SUPPLEMENTARY INFORMATION

Youth-Like Precision of Slow Oscillation–Spindle Coupling Promotes Memory Consolidation Across the Adult Lifespan

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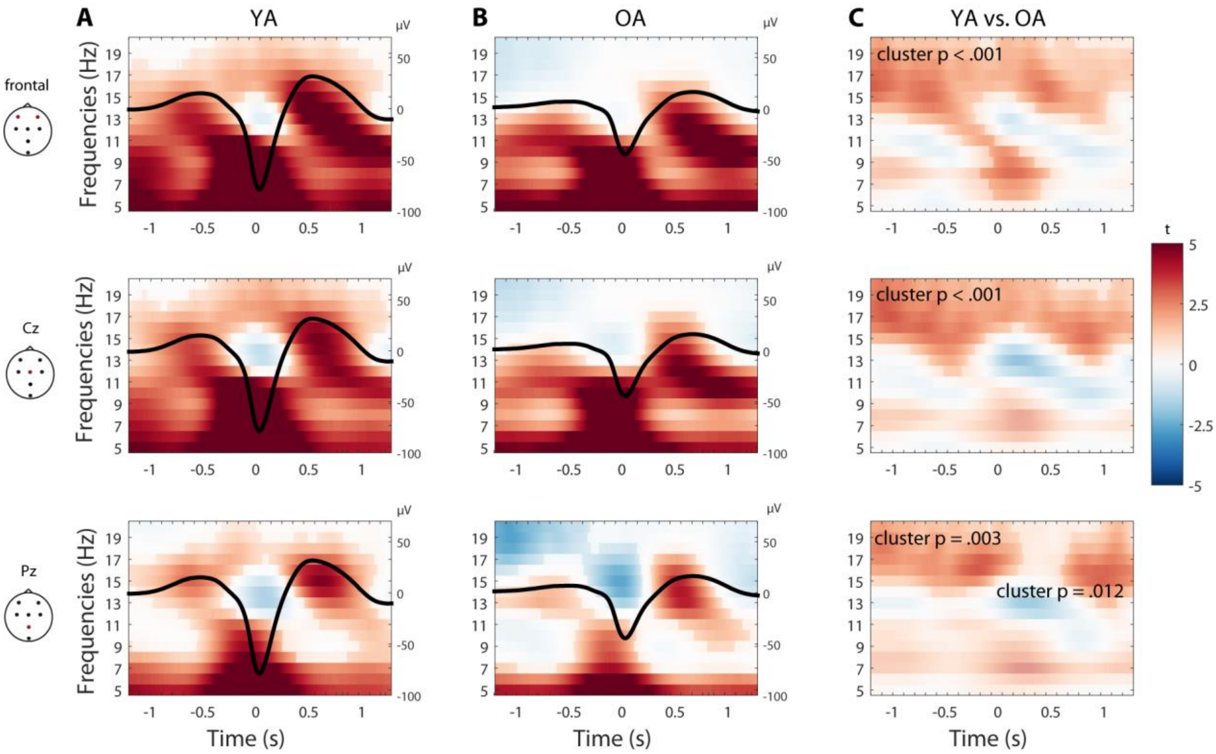
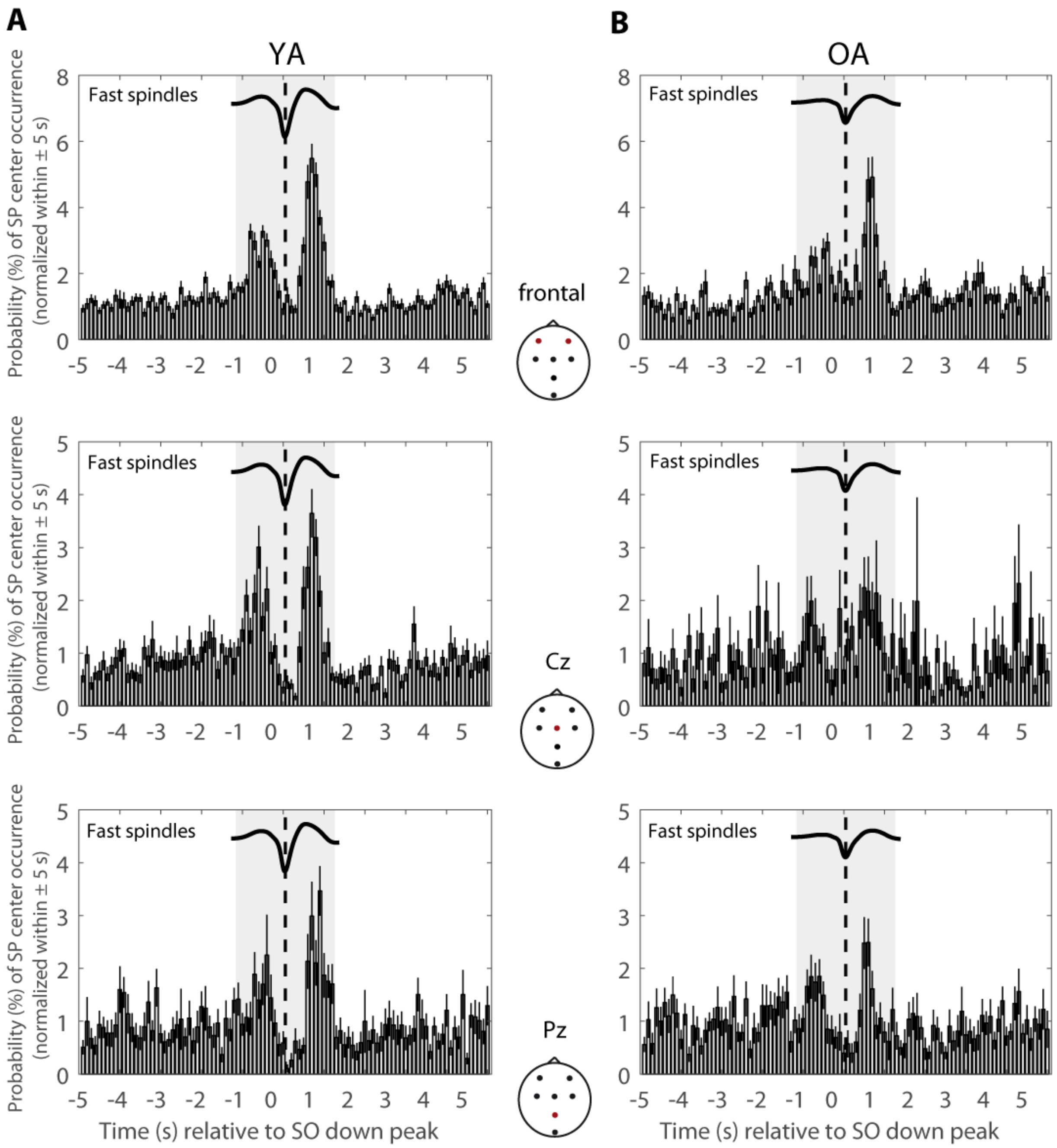
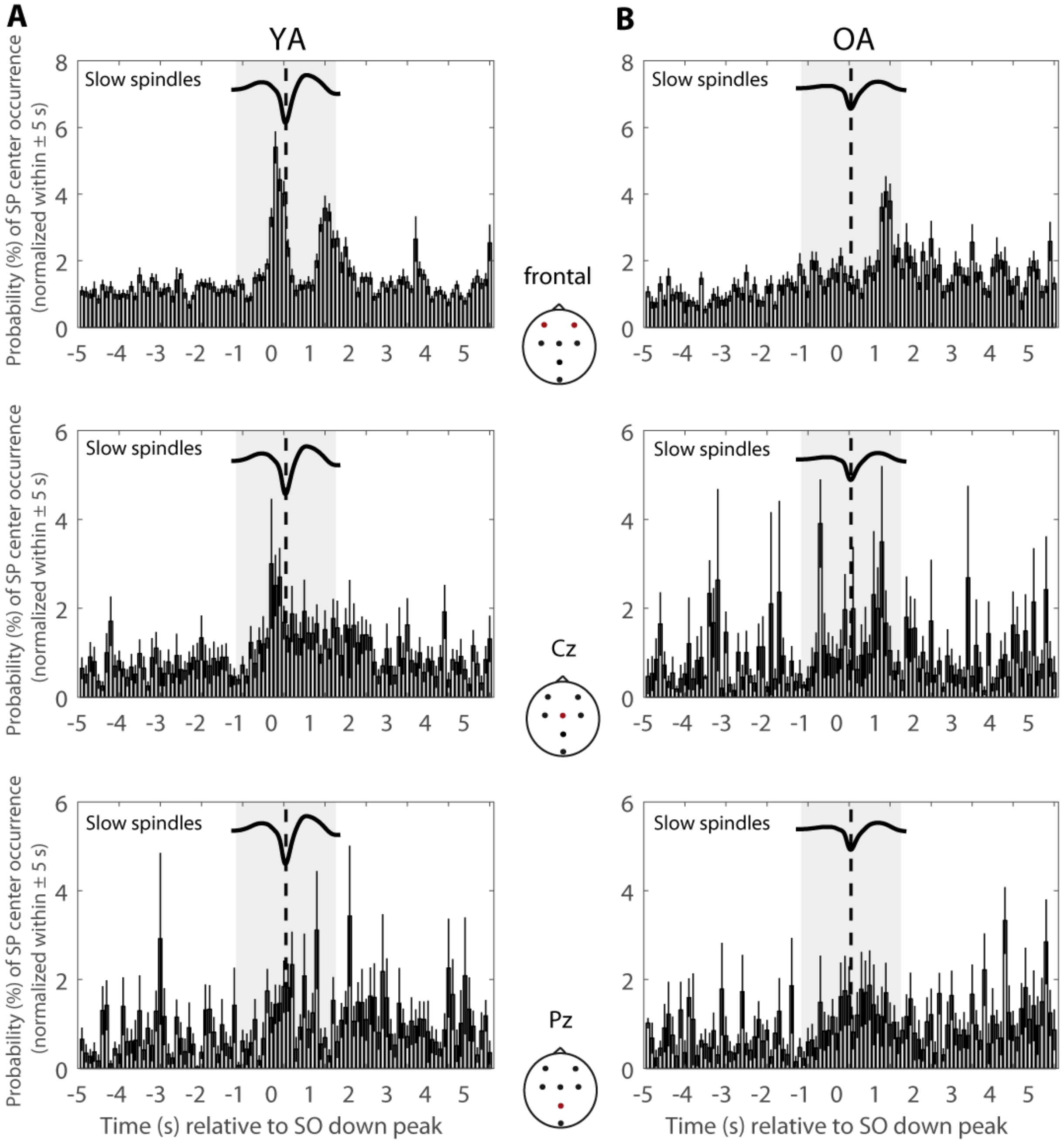


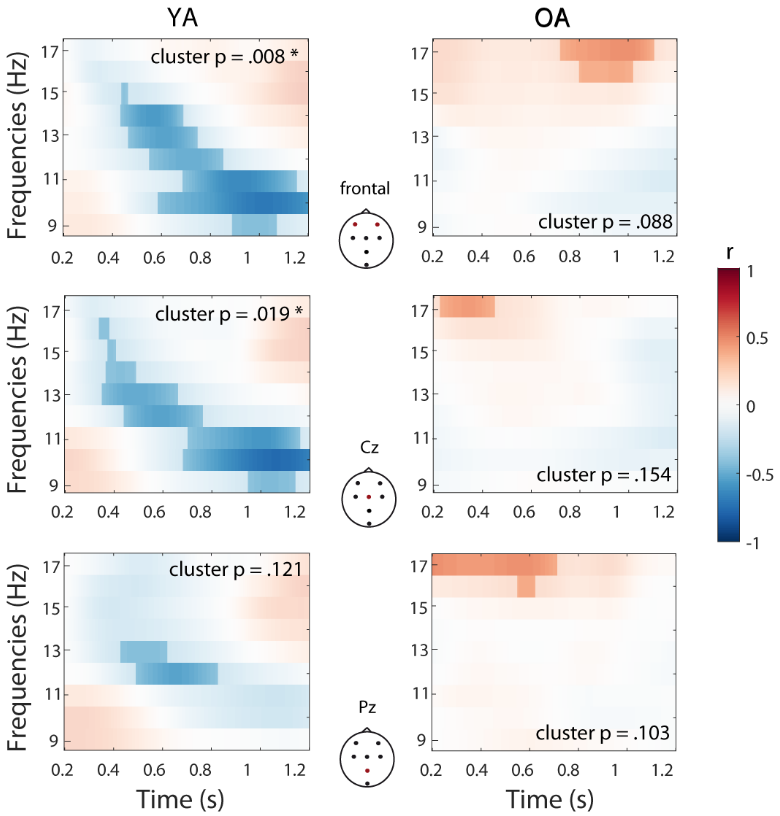
Supplementary Figure 1. The timing and topography of fast and slow SP activity during SOs differs for younger and older adults. (A + B) Differences in wavelet power for SO trials (respective down peak ± 1.2 s) compared to trials without SOs are depicted (in *t*-score units). Significant clusters (cluster-based permutation test, cluster $\alpha < 0.05$) are highlighted. The average frontal SO for each age group is inserted in black (the scale in µV is indicated on the right of each time–frequency graph). In both age groups, EEG power is modulated as a function of the SO phase. (A) In younger adults, fast SP activity (12–15 Hz) peaks during the up-state in all derivations but the effect is most specific in centroparietal electrodes where it appears precisely during the up peak of the SO. Slow SP power (9–12 Hz) is strongest at the up-to down-state transition in frontal channels and at Cz. (B) In older adults, a specific fast SP power peak is only seen at Pz but is less tied to the SO up peak. In general, power increases are shifted to lower frequencies as compared to younger adults. (C) The *t*-map of the time–frequency age comparison is displayed (significant cluster highlighted, cluster $\alpha < 0.05$). In all channels, significant age-related reductions in fast SP power are tied to the SO up-state only. YA: younger adults; OA: older adults; SO: slow oscillation; SP: spindle.



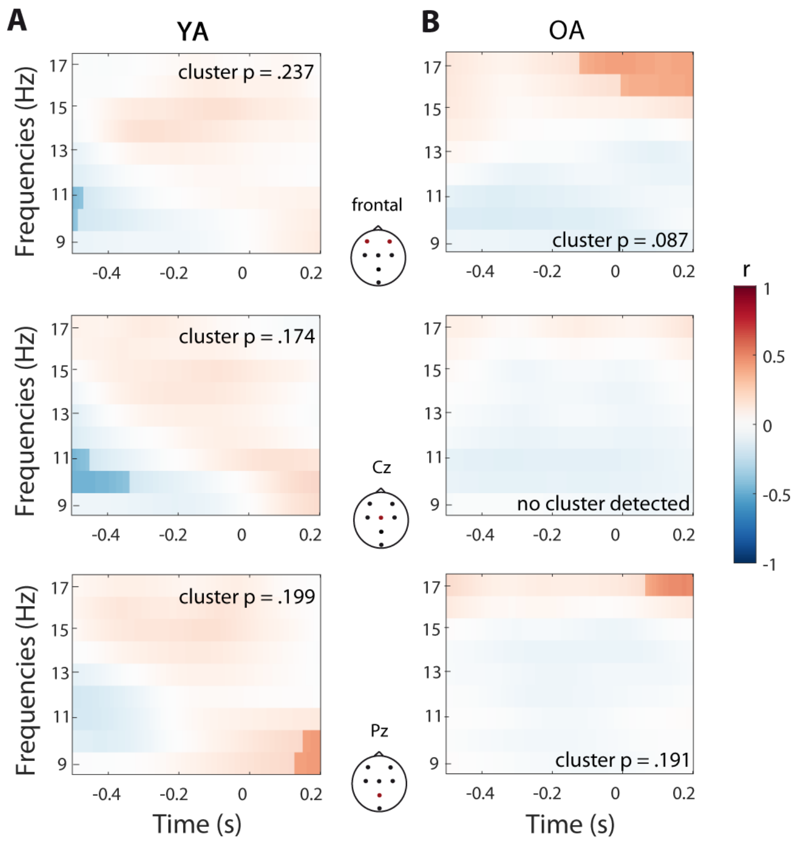
Supplementary Figure 2. The timing and topography of fast SP events differs for younger and older adults. Peri-event time histograms (PETHs) of fast SPs (12–15 Hz) at frontal channels, Cz and Pz, co-occurring with frontal SOs, are shown for both age groups. PETHs are computed for time intervals of ± 5 s relative to the SO down peak. Standard errors of the 100-ms bins are included as black vertical lines. The average SO for each age group is inserted and the corresponding time interval (± 1.2 s) is shaded in gray. Dashed vertical lines mark the down peak of the SO. (A) In younger adults, a distinct increase in fast SPs during the SO up-state is observed in all derivations. (B) In older adults, the fast SP peak occurs before the SO up peak. Overall, fast SP modulation is less specific, in particular at electrode Cz. YA: younger adults; OA: older adults; SO: slow oscillation; SP: spindle.



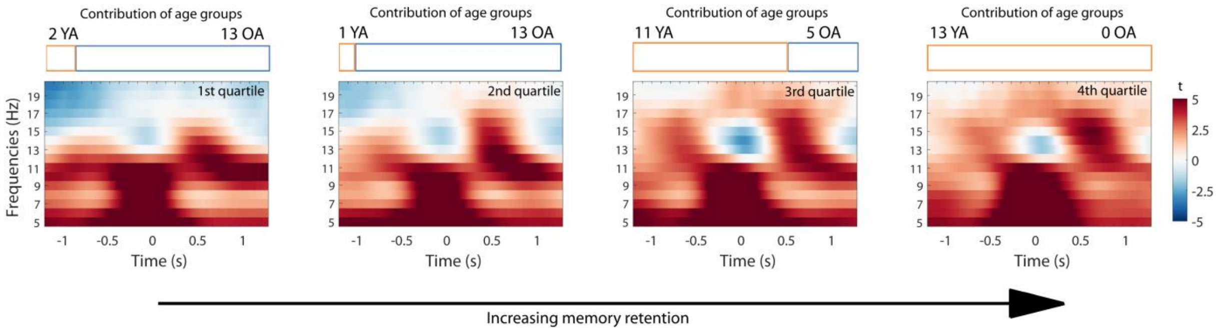
Supplementary Figure 3. Fine-tuned slow SP modulation is specific to frontal channels in both younger and older adults. Peri-event time histograms (PETHs) of fast SPs (9–12 Hz) at frontal channels, Cz and Pz, co-occurring with frontal SOs, are shown for both age groups. PETHs are computed for time intervals of ± 5 s relative to the SO down peak. Standard errors of the 100-ms bins are included as black vertical lines. The average SO for each age group is inserted and the corresponding time interval (± 1.2 s) is shaded in gray. Dashed vertical lines mark the down peak of the SO. In both age groups, slow SP modulation is most specific to frontal channels. (A) In younger adults, slow SPs globally peak at the up-to down-state transition. (B) In older adults, the frontal slow SP peak at the up-to down-state transition preceding the down peak disappears. YA: younger adults; OA: older adults; SO: slow oscillation; SP: spindle.



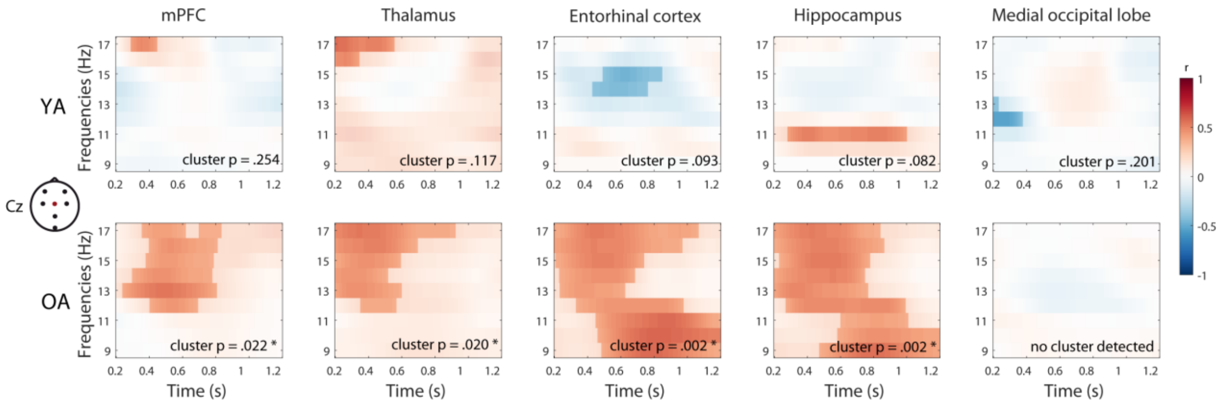
Supplementary Figure 4. Neuronal activity during the SO up-state predicts memory retention. Pearson's correlation coefficients between memory retention and neuronal activity during SO up-states are displayed for both age groups. In each plot the cluster with the smallest *p*-value (after control for multiple comparisons using a cluster-based permutation test) is highlighted and its significance (cluster α < 0.05) is marked by asterisks. In younger adults, a significant negative correlation cluster appears over frontal channels and at Cz. More positive values in this cluster are associated with worse memory retention. No robust cluster was detected in older adults. YA: younger adults; OA: older adults; SO: slow oscillation.



Supplementary Figure 5. Neuronal activity during the SO up-to down-state does not predict memory retention. Pearson's correlation coefficients between memory retention and neuronal activity at the up-to down state transition are displayed for both age groups. In each plot the cluster with the smallest *p*-value (after control for multiple comparisons using a cluster-based permutation test) is highlighted and its significance (cluster $\alpha < 0.05$) is marked by asterisks. No robust association with memory retention was detected. YA: younger adults; OA: older adults; SO: slow oscillation.



Supplementary Figure 6. Central SO–SP coupling changes as a function of memory retention. Participants are grouped in quartiles with regard to their ability to retain memories overnight (from 1st quartile – low performance – to 4th quartile – high performance). For each subgroup SO-modulated EEG activity is depicted. Bar charts above the time frequency plots indicate the number of subjects of each age group contributing to the depicted pattern. With increasing memory retention, more fast SP activity between 400 to 700 ms after the SO down peak is observed. Vice versa, the worse memory retention is, the more the power peak shifts to lower frequencies and later time points. YA: younger adults; OA: older adults; SO: slow oscillation; SP: spindle.



Supplementary Figure 7. Central SO–SP coupling relates to brain integrity in old age. Pearson's correlation coefficients between brain volume in extracted ROIs and neuronal activity during SO up-states are displayed for both younger and older adults. In each plot the cluster with the smallest *p*-value (after control for multiple comparisons using a cluster-based permutation test) is highlighted and its significance (cluster α < 0.05) is marked by asterisks. In older adults, significant positive correlation clusters were detected for mPFC, thalamus, entorhinal cortex, and hippocampus. More positive values in this cluster are associated with greater brain volume in the respective ROI. Except for the medial occipital lobe, all extracted ROIs relate to enhanced neuronal activity during the SO up-state. For mPFC and thalamus, source regions of SO and SP generation, the effects are more specific to fast SP frequencies. Greater volume in entorhinal cortex and hippocampus relates to a broader enhancement of neuronal activity reaching into the slow SP frequency band. No significant correlation cluster was found in younger adults. YA: younger adults; OA: older adults; mPFC: medial prefrontal cortex; ROI: region of interest; SO: slow oscillation; SP: spindle.