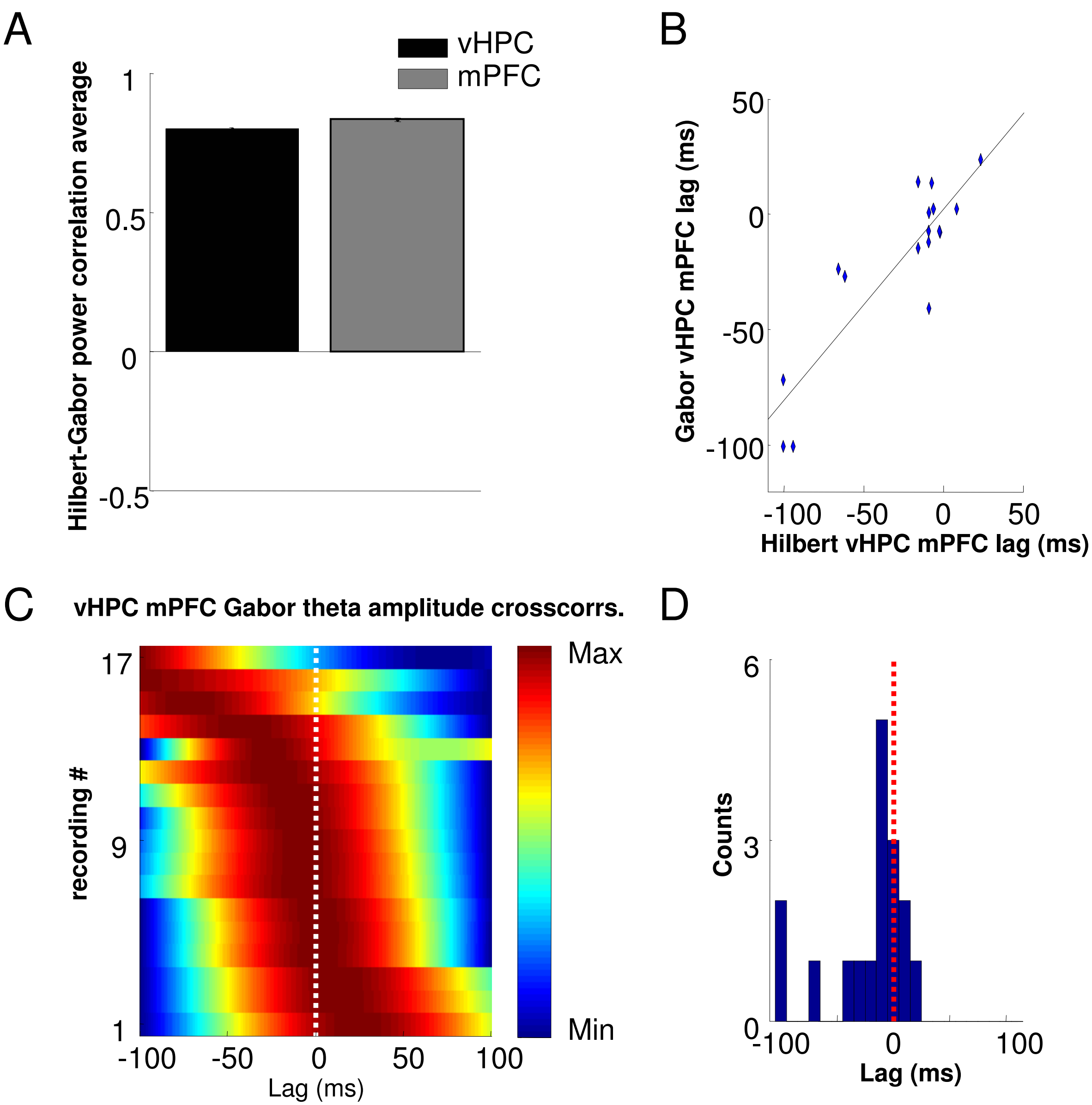
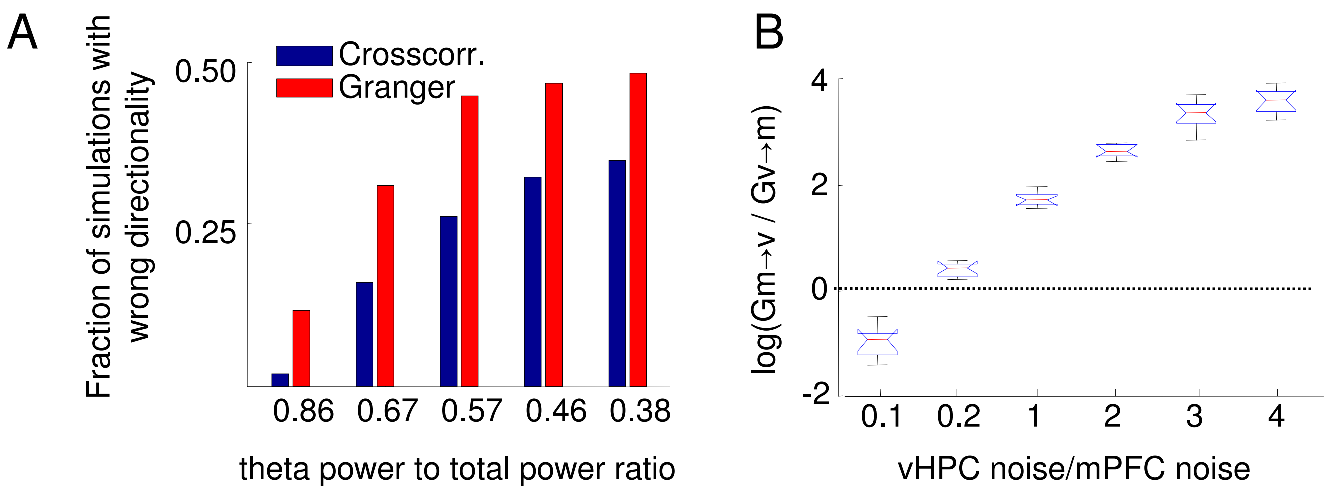
Supplemental Figure 1



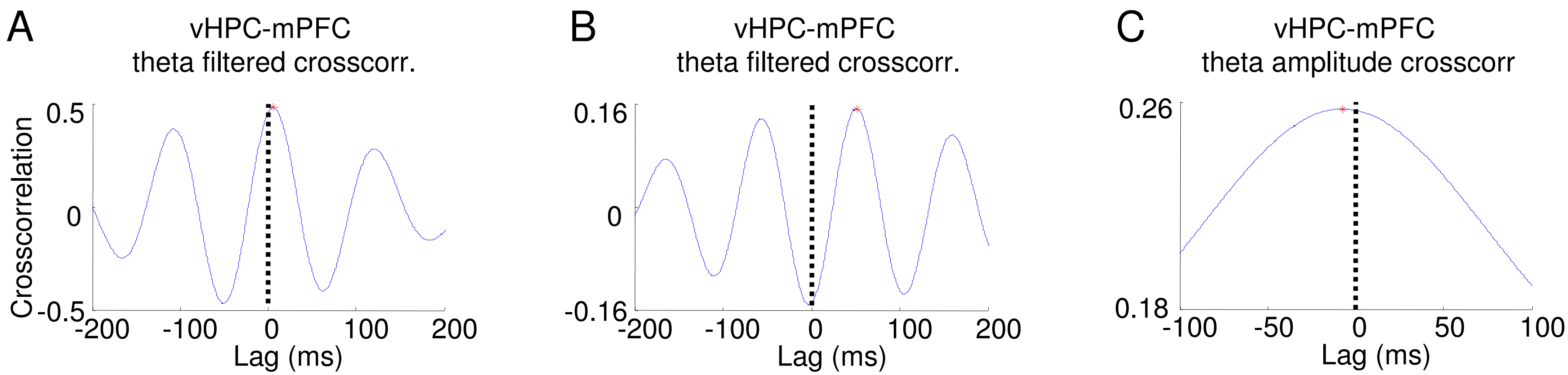
Supplemental Figure 1- vHPC-mPFC lags calculated with the Gabor transform and the Hilbert transform are in good agreement. To calculate the Gabor transform instantaneous amplitudes are calculated by convolving the signal at each frequency with a complex sinusoidal wavelet with a Gaussian envelope that has a standard deviation proportional to 1/frequency. The squared absolute magnitude of the result of the convolution at a given frequency provides the estimate of power. (A) The average correlation of instantaneous theta amplitude, calculated via the Hilbert Transform, and power, calculated using the Gabor Transform, in recordings made in the vHPC (black bar) and mPFC (grey bar). Note that both methods produce very similar estimates of instantaneous power. (B) Correlation (r=0.88) of vHPC-mPFC lags calculated by Gabor and the Hilbert transforms. (C) Normalized color plots of amplitude cross-correlations from 17 recordings. Warmer colors indicate higher cross-correlation. Each row corresponds to a single LFP recording. Rows are arranged according to the peak lag. (D) histogram showing the distribution of lags calculated through the Gabor transform. This distribution is significantly negative ($p<0.05$, Wilcoxon's test, mean lag=-21±9.1 ms).

Supplemental Figure 2



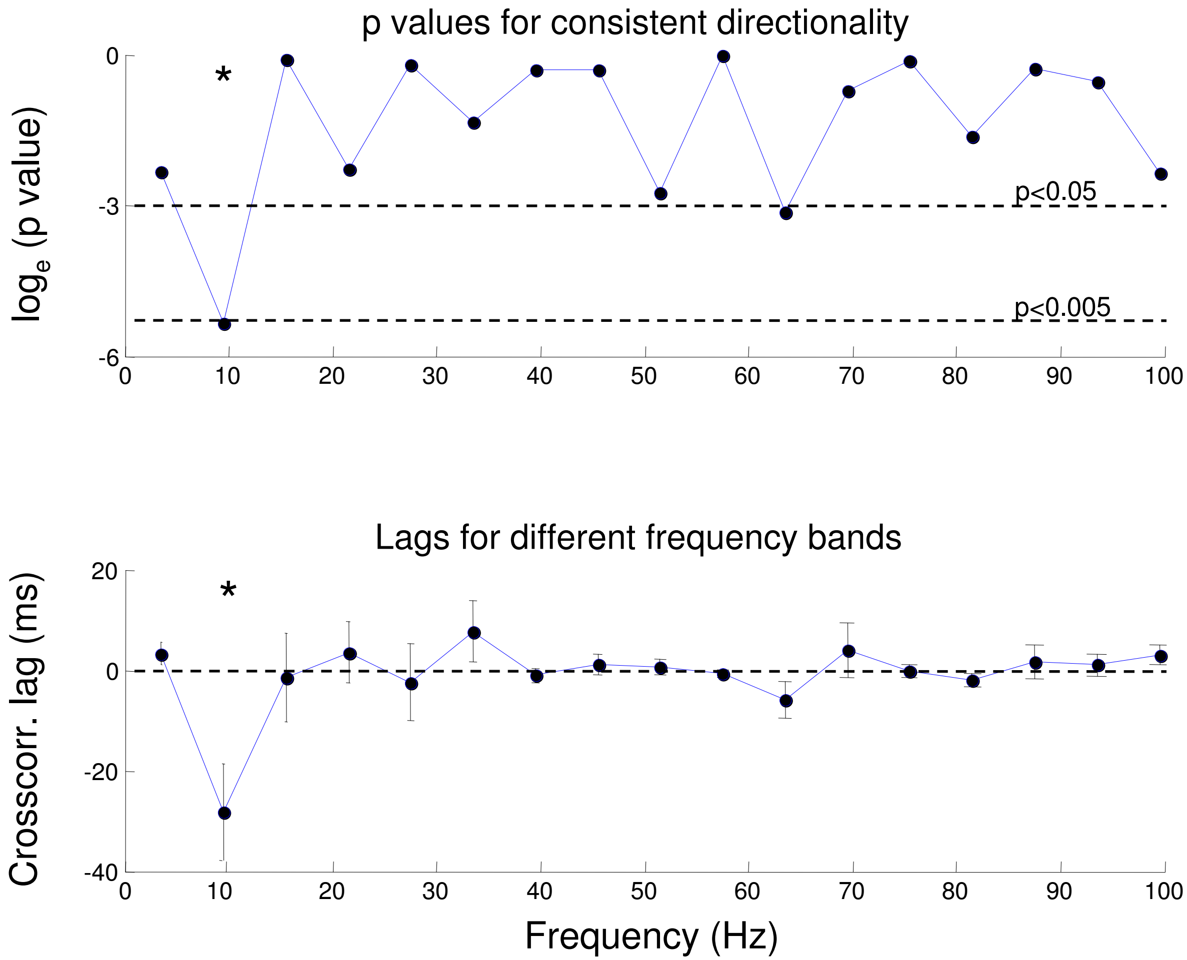
Supplemental Figure 2- Granger causality is more susceptible to noise than the amplitude crosscorrelation method. (A) As described in the text and Figure 6, we added equal amounts of pink noise to two identical signals shifted by 28 ms and calculated the predominant directionality using Granger Causality (REF). The percentage of simulations in which the wrong directionality was calculated is shown separately for each noise level. At every noise level Granger causality had a significantly higher failure rate than the amplitude crosscorrelation method ($p<0.05$, Fisher's exact test). All Granger causality values shown are averages across the theta-range. (B) As described in the text and in Figure 7, we tested the ability of unequal amounts of noise to artifactually induce directionality. A small and constant-level amount of pink noise was added to the mPFC, while different levels of noise was added to the vHPC signal. The directionality of the traces after adding noise was computed through Granger causality in 500 simulations at each noise level, Note that Granger Causality tends to find directionality from the signal with lower variance to the signal with higher variance, independently of the underlying directionality. Gm→v indicates Granger causality values for the mPFC to vHPC direction.

Supplemental Figure 3



Supplemental Figure 3- Cross-correlation of filtered LFPs cannot be used to estimate the lag between two areas. (A) Example of a cross-correlation between 7-12 Hz filtered vHPC and mPFC LFPs. As the position of the peak is strongly influenced by the phase offset between the two areas, the position of the peak (marked with a star) does not reflect the lag between these signals. (B) Another example cross-correlation of filtered LFP showing multiple peaks. Frequently, due to the phase offset, multiple peaks may be visible near the 0 ms lag. In such cases, it is unclear which peak represents the true lag between the signals. Amplitude crosscorrelation of the same signals in (A) are shown in (C). Amplitude crosscorrelations do not have this problem, as they always have only one peak. Note that the crosscorrelation peaks at a negative lag, indicating that the vHPC is leading the mPFC.

Supplemental Figure 4



Supplemental Figure 4- Identification of the frequency band at which directionality of functional connectivity occurs. Crosscorrelations of the amplitude envelopes of vHPC and mPFC LFPs were computed after filtering the signals for different 5 Hz ranges. The p values (upper panel) and lags (lower panel) are shown for a broad range of frequency ranges, from 1 to 100 Hz, in non-overlapping 5 Hz windows. Note that a lag significantly different from zero across animals ($p<0.0048$, Wilcoxon's test, n=17) occurs only for the theta (7-12 Hz) range. Applying the amplitude crosscorrelation method in this unbiased way allows for the identification of the frequency range at which directionality occurs.