

SUPPLEMENTARY MATERIAL

In this study most of our analyses have included responses to component 1 at the preferred condition (optimal stimulus orientation and direction). In Supplementary Figure 2 we show rate, gamma power and coherence computed for all conditions tested. In the plots, the deviation is expressed relative to the optimal spiking response to component 1. As before, the green and red colors denote responses to single and superimposed components, respectively. Notice, that for a given deviation, component 1 was the same for both stimuli. For responses to component 1 alone, we observed that the rates, gamma power and gamma coherence were strongly dependent on the orientation, as seen from the U-shape of the curves. Modulation was pronounced for the firing rates, indicating that the neurons were generally orientation selective (one-way ANOVA for repeated measures, $F(8, 2896) = 257.6, p < 10^{-6}$). Selectivity for gamma was striking for power of the LFP and coherence of the LFP-MUA ($F(8, 3240) = 77.28, p < 10^{-6}$; $F(8, 1144) = 310.0, p < 10^{-6}$). For the power of MUA, the modulation was weaker but significant ($F(8, 496) = 27.7, p < 10^{-6}$). Responses to the two components (plaids), on the other hand, showed clearly less modulation for all measures. For the rates, both curves were similar in shape. The reason is probably that the plaid stimuli were depth-ordered, and component 1 probably dominated the responses. The vigorous responses we see for the non-optimal orientation are probably due to component 2. Another possibility, that we cannot completely exclude in our MUA recordings, is the recruitment of new cells. In any case, the gamma responses were much attenuated for the plaids as compared to the gratings. In the LFP-MUA coherence, the effect was present only for the optimal orientation (0° and 180° deviation). For the non-optimal orientation (90° deviation), we obtained a coherence value significantly higher for the plaids (Fisher's least significant difference test, $df = 2431, p < 10^{-6}$). Surprisingly, at this deviation point the gamma power of the LFP and MUA were lower for the plaids ($df = 6885, p < 10^{-6}$; $df = 1054, p < 10^{-6}$, respectively).

In our study we have obtained simultaneous recordings for sites in the opercular and calcarine sulcus regions. With this novel approach, we could obtain coherence estimates for sites separated by long distances in V1, corresponding to more than 7° of visual angle. In all cases, the cell pairs were stimulated by a single object covering the RFs. In Supplementary Figure 3 we show average coherence measures as function of distance between the recording sites for Monkey 1. Short-distance pairs comprised cases where both electrodes were placed in the operculum or in the calcarine sulcus (distances from 1.5 to 3.5 mm). Long-distance pairs, on the other hand, comprised cases where one electrode was placed in the operculum and the other in the calcarine sulcus. From the plots it is clear that recording site

distance had a strong impact on coherence, both for gratings and plaids. For the LFP there was a significant attenuation effect, of 31% and of 29%, respectively (paired t-test, $df = 211$, $p < 10^{-6}$ for both stimuli). In general the coherence measured for the MUA was lower than the one for the LFP. For the analysis of LFP-MUA coherence we could include measurements from the same electrode. Notice that coherence assumed high values locally, decaying rapidly with distance. From same-electrode to short-distance pairs, reduction was of 55% and of 52% for grating and plaid stimuli, respectively (Fisher LSD test, $df = 536$, $p < 10^{-5}$ for both stimuli). From short- to long-distance pairs, the reduction was 19% and 11% (Fisher LSD test, $df = 536$, $p < 10^{-5}$ for gratings and $p < 10^{-2}$ for plaids).

Supplementary Figure 1. Control for effects due to component 2 onset transient. LFP and MUA power spectra (left and right plots, respectively) were computed for responses to sequences in which component 2 appeared gradually. Notice the clear reduction in power and shift in oscillation frequency for the LFP. For the MUA, there was a disruption of the response oscillatory patterns. These results are fundamentally the same as the ones shown Fig. 2. Data obtained from a calcarine site in Monkey 1. Conventions as in Fig. 2.

Supplementary Figure 2. Firing rate responses, LFP and MUA spectra, and LFP-MUA coherence for the full range of movement directions tested. Stimulus conditions with increasing deviations from the preferred direction of component 1 (represented by the null deviation) are depicted in the abscissa of all four plots. Green curves stand for component 1 presented alone, while the red curves represent the component 1 superimposed over component 2. The number of sites employed in each of the analysis is given on the top left hand side of the respective plot. Only those sites showing significant activity for component 1 relative to baseline are plotted. The U-shape of the curves representing the responses to component 1 reveal that the sites recorded were predominantly orientation selective. Additionally, it shows that the orientation preference at a given site was shared by all four measures. For the coherence analysis, only responses from LFP-MUA pairs recorded from the same electrode were included. Error bars indicate the 95% confidence interval of the mean. The power and coherence values constitute the average of all bins between 30 and 90 Hz.

Supplementary Figure 3. Decay of the LFP-LFP, MUA-MUA and LFP-MUA gamma coherence with the distance between the sites of a recording pair. Activity recorded between electrode tips standing at a distance of around 3.2 mm or less were considered short (distance), while those with distances above that limit were labeled long. For the LFP-MUA coherence, there was further the possibility of analyzing the LFP and MUA from the same electrode (same). Green curves correspond to the single component grating stimulus, while the red curves correspond to components 1 and 2 superimposed. The numbers of recording pairs analyzed are given beside each data point. Error bars enclose the 95% confidence interval of

the mean. The coherence values constitute the average of all bins between 30 and 90 Hz. LFP-LFP and MUA-MUA number of pairs: short, 112; long, 101. LFP-MUA number of pairs: same, 113; short, 224; long, 202.

Supplementary Figure 4. Control for effects of spatial frequency and speed on LFP gamma activity. (A) Example of responses to grating stimuli with spatial frequencies ranging between 1.0 and 1.5 $\text{cyc}/^\circ$. The thick curve refers to the LFP gamma power, while the thin curve refers to the firing rate. Despite the strong modulation of the LFP gamma power, the gamma frequency was only marginally affected by varying spatial frequencies of the grating (bottom panel). Continuous and dotted horizontal lines depict the population gamma frequency for the grating and plaid stimuli, respectively. (B) Example of responses to grating stimuli with speed ranging between 0.5 and 2.0 $^\circ/\text{s}$. Top panel: the drifting speed of the gratings, while having modest or no effect on the firing rate (thin line), greatly impacted gamma power (thick line). Stronger gamma oscillations were observed for stimuli moving at slower velocities. Concomitantly, the oscillation frequency was higher for increasing speeds (bottom panel). Two individual data points are additionally plotted on the bottom panel. The open circle refers to a grating stimulus as used throughout this study. The filled square refers to a plaid stimulus where component 1 slides over a static and orthogonal component 2. A significant frequency shift is still observed despite the absence of higher resultant velocities for the plaid intersections. Continuous and dotted horizontal lines were plotted to help visualize the respective means of both data points. Error bars enclose the 95% confidence interval of the mean. A drifting speed of 1.0 $^\circ/\text{s}$ and a spatial frequency of 2.0 $\text{cyc}/^\circ$ were used in (A) and (B), respectively.

Supplementary Figure 5. Control for oscillation cycle skipping. (A) Spike triggered average (STA) of the LFP for the same data set presented in Fig. 1B (SUA, cell 1a). The green and red curves represent the STA for the grating and plaid stimuli, respectively. For this case, the monkey responded to a color change of the fixation point. An approximate 5-fold reduction in the amplitude of the LFP is observed for the plaid compared to the grating condition. Thus, skipping of spike events relative to the ongoing LFP gamma oscillations does not explain the attenuation of gamma activity for the plaid condition. (B) Same data as in Fig. 10A (MUA), which corresponds to the site shown in Fig. 1A with attention directed to component 1. The attenuation of gamma oscillation was equivalent in magnitude to the one observed in (A), showing that attending to component 1 did not prevent the attenuation of gamma oscillations that occurred after onset of component 2.