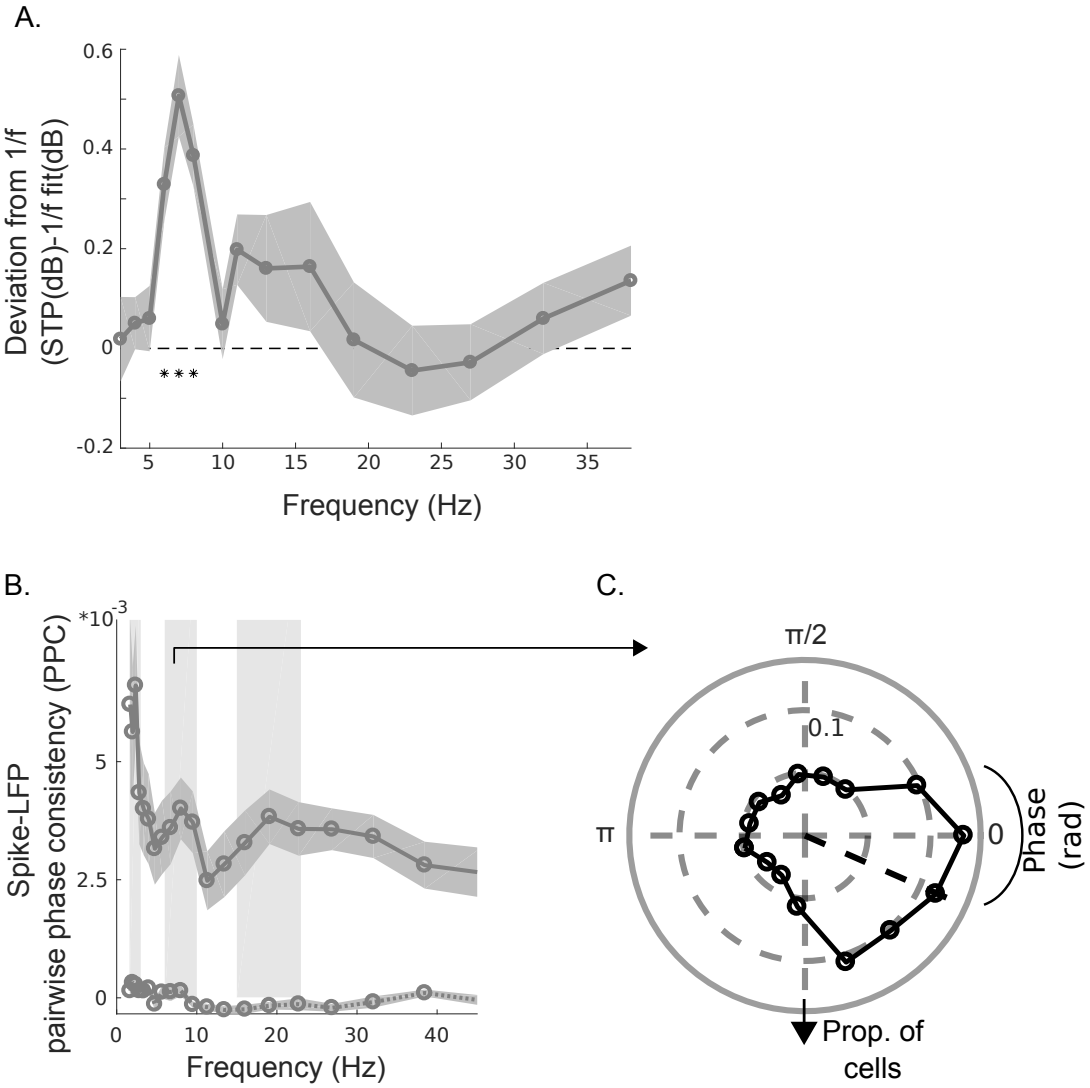

Figure S1. Related to Figure 2. A) Theta oscillations in the power spectra of the spike triggered power (STP) during the sequence learning sessions. For each spike we extracted a short LFP segment, 500 ms before and after the time of the spike. The absolute power spectrum of each segment was then computed (Fries et al., 2001). The average power spectrum of all the LFP traces was estimated by taking the average of the absolute values (the power) of the spectra of all LFP segments per channel. The resultant power spectrum was fitted to a 1/f function, and the ratio (in decibel units) computed for each channel. Significance was estimated with a t-test, Bonferroni corrected for multiple comparisons. Prominent theta oscillations (6-10Hz) are observed in the LFP segments around each spike. The shaded area corresponds to the standard error of the mean across channels. B) Spike-LFP PPC computed over all cells (*N*=41) in the screening sessions that fired at least 500 spikes and showed a selective response to at least one stimulus (see methods). C) The distribution of preferred phase in the 6-10 Hz frequency range across all cells in the screening sessions that showed a selective response to at least one stimulus.

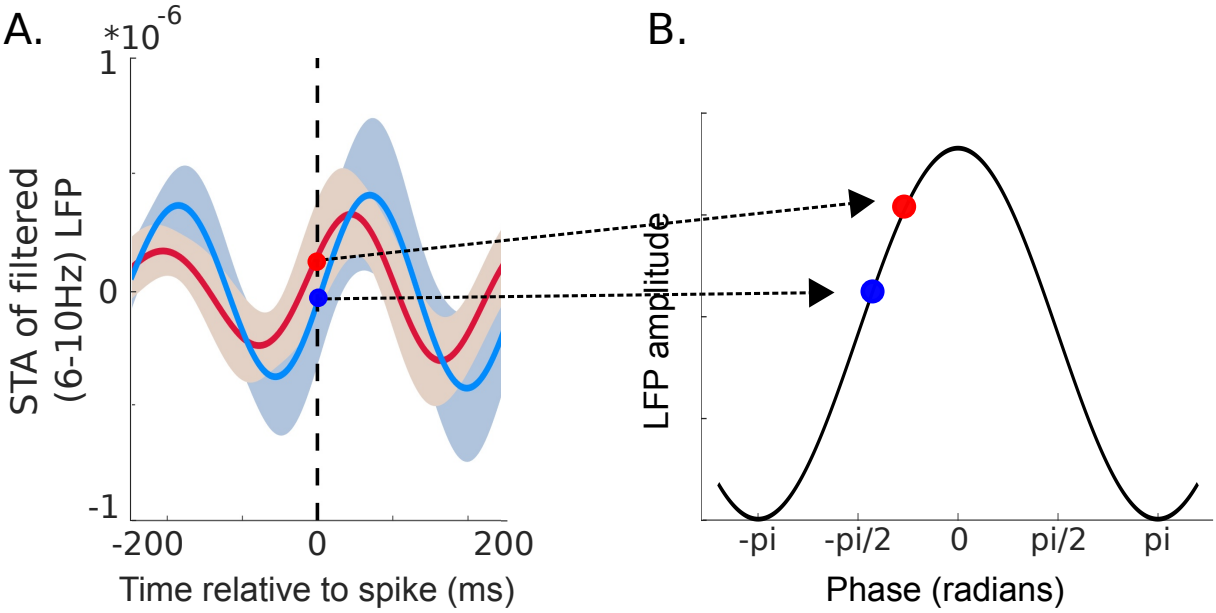

Figure S2. Related to Figures 3 and 5. A) The spike-triggered average (STA) for the preferred (red curve) and the preceding (blue curve) stimuli, averaged across all cells. Time=0 s corresponds to the moment of each spike. Note the different phases at which the spikes occurred for the two stimulus types. Error bars represent the *SEM*. B) Notation used for the phase of a spike. A phase of zero corresponds to the spike occurring at the peak of the oscillation. A phase of ± pi radians (± 180 degrees) corresponds to the spike occurring at the trough. A phase of pi/2 (90 degrees) corresponds to the spike occurring after the peak of the LFP.

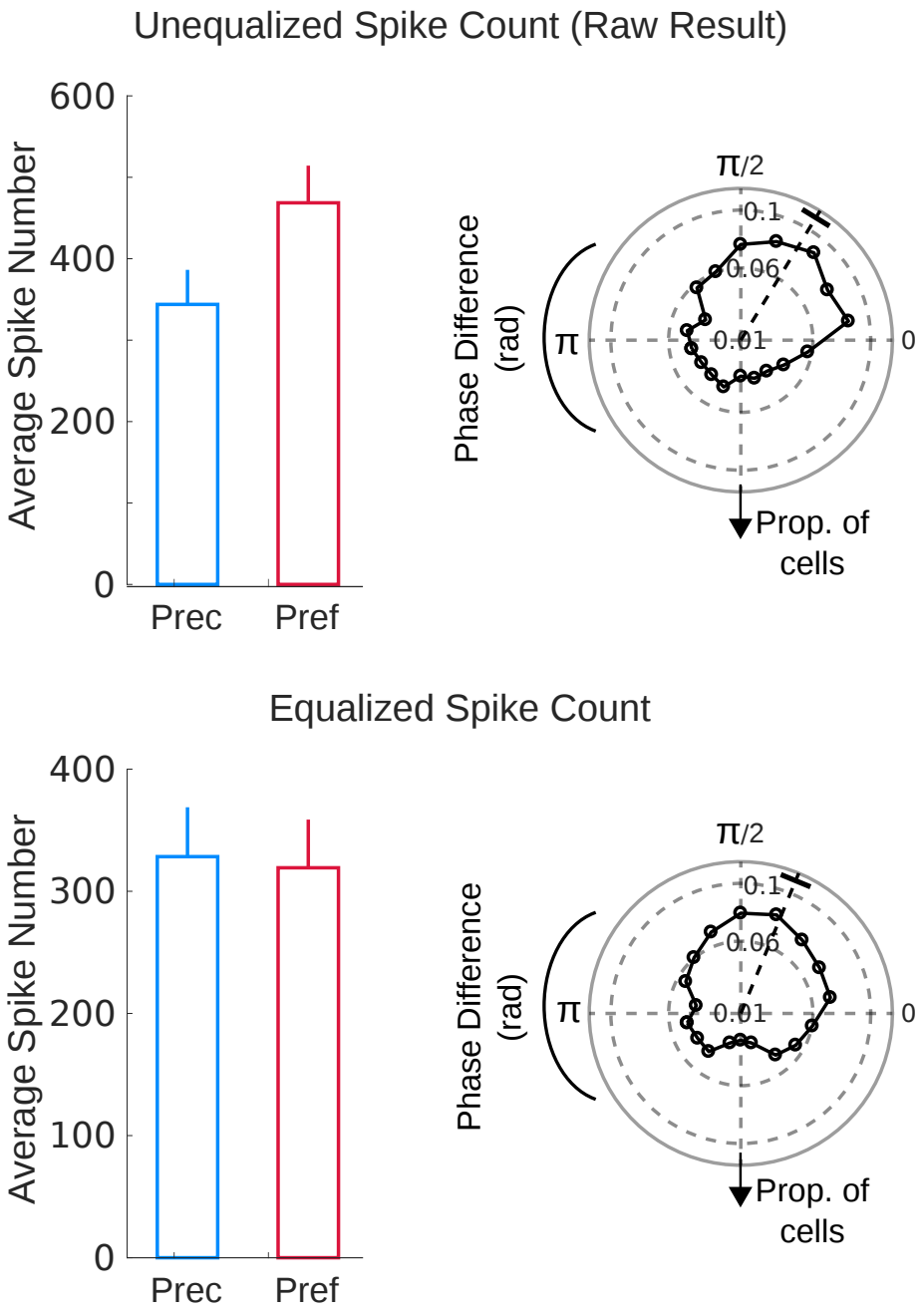

Figure S3. Related to Figure 3. To control for the effect of spike number on phase differences between the preferred and preceding stimuli, we equalized the number of spikes for each neuron by rejecting the highest firing rate trials for the preferred stimulus and the lowest firing rate trials for the preceding stimuli. This procedure was performed progressively per cell until the difference in the mean number of spikes for the two stimuli was less than 0.005. Finally, we re-computed the preferred phases for the preceding and preferred stimuli, while only considering the reduced number of trials. The top panel shows the raw result of Figure 3, which includes all spikes fired. The bottom panel shows the phase difference in the control analysis after the spike numbers were equalized ($F(1,125)=8.2$; $p<0.005$)).

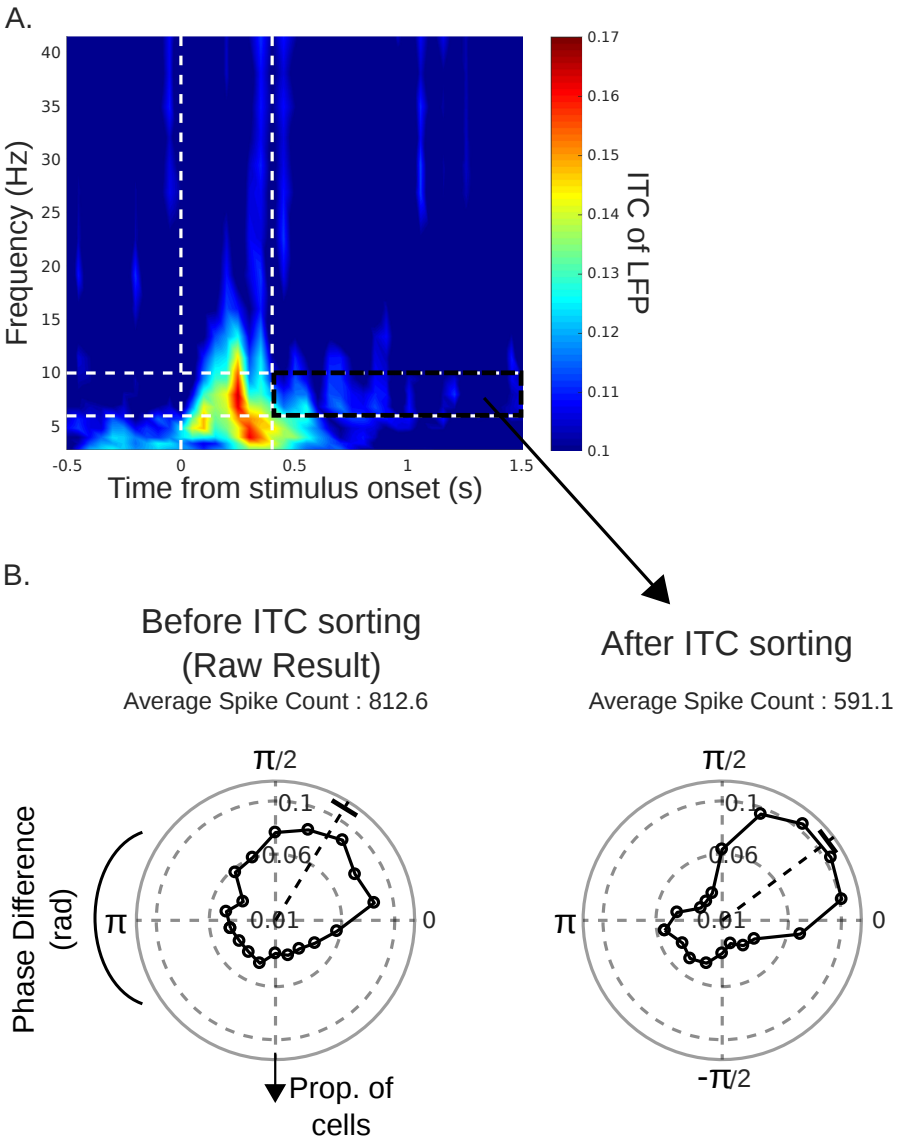

Figure S4. Related to Figure 3. Phase-rest and inter-trial coherence (ITC). A) The inter-trial coherence was computed at each time and frequency point with respect to the onset of the preferred and preceding stimuli (see methods). B) *(left)* The phase difference between the preferred and preceding stimuli calculated from the raw data (Figure 3). *(right)* Phase difference after removing all spikes fired in the 0-400ms window post-stimulus onset where ITC is expected to be maximal (on average more than 20% of all spikes were excluded). The phase difference was computed using only spikes in the black dotted window of panel A) as indicated by the arrow. The difference between the preferred and preceding phases was significant despite rejecting spikes fired after stimulus onset ($F(1,125) = 7.17$; $p<0.001$).

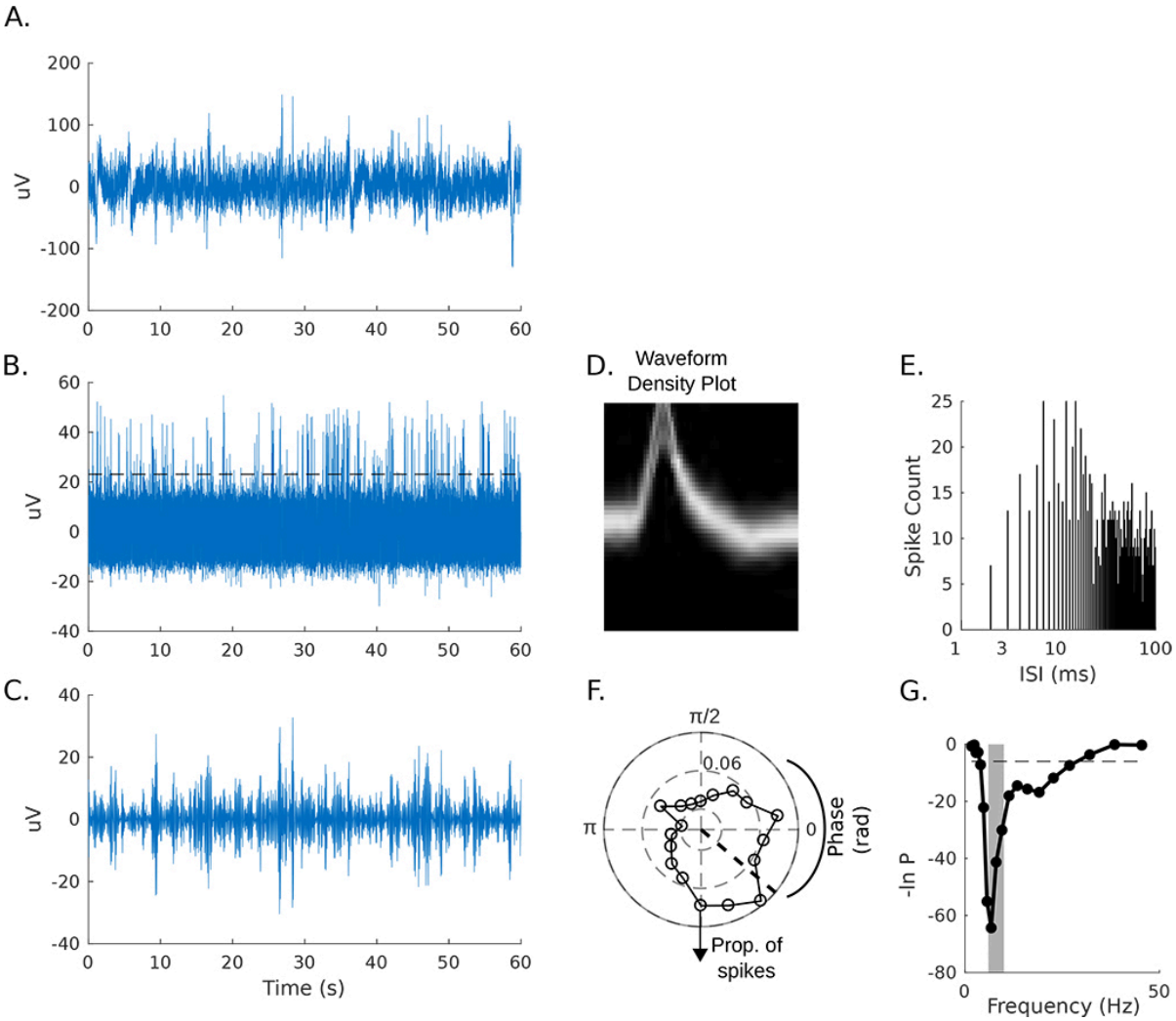

Figure S5. Related to Figure 2. Signal recorded from one microwire. A) A 60s trace of raw signal recorded on one microwire. B) The signal was filtered between 300-3000Hz to extract spikes. The dashed black line corresponds to the threshold used for spike detection. The density plot of the spike waveforms and the corresponding inter-spike interval distribution are shown in D and E. C) The LFP was bandpass filtered between 6-10Hz to extract the phase of each spike. F) Phase distribution of spikes in the 6-10Hz theta band. The dashed black line indicates the mean phase for this cell. G) Significance of phase locking (Rayleigh test). The threshold for significance (horizontal black dashed line) is set to $p<0.05$, Bonferroni-corrected for multiple comparisons. The shaded gray area corresponds to the 6-10Hz theta band. This cell shows significant theta phase locking.