Supplementary analyses

1. *Comparison of pre- and poststimulus power effects*

The observed memory-related prestimulus effects are rather inverse to the poststimulus effects (see pages 8,9 of the main manuscript), arguing against the idea that they are strongly influenced by poststimulus activity from the preceding trial. However, we conducted several analyses to further elucidate this hypothesis. First, we separately evaluated the selected measures (see table 1) for the three different groups of interstimulus intervals (ISIs): short (1600 ± 200 ms; n = 6), intermediate (2000 ± 200 ms; n = 16) or long (2700 ± 200 ms; n = 9). These results are shown in the supplementary figure 1. For all six measures, the effects were similar across ISI groups. Two-way ANOVAs with MEMORY (later remembered vs. forgotten) as repeated measure and ISI as independent factor yielded main effects of MEMORY for all six measures (each $p < 0.05$, $F_{1,28} > 4.57$). For none of the six measures a MEMORY*ISI interaction was detected (each $p > 0.22$, $F_{1,28} < 1.56$) indicating that the observed prestimulus effects do not depend on the choice of the interstimulus interval. Second, as already mentioned in the main text, we calculated interindividual correlations between pre- and poststimulus differences for rhinal alpha ($r = -0.436$, $p < 0.01$) and hippocampal theta activity ($r = -0.452$, $p < 0.01$) and depicted these correlations in two scatterplots (Supplementary figure 2). While the negative correlation can be unambigously detected for hippocampal theta activity, for rhinal alpha activity the correlation exhibits an outlier. When excluding this value, the negative correlation is smaller and not statistically significant ($r = -0.146$; $p = 0.22$). Moreover, also pre- and poststimulus rhinal theta ($r = -0.379$, $p < 0.05$) and hippocampal alpha activity ($r = -0.673$, $p < 0.0001$) are negatively correlated.

Taken together, these data corroborate our finding that prestimulus and poststimulus effects of successful memory formation are actually inverse. An influence of poststimulus

activity in trial n on prestimulus activity in the next trial n+1 would still be possible, however, if encoding success would usually be followed by encoding failure: In this case, poststimulus effects in trial n would result in spurious inverse prestimulus effects in trial n+1. To test this possibility, we analyzed whether successful encoding of a (new) word in trial n was predictive of forgetting of a word in the next trial n+1. Obviously, this analysis had to be restricted to those trials in which at least two new words were presented in direct succession. However, we found that the probability of successful encoding was actually higher if the directly preceding word was already successfully encoded as compared to when the directly preceding word was not successfully encoded (mean ± std.: 0.73 ± 0.22 vs. 0.64 ± 0.24; $t_{30} = 2.48$; $p = 0.02$). This analysis argues against the hypothesis that the observed prestimulus effects reflect poststimulus effects in directly preceding trials.

2. *Correlation of prestimulus power and stimulus-related phase locking*

In a previous analysis based on the same data set, we observed a stimulus-related phase-locking of rhinal and hippocampal theta and alpha activity, which was more pronounced for later remembered compared to forgotten words (see Fell et al. 2008). We examined the correlation between these memory-related poststimulus phase-locking effects and the prestimulus power effects reported in the current study. A statistically significant correlation was found for none of the measures, i.e. neither between rhinal prestimulus theta power and poststimulus theta phase locking, nor between rhinal prestimulus alpha power and poststimulus alpha phase locking, nor between hippocampal prestimulus theta power and poststimulus theta phase locking, nor between hippocampal prestimulus alpha power and poststimulus alpha phase locking (each $r < 0.2$; each $p > 0.16$).

3. Analysis of prestimulus event-related potentials

Previous studies described subsequent memory effects in slow prestimulus event related potentials (Otten et al. 2006) using scalp EEG. We therefore investigated event-related potentials (ERPs) in rhinal cortex and hippocampus as a function of subsequent memory. As a baseline, we chose the period between -1000 ms and -900 ms before stimulus presentation. These data are presented in the supplementary figure 3. Subsequent memory ERP effects in the poststimulus period are described elsewhere (Fell et al. 2008). In the prestimulus period, there was no significant difference between subsequently remembered and forgotten trials: When we compared average ERP potentials in each of the nine consecutive non-overlapping windows of 100 ms length between -900 ms and 0 ms, no difference emerged in either region even for the most liberal comparison using multiple individual paired T-tests (all $p > 0.1$; uncorrected values). Also, when we averaged across the period between -500 ms and 0 ms where a difference might be expected upon visual inspection of the data, there was no significant effect ($p > 0.2$ in both rhinal cortex and hippocampus).

4. Analysis of prestimulus power effects based on FFTs

To directly assess theta power differences without mirroring the data, we performed Fast-Fourier-Transforms (FFTs) with cosine windowing (Hann-window). Edge effects are excluded by this method, because the cosine window attenuates the data to zero at the edges. In order to obtain a reasonable frequency resolution, we fed time segments of 256 data points into the FFTs (corresponding to a frequency resolution of 0.78 Hz) and filled the data points outside the analysed windows with zeros (zero padding). To mimic the broader frequency catchment area of the wavelet transform, we analysed the frequency ranges 2-8 Hz (hippocampus, formerly 3-7 Hz) and 3-8 Hz (rhinal cortex, formerly 4-7 Hz). For the

hippocampal recordings, we found a significant increase of theta activity in the time window [-1000 ms; -600 ms] for later remembered compared to forgotten trials (two-tailed paired T-test, $p < 0.05$), similar to the effect reported based on Wavelet-analyses. For the rhinal recordings, we observed no significant memory-related effect for the time window [-1000ms; -700ms]. We only found a trend ($p = 0.1025$) for a memory-related increase of rhinal theta activity in the first half of the time window [-1000ms; -850 ms]. The comparatively low significance for the FFT-based compared to the wavelet-based power effects is probably due to the cosine tapering and the poor time/frequency resolution of the FFT. A window length of 300 ms, for instance, would yield a frequency resolution of only 3.3 Hz. To obtain a reasonable frequency solution, epochs were enlarged and zero-padded, which may reduce statistical power of the memory-related effect.

5. *Directional coupling analyses*

Finally, we analysed directional rhinal-hippocampal interactions in the prestimulus time range by applying a previously described phase-based method (Axmacher et al. 2008; Rosenblum and Pikovsky 2001; Wagner et al. 2010). In short, this approach is based on a cross-channel prediction of phase values and on modelling the phase dynamics by Fourier-series. Directional coupling D was quantified for the theta, alpha, beta1 and beta2 range based on time intervals of 100 ms duration. Because the prediction steps introduce a delay depending on the average oscillatory period, no results are obtained for the delay period at the beginning of the trial (for instance, results can be evaluated starting with the second interval for the alpha range). A modified Bonferroni-correction was applied accounting for the average intraindividual correlation between the directional coupling values for the different time intervals (Perneger 1998; Sankoh et al. 1997). No statistically significant effects of

subsequent memory were detected for the theta (3-7 Hz), beta1 (13-17 Hz) and beta2 (23-34 Hz) band. For the alpha range (8-12 Hz), we found a significant directional coupling effect for the time interval [-200ms; -100ms] ($p = 0.0061$; modified Bonferroni-threshold = 0.0063, $r = 0.06$). This coupling effect indicates a stronger influence of the hippocampus on the rhinal cortex during trials corresponding to later remembered ($D = 0.0022 \pm 0.0033$; mean $\pm$ s.e.m.) compared to later forgotten words ($D = -0.0118 \pm 0.0046$).

References

Axmacher N, Schmitz DP, Wagner T, Elger CE, Fell J (2008) Interactions between medial temporal lobe, prefrontal cortex, and inferior temporal regions during visual working memory: a combined intracranial EEG and functional magnetic resonance imaging study. J Neurosci 28: 7304-7312.

Perneger TV (1998) What is wrong with Bonferroni adjustments. Brit Med J 136:1236-1238.

Rosenblum MG, Pikovsky AS (2001) Detecting direction of coupling in interacting oscillators. Phys Rev E 64: 045202.

Sankoh AJ, Huque MF, Dubey SD (1997) Some comments on frequently used multiple endpoint adjustments methods in clinical trials. Stat Med 16: 2529-2542.

Wagner T, Fell J, Lehnertz K (2010) The detection of transient directional couplings based on phase synchronization. New J Phys 12: 053031.

Supplementary figure legends

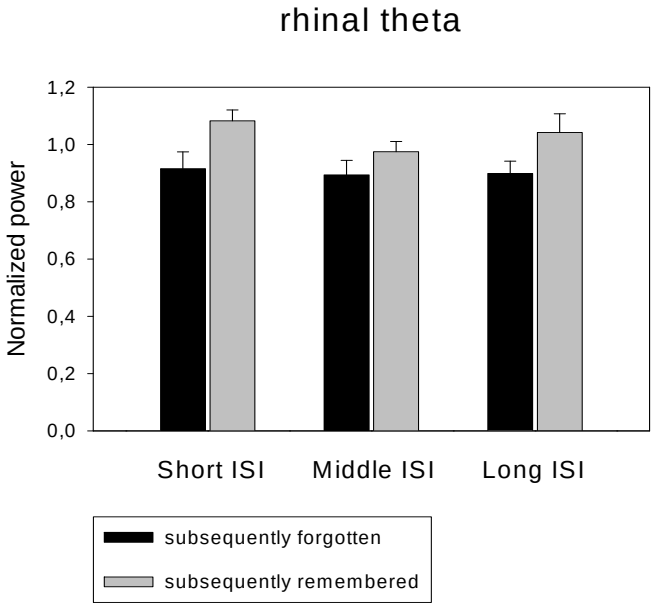
Supplementary Figure 1:

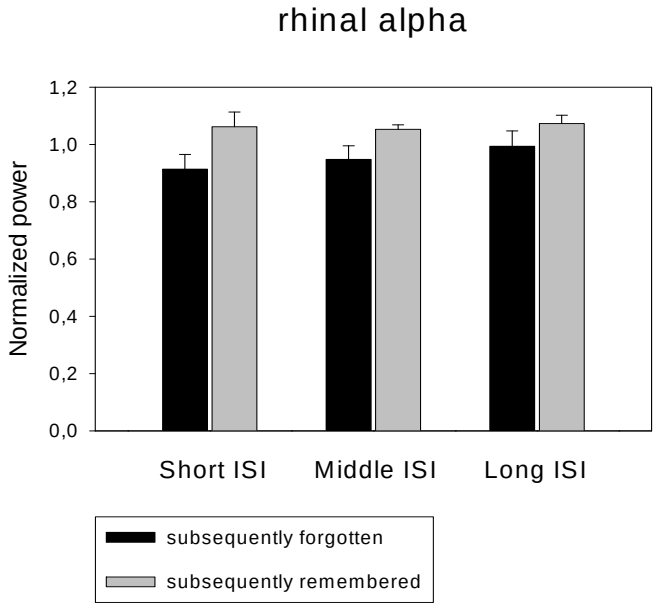
Average rhinal and hippocampal prestimulus power values (mean ± s.e.m.) related to subsequently remembered and forgotten words for different interstimulus intervals (short, intermediate, long).

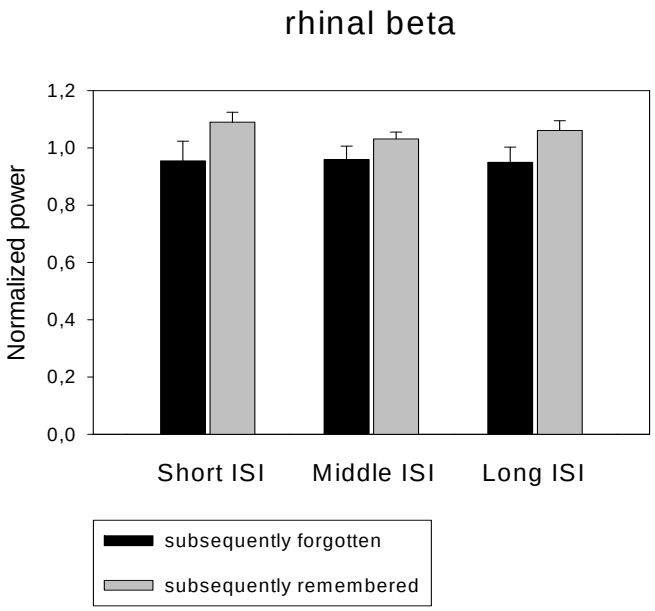
Supplementary Figure 2:

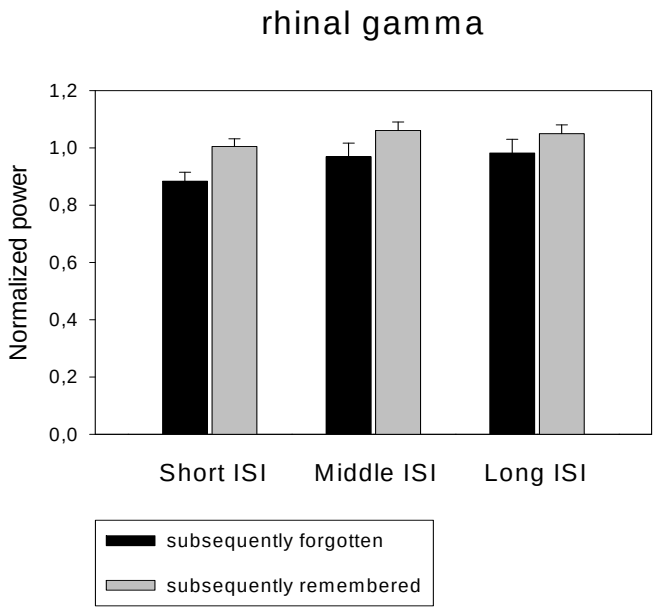
Scatterplot depicting the correlation between prestimulus and poststimulus subsequent memory-related differences of power values.

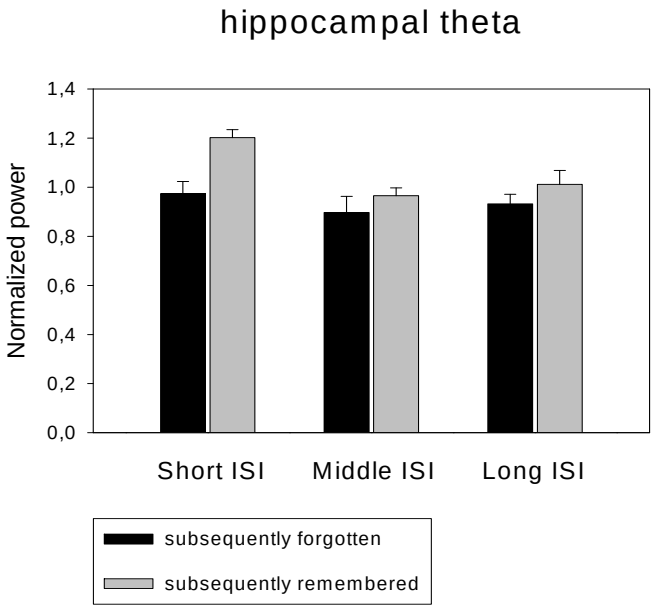
Supplementary Figure 3:
Event-related potentials in the pre- and poststimulus range for later remembered versus forgotten words. The prestimulus interval [-1000ms;-900ms] served as a baseline.

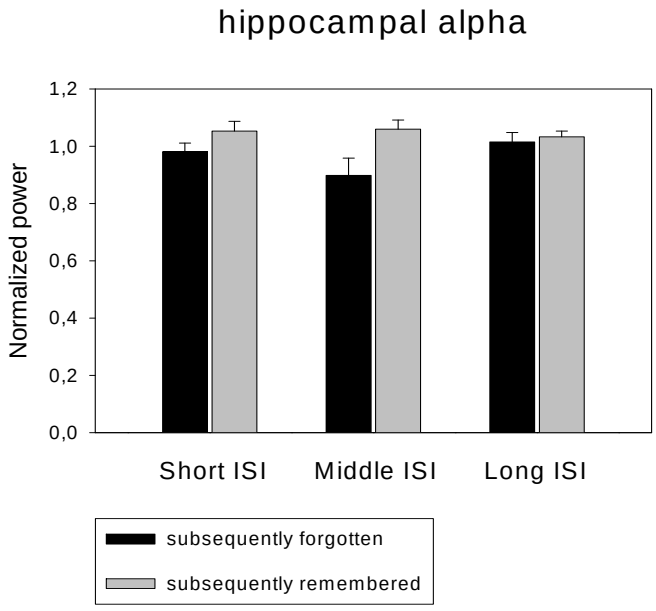

rhinal theta
Normalized power
1,2
1,0
0,8
0,6
0,4
0,2
0,0
Short ISI
Middle ISI
Long ISI
subsequently forgotten
subsequently remembered


rhinal alpha
Normalized power
1,2
1,0
0,8
0,6
0,4
0,2
0,0
Short ISI
Middle ISI
Long ISI
subsequently forgotten
subsequently remembered

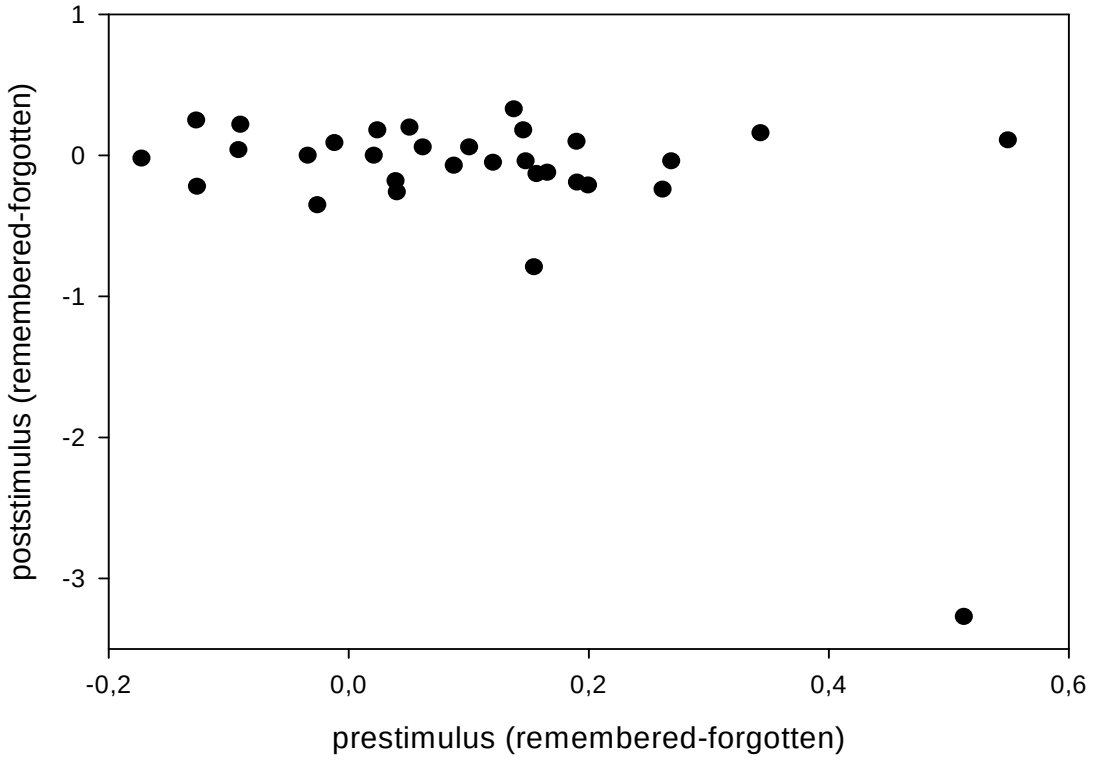

rhinal beta
Normalized power
1,2
1,0
0,8
0,6
0,4
0,2
0,0
Short ISI
Middle ISI
Long ISI
subsequently forgotten
subsequently remembered


rhinal gamma
Normalized power
1,2
1,0
0,8
0,6
0,4
0,2
0,0
Short ISI
Middle ISI
Long ISI
subsequently forgotten
subsequently remembered

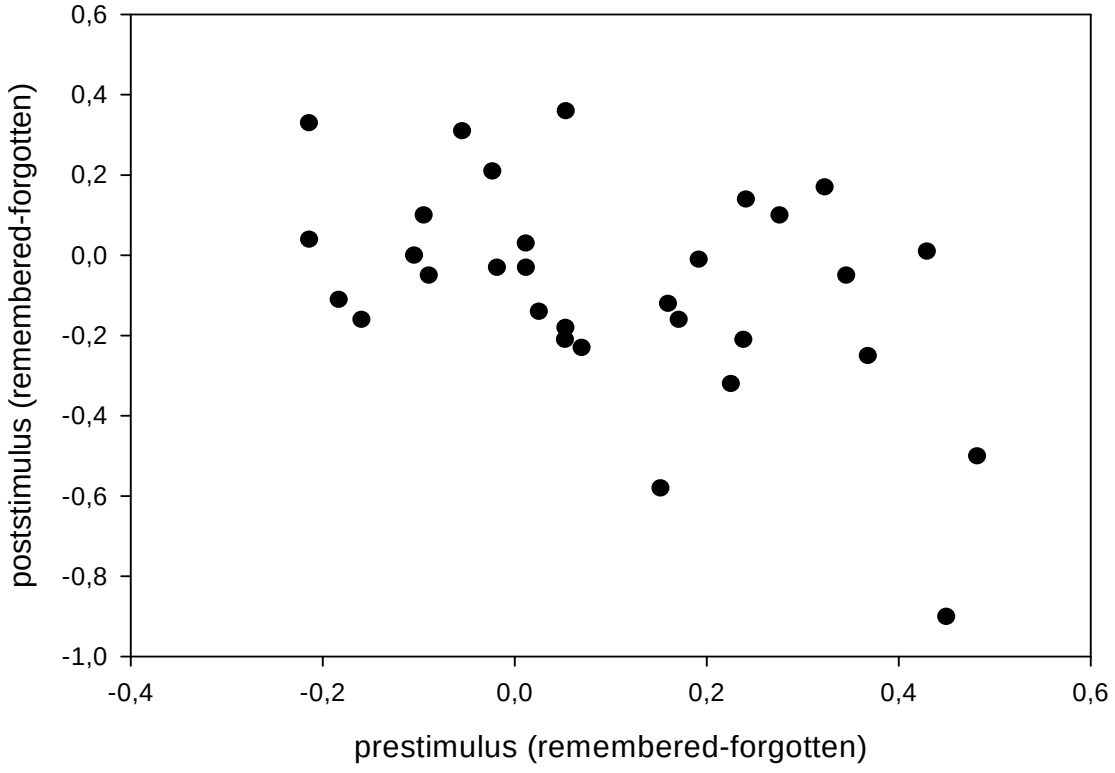

hippocampal theta
Normalized power
1,4
1,2
1,0
0,8
0,6
0,4
0,2
0,0
Short ISI
Middle ISI
Long ISI
subsequently forgotten
subsequently remembered

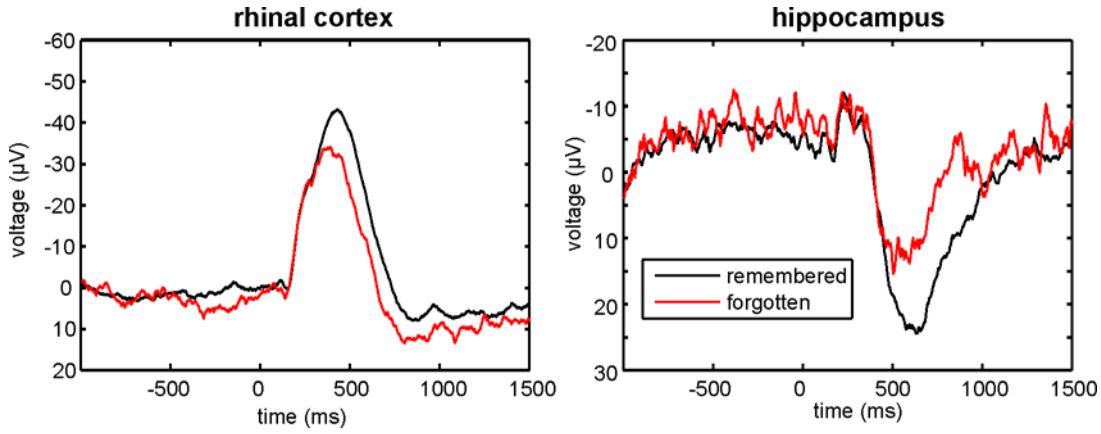

hippocampal alpha
Normalized power
1,2
1,0
0,8
0,6
0,4
0,2
0,0
Short ISI
Middle ISI
Long ISI
subsequently forgotten
subsequently remembered

rhinal alpha



hippocampal theta




rhinal cortex
hippocampus
voltage (μV)
time (ms)
remembered
forgotten
-60
-50
-40
-30
-20
-10
0
10
20
30
-500
0
500
1000
1500