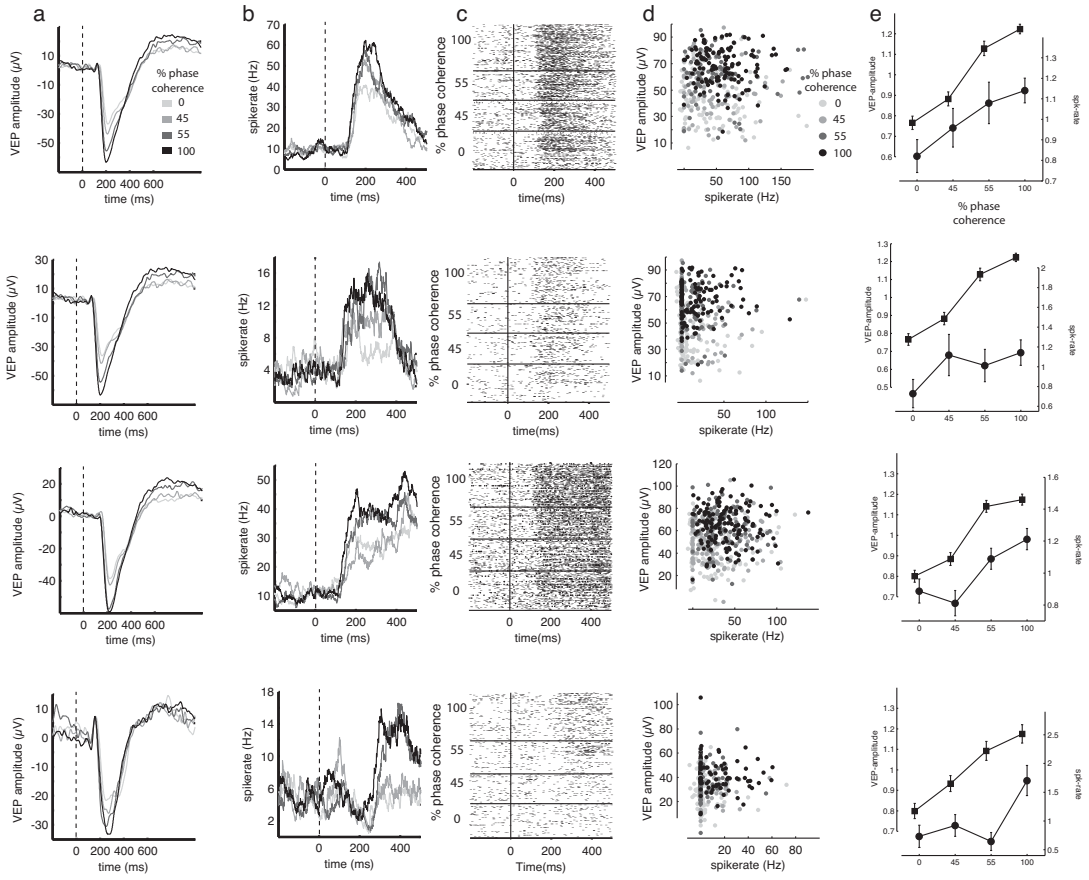


A. Monkey 2

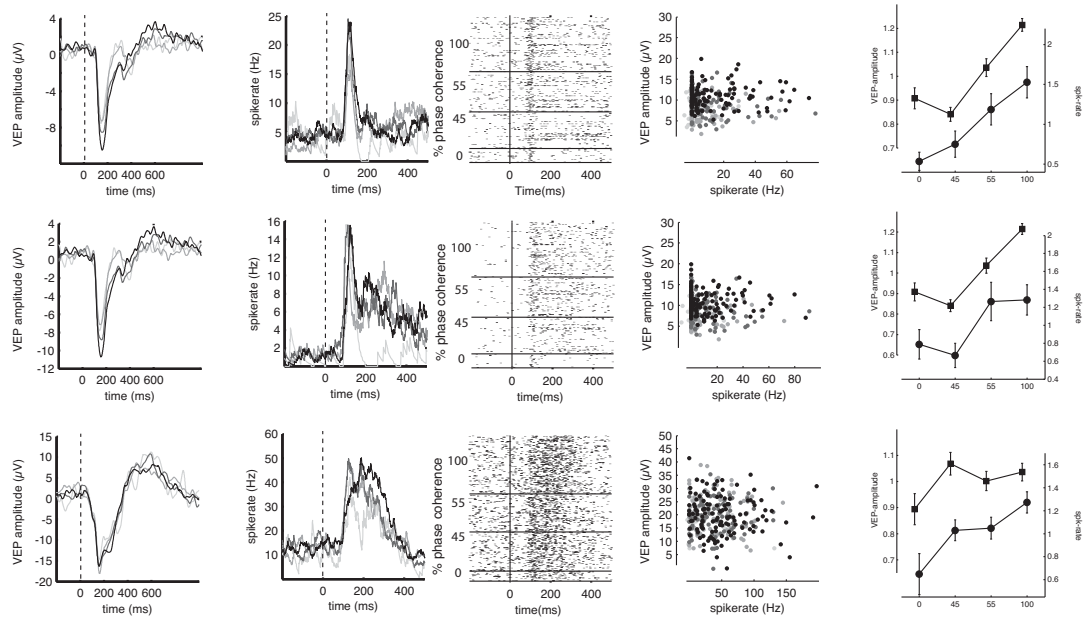


Supplementary Figure 2. Representative examples showing dissimilarity between VEP and spike tuning in V4. Each row represents a LFP site and a unit recorded at that site. The first two rows show examples from monkey 1, the last three rows show examples from monkey 2.

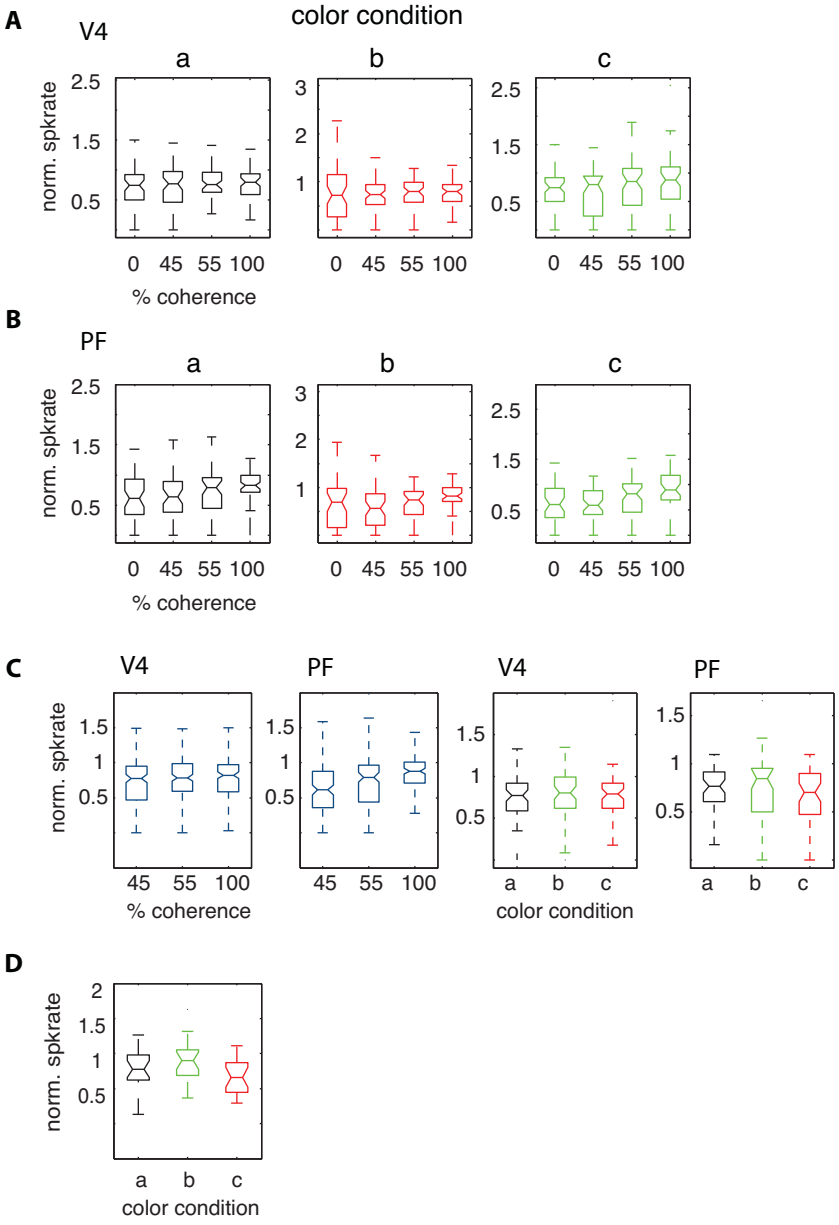
A. Monkey 1



B. Monkey 2



Supplementary Figure 3. Representative examples showing similarity between VEP responses and spiking activity in PF cortex. Each row represents a LFP site and a unit recorded at that site. The first four rows show examples from monkey 1, the last three rows show examples from monkey 2.

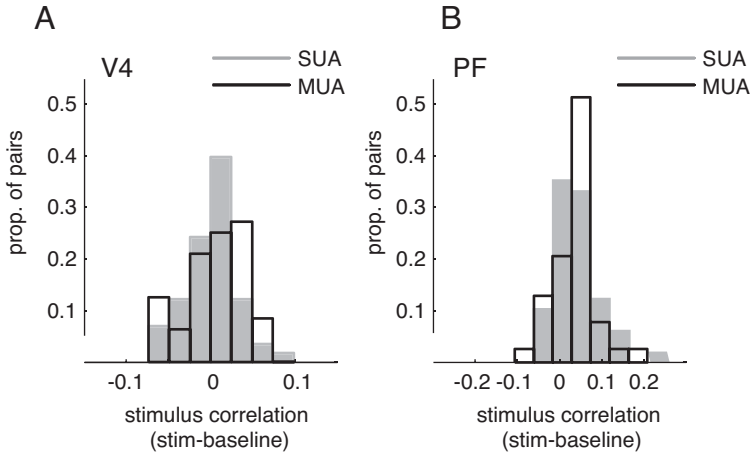


Supplementary Figure 4.

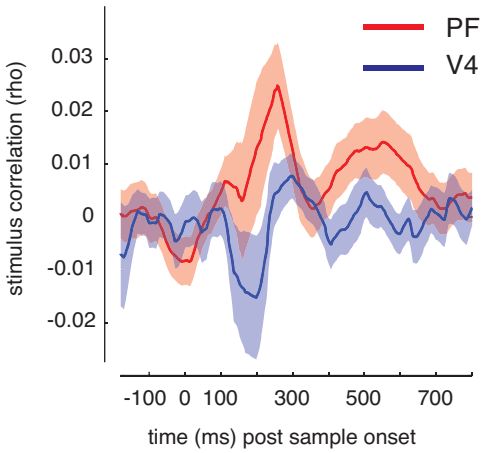
A/B. Normalized spike rates across all V4 (A) and PF (B) units as a function of phase coherence for each color condition a, b and c (plotted in separate panels for better visualization). Across the population of V4 neurons, we did not observe a systematic effect of color or coherence (repeated measures ANOVA both monkeys, F_{coh}:2.91, F_{col}:0.65, F_{int}:1.28, $p>0.05$, F_{coh}: 2.7/0.04, F_{col}: 0.21/2.09, F_{int}:1.25/0.73 $p>0.05$, for monkeys 1/2). In PF, spiking activity did significantly differ between coherence levels with higher levels of coherence leading to larger spiking activity in all color conditions (two-way rep.measures ANOVA both monkeys: F_{coh}= 13.82, $p<0.001$; F_{col} = 1.57, $p>0.05$, F_{int} = 2.07, $p>0.05$; for monkey 1: F_{coh}= 8.26, $p<0.0001$, F_{col} = 0.55, $p>0.05$, F_{int} = 1.77, $p>0.05$; for monkey 2: F_{coh} = 3.19, $p<0.05$, F_{col} = 2.2, $p>0.05$, F_{int} = 0.91, $p>0.05$).

C. Left graphs: Normalized spike rates plotted as a function of coherence level for spiking activity in V4 (left panel) and PF (right panel) across all neurons in both monkeys. No significant differences were found between coherence conditions in V4 (across monkeys: 1-way rep. measures ANOVA, F_{coh}= 2.18, $p>0.05$; for monkey 1: F_{coh}= 0.21, $p>0.05$; for monkey 2: F_{coh} = 2.09, $p>0.05$). In contrast, in PF spiking activity differed between coherence conditions with

higher coherence levels leading to significantly larger spiking activity (across monkeys: 1-way rep. measures ANOVA, F_{coh}= 10.83, p<0.0001; for monkey 1: F_{coh}= 8.19, p<0.0001; for monkey 2: F_{coh} = 3.14, p<0.05). Right graphs: Normalized spike rates plotted as a function of color conditions a, b and c for spiking activity in V4 and PF across all neurons in both monkeys. No significant differences were found between the color conditions in either V4 (across monkeys: 1-way rep. measures ANOVA, F_{col}= 0.43, p>0.05; for monkey 1: F_{col}= 2.7, p>0.05; for monkey 2: F_{col} = 0.03, p>0.05) or PF (across monkeys: 1-way rep. measures ANOVA, F_{col}= 1.19, p>0.05; for monkey 1: F_{col}= 0.55, p>0.05; for monkey 2: F_{col} = 1.53, p>0.05).
D. Spiking activity across PF units showing significant effect of color condition (1-way ANOVA F=3.15,p=0.05, t-test b vs.c, t=2.26,p=0.03, avs.b and cvs.b, p>0.05).

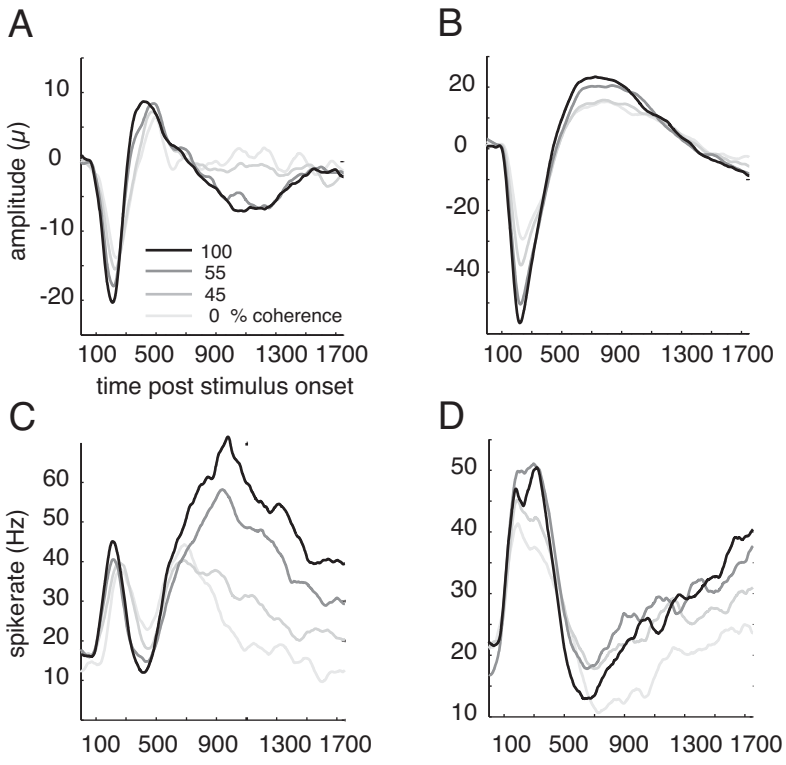


Supplementary Figures 5
Histograms of stimulus correlation for multi-unit activity in V4 (a) and PF (b). To compute the stimulus correlation between VEP amplitudes and multi-unit activity, we merged spike trains recorded from multiple single units at one electrode, which resulted in 39 pairs in PF, and 47 pairs in V4. In PF median stimulus correlation was higher when using the multi unit activity compared to SUA (median SUA 0.025, median MUA 0.04, Signrank test Z>2.3, p<0.05). This effect was even more prominent when we compared sites with single unit activity versus sites with multi-unit activity separately: median SUA: median 0.03, MUA 0.06, Ranksum Test Z=2.3, p<0.05). In V4, stimulus correlation was similarly low and also not significantly different from baseline in both cases (median SUA 0.01, MUA 0.016, signrank test Z<1.8, p>0.05). Note the difference in xaxis between the graphs.



Supplementary Figure 6

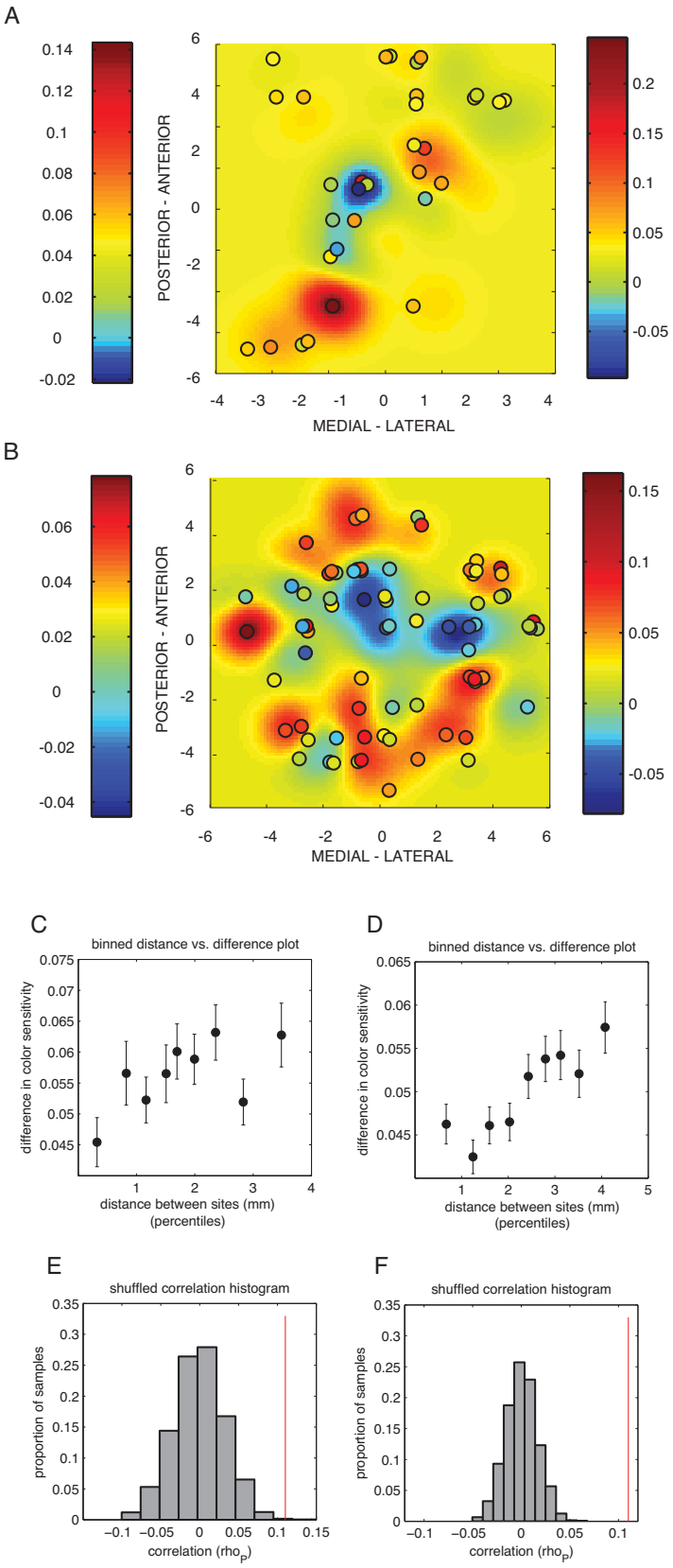
Mean stimulus correlation across all 12 stimulus conditions between VEPs and SUA is significantly different from baseline for PF (red) but not V4 (blue). (Paired t-test baseline vs. stimulus period: in PF t= 4.03 and 2.79, p<0.01 and in V4 t=1.77 and 1.9, p>0.05 for monkeys 1 and 2, respectively). In contrast to the stimulus correlation presented in Figure 7 of the main manuscript, we did not arrange trials according to stimulus features VEPs were sensitive to (i.e. we treated each of the 12 stimulus conditions as independent 'labels'). Rank correlation coefficients were computed at a 1ms resolution, subsequently we applied a moving average filter encompassing a window of 50ms in 5ms steps. Error bars (shaded area) denote +/- 1 standard error of mean.



Supplementary Figure 7

A/B VEP (upper graphs) and C/D PSTH (lower graphs) plotted for two example SUA-LFP pairs exhibiting significant stimulus correlation during the delay period (p<0.05 of rank correlation

during last 1000ms before sample onset. Time scale (x-axis) describes time post sample onset and ends at test onset.



Supplementary Figure 8. Panel A/B. Color tuning of single LFP sites recorded from V4 for different recording locations. Single symbols represent individual LFP sites and their coloring

corresponds to magnitude of color tuning derived from the mean across slope estimates of individual amplitude vs. coherence functions for color conditions b and c for monkeys 1/2 (as already shown in Figure 4 of the main manuscript). Red coloring corresponds to positive slope estimates, blue coloring to negative slope estimates (color bar on the right side). Symbols are slightly scattered around their original recording locations for better visualization. Recordings were made along the anterior-to-posterior (Y-Axis) and medial-to lateral-axis (X-axis). One unit on the grid corresponds to 0.5 mm. Panels A and B also show smoothened color tuning maps that were computed by convolving the color tuning values of one - several LFP sites at their respective recording locations with a two-dimensional Gaussian kernel (kernel width= 0.35 mm). (Note, that the color axis is similar but not identical between the symbols and the smoothed map, color bar for map on the right side of graph). Both maps reveal a non-uniform distribution of color tuning across individual LFP sites.
Panels C/D plot the difference in color tuning between LFP sites as a function of their distance in recording location. We computed the difference in tuning by subtracting the slope estimate at location $[X_1,Y_1]$ from the slope estimate at location $[X_2/Y_2]$ and the distance in locations was computed from hypotenuse's length between locations $[X_1,Y_1]$ and $[X_2,Y_2]$ for each SUA-LFP pair. Distances were binned according to percentiles using a step size of 10% resulting in 9 equally spaced bins. Differences were sorted according to the bins and averaged per bin. Panels C and D show distance percentiles plotted against the mean difference in tuning per bin. In both animals, the difference in color tuning between sites increases as a function of their recording location distance. Correspondingly, we found a significant positive correlation between the two measures (Spearman rank-correlation rho_S: 0.18 and 0.11, $p<0.001$ for monkey 1 and 2, respectively).

Supplementary Method Section

Visual Stimuli and Display characteristics

Stimuli were 7°x7° in size, with 24-bit color depth and presented at the center of gaze on a monitor (Intergraph 21sd107) with linear luminance response (gamma corrected) at a distance of approximately 110 cm from the monkeys. For each experiment a set of three or four natural images was presented. Prior to the recording sessions, the monkeys had been familiarized with the images and we ensured that monkeys did not show performance changes due to learning anymore; for details see (Liebe et al., 2009). The images were chosen from the Corel-Photo-CD “Corel Professional Photos” comprising a collection of natural images showing birds, flowers, monkeys and butterflies in their natural surroundings and were randomly selected. We parametrically altered the amount of shape and color information that was contained in natural images by linear interpolation with a random phase mask. Our method is described in detail in a previous study and has been used in several other studies (Liebe et al., 2009; Rainer et al., 2004b; Rainer and Miller, 2000b). In brief, we parametrically varied the amount of visual noise by combining the Fourier phase spectra of the natural images with a random phase spectrum using the inverse Fourier transform, at four coherence levels (0%, 45%, 55% and 100%) to obtain the pure noise-, intermediate noise- and full image conditions. All images were normalized to mean intensity of 0.5 and rms-contrast of 0.033 in a range of 0-1. The space averaged mean luminance was 37.7 cd/m2. For each recording session, three-four noise masks were newly generated and

each of the natural images shown was interpolated with every mask at various interpolation levels and at any given degradation level.

Surgical procedures and recording apparatus

Single-unit activity and the local field potential (LFP) were recorded from two recording chambers placed on the surface of the skull. Based on anatomical brain scans previous to the implantation of the recording chambers, dorsal V4 and a region encompassing the medial portion of the principal sulcus extending into the dorsolateral (upper bank) and ventrolateral (lower bank) were chosen in order to implant the chambers above those regions. The anatomical brain scans were also made to ensure the similarity in the position of the recording chambers between the two monkeys. The Horsley-Clarke coordinates for the center of the V4 recording chambers for monkey 1 were AP:-6.5, ML: -29.7, and the PF chamber AP:33, ML:-23.7, . For monkey number 2 for the V4 chamber were AP: -5.2, ML: -29.9 , and the PF chamber AP: 34.5, ML:-22.6.
The implantation as well as surgical procedures used is described in detail in (Lee et al., 2005).
We have also added Supplementary Figure 9, which shows histological coronal sections centered approximately at the center of the recording chambers showing our recording locations. The sections were taken from animal 1 after this animal had been sacrificed.
Neural signals were measured using two custom made micro drives mounted on a plastic grid (Crist Instruments, Hagerstown, MD, USA). In each recording session 4-6 tungsten microelectrodes (UEWLGDSMNN1E, FHC Inc., Bowdoinham, ME, USA) were manually lowered down in pairs with a minimal separation between electrodes of 0.5mm. The impedance of the microelectrodes was approximately 1MΩ. The signal from each electrode was preamplified (factor 20, Thomas Recording, Giessen, Germany) using the recording chamber as the external reference. The analog signal was split into two signals and filtered and amplified separately (BAK electronics, Germantown, MD, USA) to separately extract single unit activity (SUA) as well as the local field potential (LFP) responses. The spiking activity was obtained by band – pass filtering the signal between 300Hz and 4 kHz and digitizing with a sampling rate of 22.231 kH. From the spiking activity single units were extracted using standard spike sorting routines (Offline Sorter, Plexon, Dallas, TX, USA). At each recording session we advanced the electrodes until we could reliably isolate one or more single neurons and did not select neurons based on task selectivity. After an additional waiting period for at least 1 hour we started the recordings. The LFP was obtained by band-pass filtering the signal between 0.1 and 300Hz and digitizing with a sampling rate of 4464Hz. One unit of the analog-to-digital converter corresponds to 5 μV.