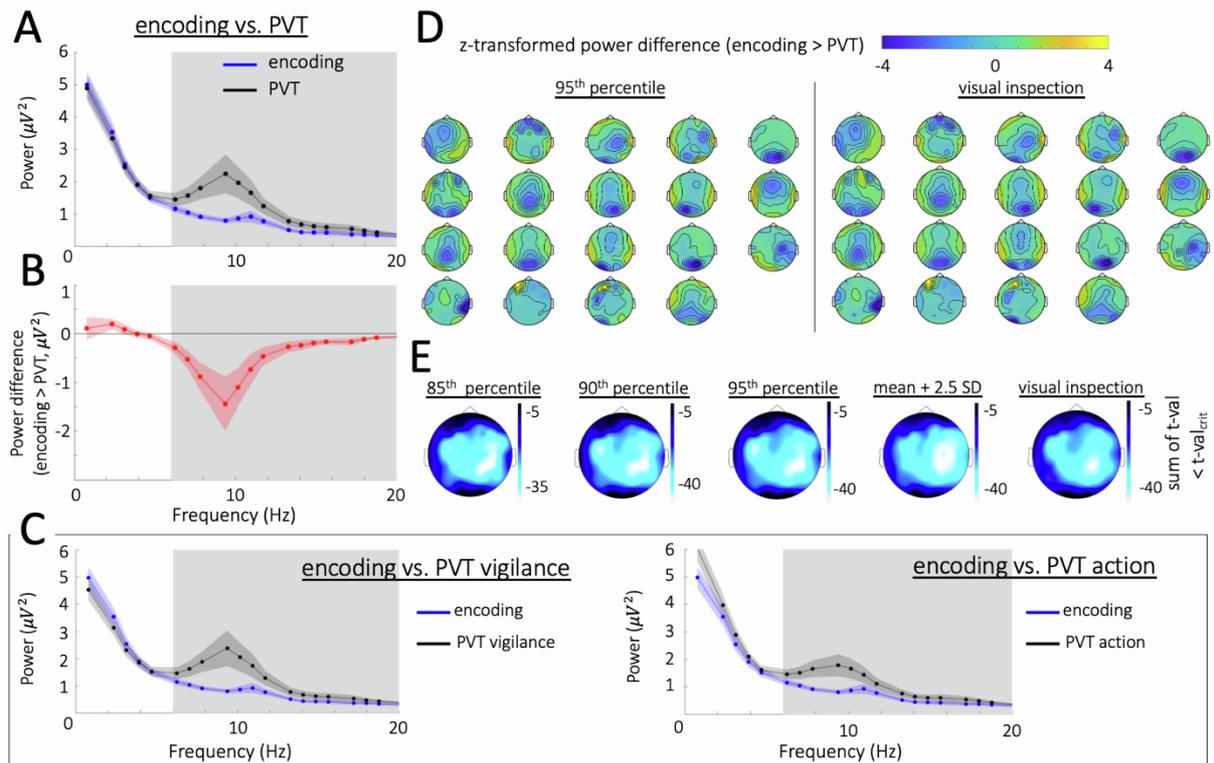


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**Supplemental Information**

**Sleep spindles track cortical learning  
patterns for memory consolidation**

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**Figure S1. Frequency spectra and topographies of power differences between encoding and PVT. Related to Figure 1E.**

(A) Power spectra (mean  $\pm$  SEM) for encoding (blue), PVT (black) as well as their difference (red, shown in B, statistically significant differences are highlighted in grey,  $p < .05$  cluster corrected) are shown for electrode CP4 (cf., main Figure 1E). These were the raw values entering statistical analyses presented in main Figure 1E. (C) Power spectra (mean  $\pm$  SEM) for encoding and PVT 'vigilance' (left) as well as encoding and PVT 'action' (right). For the PVT 'vigilance' component, 10 sec pre-counter (minimum for which the fixation cross, without any motor responses, was presented) and for the PVT 'action', 4 seconds post-counter (time during which motor responses were given) were included. Statistically significant differences are highlighted in grey,  $p < .05$  cluster corrected. (D) Participant-specific topographies of the 6-20 Hz power changes during encoding relative to the PVT (after excluding epochs based on the 95<sup>th</sup> percentile or after visual inspection). Power changes were z-transformed for comparability across participants. (E) Applying different thresholds (85<sup>th</sup>, 90<sup>th</sup>, 95<sup>th</sup> percentile, mean + 2.5 SD or visual inspection) to exclude potential artifacts result in comparable encoding patterns (the frequency range in which encoding and PVT significantly differ is always 6-20Hz).

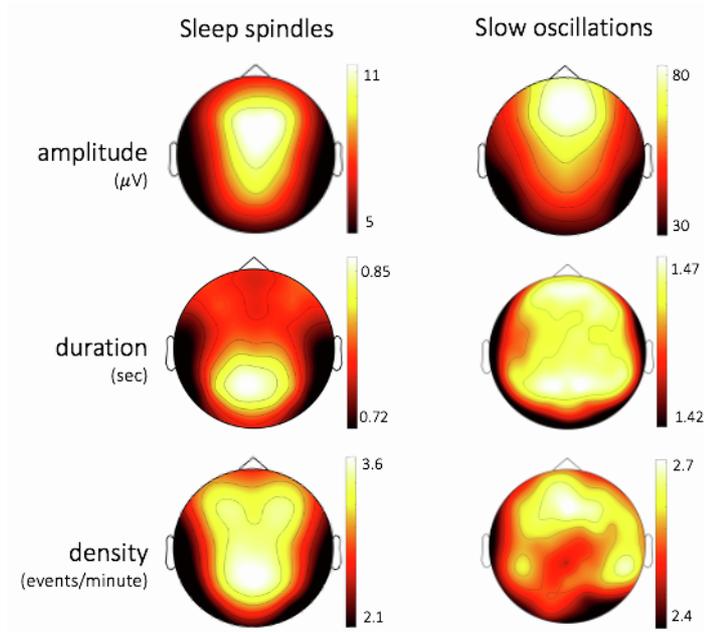
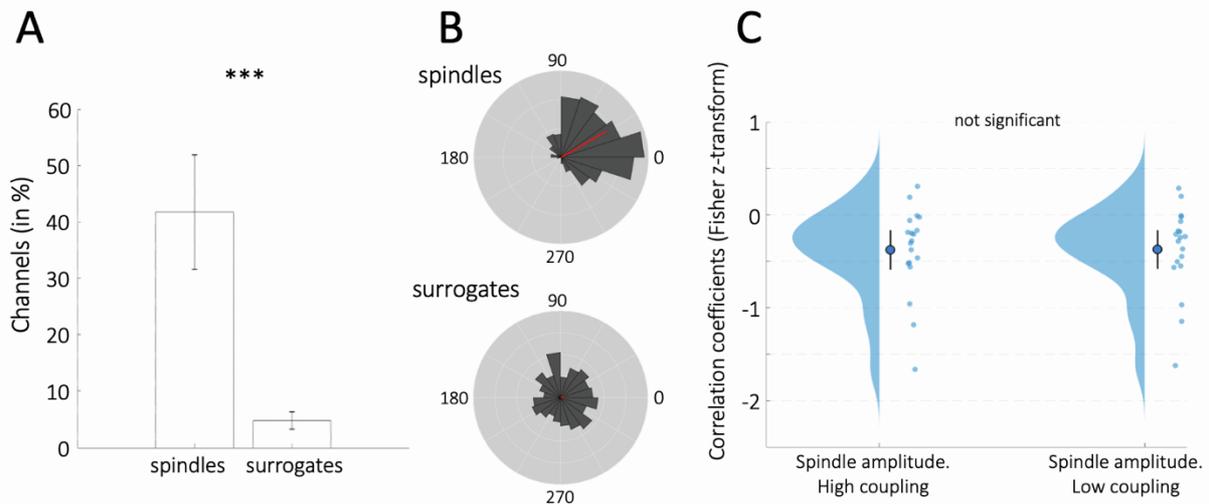


Figure S2. Group-level topographies of amplitude, duration and density of sleep spindles and slow oscillations. Related to Figure 2A.



**Figure S3. Coupling of spindles and surrogate events to the phase of the signal filtered in the SO frequency range (0.3 -1.25). Related to Figure 2B.**

(A) Mean ( $\pm$  95% confidence intervals) percentage of channels on which sleep spindles and surrogate events are significantly coupled (defined by a significant deviation from a uniform distribution, Rayleigh test:  $p < .05$ ). Spindles are coupled to SOs on significantly more channels than surrogates. Surrogates were matched control events - for each detected spindle, a spindle-free epoch within 15 seconds before or after the actual spindle event was identified<sup>51</sup>. The instantaneous phase angle of the SO filtered and Hilbert transformed signal was then extracted at the centre of the spindle-free epoch.

(B) The corresponding phase (in degrees) of spindle maxima (top) and surrogate centres (bottom) plotted across all channels with significant spindle coupling (including all participants, fixed-effects,  $n = 447$ ). While spindles significantly cluster at a phase of 30 degrees (Rayleigh test:  $z = 173.75$ ,  $p < .001$ , resultant vector length = 0.62), surrogates deviate only moderately from a uniform distribution (Rayleigh test:  $z = 3.22$ ,  $p = .040$ , resultant vector length = 0.08). Both distributions significantly differ (Kuiper test:  $p < .001$ ).

(C) No differential encoding-spindle amplitude overlap for spindles with higher (left) vs. lower (right) coupling to the SO up-state.

	N1	N2	N3	REM	TST
mean	18.39	52.53	10.42	16.24	103.58
SEM	2.46	3.66	2.56	2.85	2.28

**Table S1. Descriptive sleep data in minutes (mean and SEM). Related to Figure 1C and 2A.**

n = 19. TST = total sleep time.

electrode Fz	sleep spindles			slow oscillations		
	amplitude	duration	density	amplitude	duration	density
mean	11.13	0.76	3.27	82.97	1.42	2.49
SEM	0.63	0.01	0.16	6.11	0.01	0.13
<b>electrode Cz</b>						
mean	11.03	0.80	3.45	68.07	1.41	2.67
SEM	0.54	0.01	0.19	4.49	0.01	0.12
<b>all electrodes</b>						
mean	7.83	0.78	3.02	56.01	1.42	2.62
sem	0.36	0.01	0.15	4.14	0.01	0.12

**Table S2. Descriptive data of sleep oscillations. Related to Figure 2A.**

Descriptive data of amplitude (maximum peak for spindles and absolute value of the most negative trough for slow oscillations, in  $\mu V$ ), duration (time from beginning to end of algorithmically detected events, in seconds) and density (n events/minute) of sleep spindles and slow oscillations for electrode position Fz, Cz and averaged across all electrodes (mean and SEM). n = 19.

## Supplemental References

- S1. Ngo, H.V. V., Fell, J., and Staresina, B. (2020). Sleep spindles mediate hippocampal-neocortical coupling during long-duration ripples. *Elife* 9, 1–18.