Simultaneous EEG-MEG Sleep Recording and Source Localization Reveal Precise Spatiotemporal Distribution of Spindle Activity During Sleep

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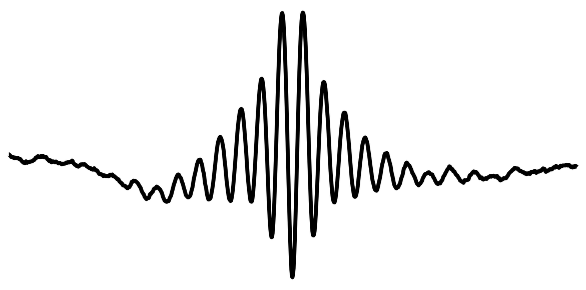
Introduction



- Spindles (12-16 Hz) are waxing-and-waning oscillations during NREM sleep, generated and sustained through thalamocortical interactions[1].
- Spindles are thought to support sleep-dependent memory consolidation via setting a timeframe for ripples to occur[2], which coordinate neuronal firing rates and drive memory reactivation.
- While intracranial EEG studies revealed spindle-ripple interactions[2], corresponding whole-brain dynamics remain unclear to limited coverage.
- MEG offers better spatial resolution than EEG and has been widely used to capture high-frequency activity, allowing for more precise mapping of spindle and ripple dynamics.

Question

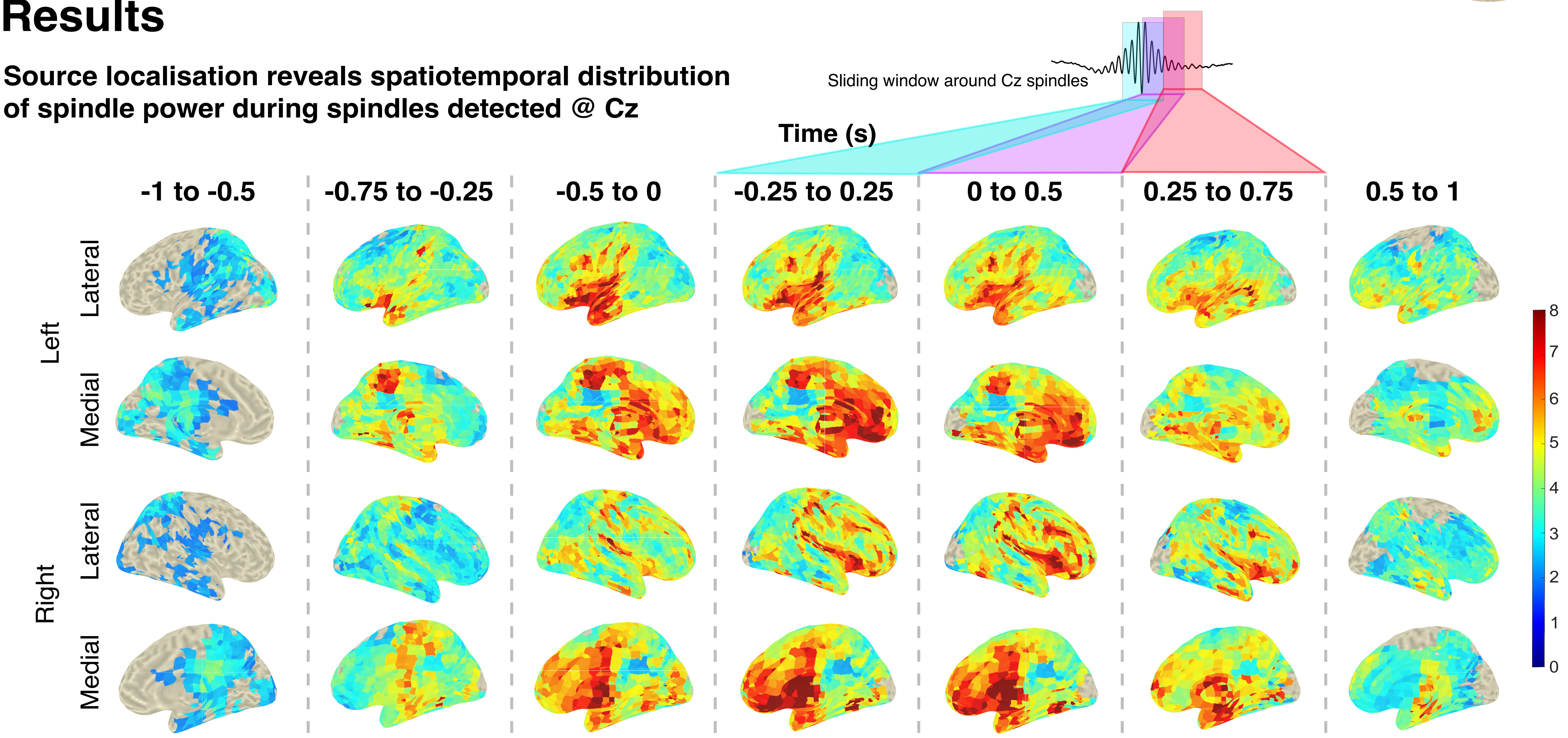
Can MEG track the whole-brain spatiotemporal distribution of spindles and characterise hippocampal ripples?

Methods

- Eleven healthy participants (6 male; age: 26.4 ± 6.3 years) slept in the MEG scanner from 11:30pm to 2am, and then slept in the adjacent bedroom with EEG until 8am, followed by a structural MRI scan.
- Data were sampled at 1000Hz using a MEGIN Triux™ Neo system with 306 MEG and 60 EEG channels.
- Spindle detection was performed on EEG Cz, based on prior iEEG and EEG studies from our group[3].
- Surrogate spindles from NREM windows without spindle events were used as a baseline.
- FLUX Toolkit was used for preprocessing: MaxFilter, Artifact detection, ICA, and Epoching.
- LCMV Beamformer was used for time-domain source localisation via FieldTrip in MATLAB.
- Spectral decomposition of spindle activity was performed at the source level.
- Hippocampal Regions of Interest (ROIs) were defined using the FieldTrip AAL atlas.

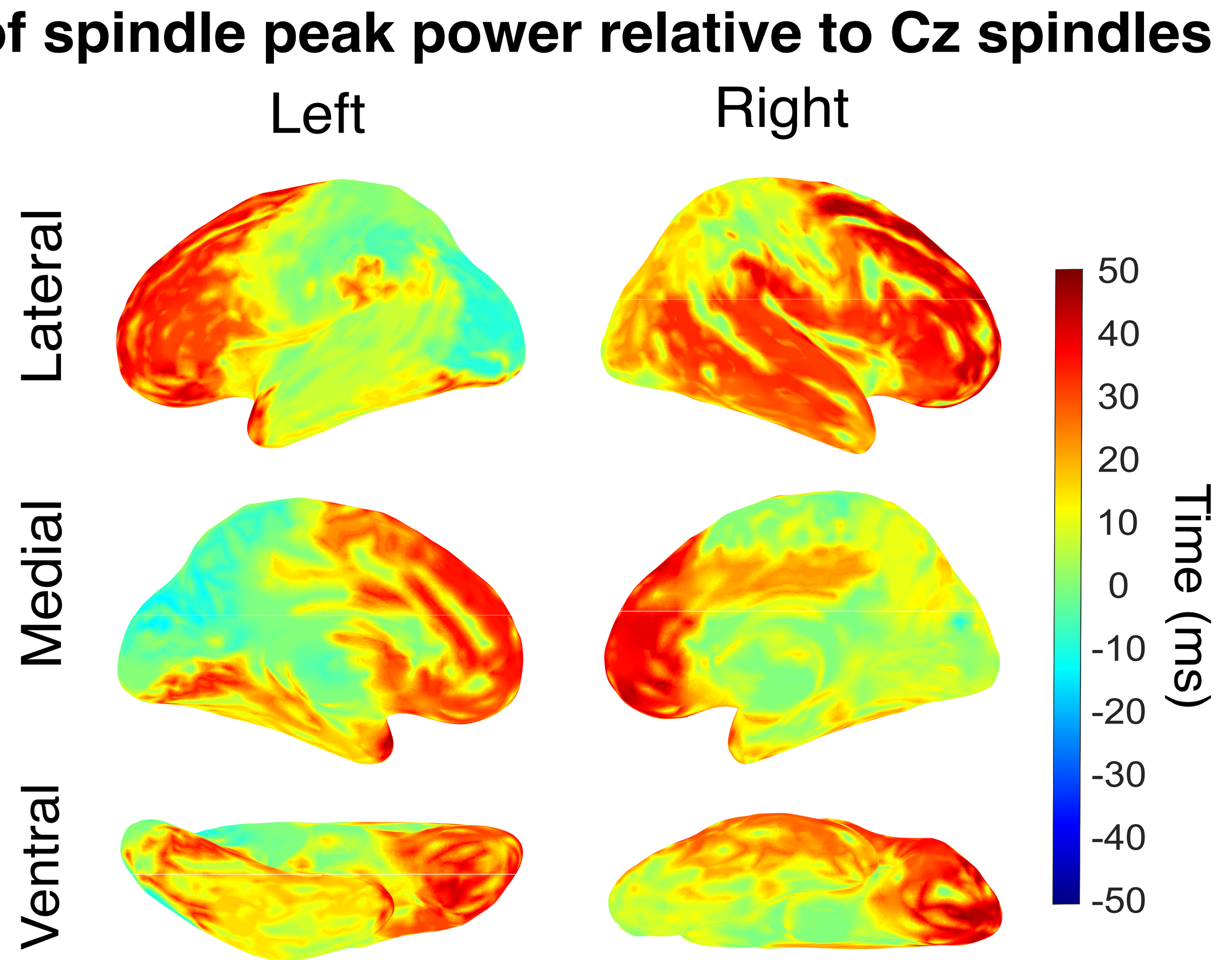
Results

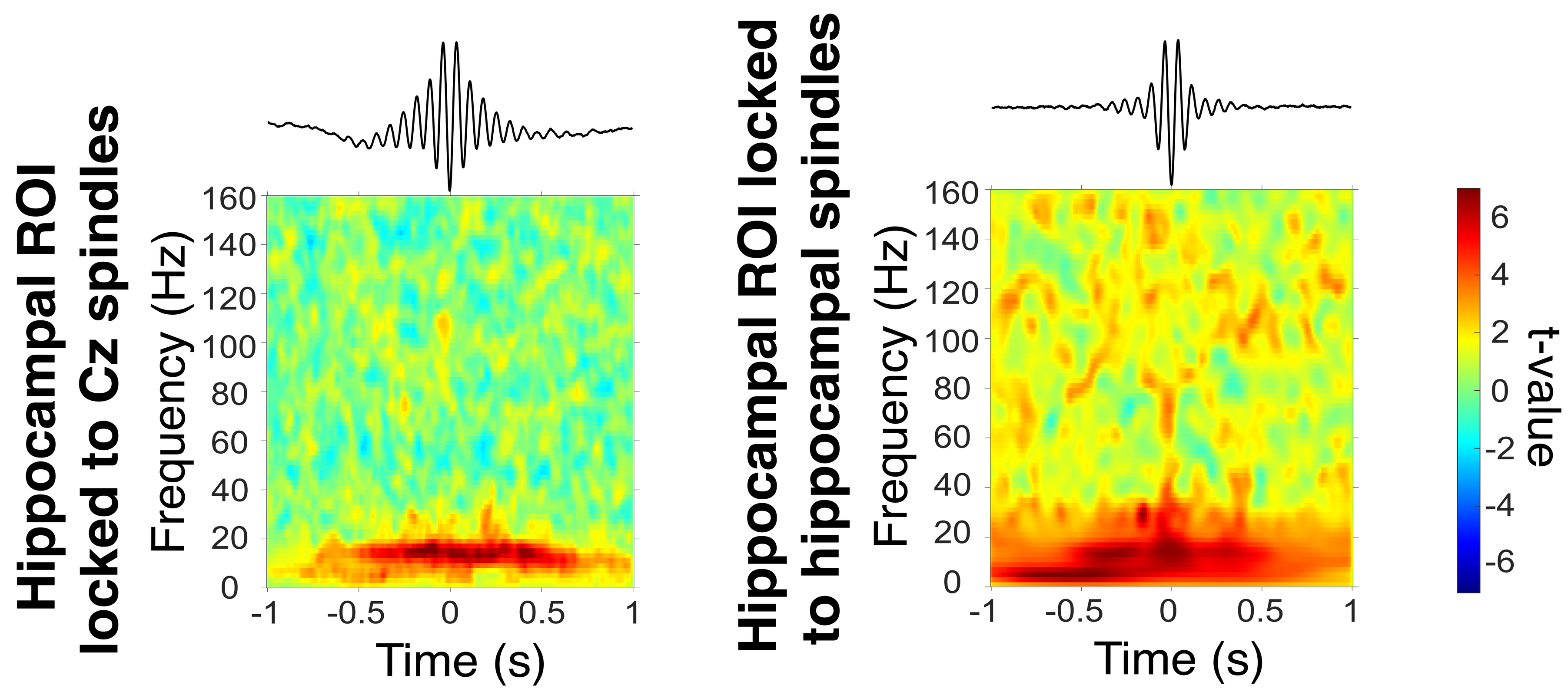
Source localisation reveals spatiotemporal distribution of spindle power during spindles detected @ Cz

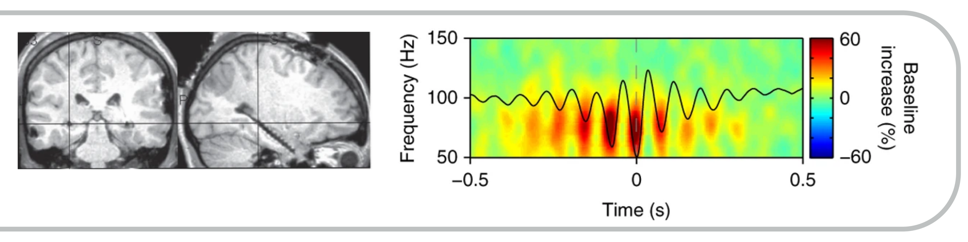


p < .05 (corrected)

Time of spindle peak power relative to Cz spindles (ms)







Previous iEEG study[3] showed nesting of ripple power within spindle troughs

Conclusions

- Source localisation revealed that spindles originate in the precuneus, parietal cortex, and thalamus, spreading to the temporal, orbitofrontal, and anterior cingulate cortices.
- We explored the feasibility of using source localisation to capture hippocampal ripples during spindles, but results remain inconclusive.

References

1. Andrillon, T., Nir, Y., Staba, R. J., Ferrarelli, F., Cirelli, C., Tononi, G., & Fried, I. (2011). Journal of Neuroscience, 31(49), 17821-17834.
2. Staresina, B. P., Bergmann, T. O., Bonnefond, M., Van Der Meij, R., Jensen, O., Deuker, L., ... & Fell, J. (2015) Nature neuroscience 18.11: 1679-1686
3. Ngo HV, Fell J, Staresina B. (2020) eLife. 9:e57011. doi:10.7554/eLife.57011.

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