Hippocampal-thalamo-cortical coupling between ripples and spindles during NREM sleep in human: a SEEG study

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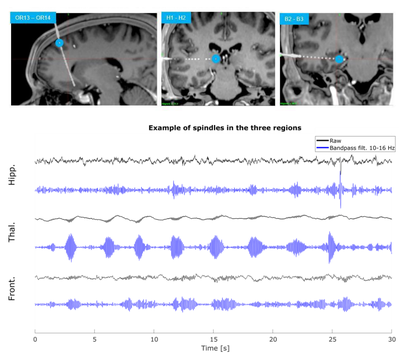
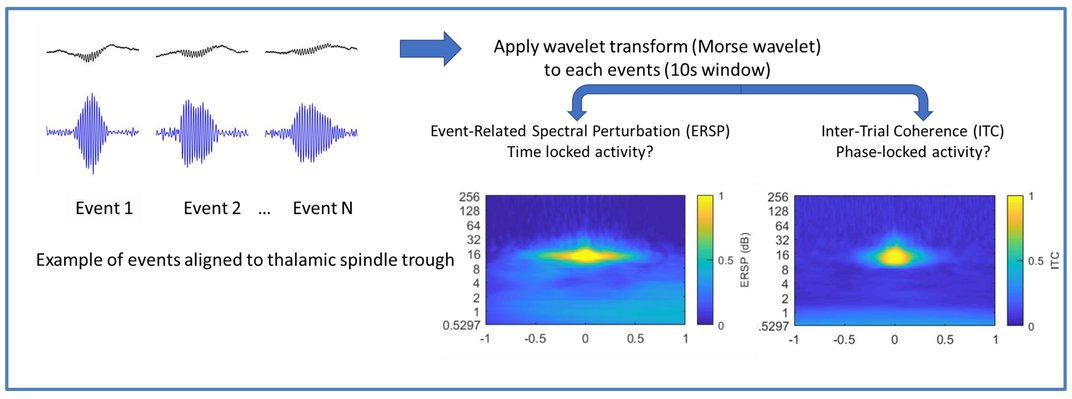
INTRODUCTION

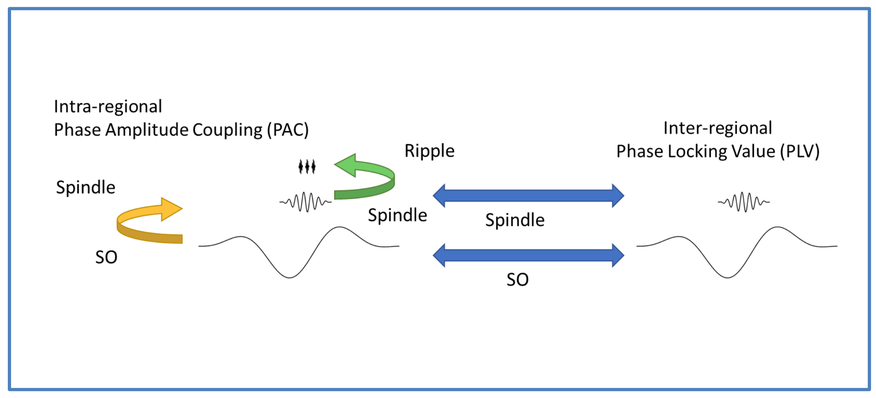
According to the Active System Consolidation Model, information is progressively transferred from hippocampus to neocortex during NREM sleep. This hippocampal-neocortical dialogue is mediated by the coupling between cortical slow oscillations (SO), thalamo-cortical spindles and hippocampal ripples. Few studies have investigated this coupling in humans. Using intracranial recordings, we aim to study the interaction of these oscillations between and within the hippocampus, thalamus, and neocortex.

METHOD

We included 12 patients who underwent intracranial recording for presurgical investigation of drug-resistant epilepsy. Inclusion criteria were: 1) electrode implantation including ipsilateral hippocampus, thalamus and middle frontal gyrus, 2) recording of NREM sleep and 3) few epileptic spikes (<15 spikes/min). We automatically detected spindles, ripples and spikes in all three regions (Delphos, Roehri et al, 2016). Spindle detection was visually corrected by two electrophysiologists in order to remove epileptiform spindle-like activities. We computed the Event-Related Spectral Perturbation (ERSP) and Inter-trial coherence (ITC), each within and between regions triggered on either spindles or ripples. Phase-locking value (PLV) analysis was used to study inter-regional coupling. Group-level statistics were corrected with FDR. Rayleigh test was used for the preferred phase of the PAC/PLV procedure.



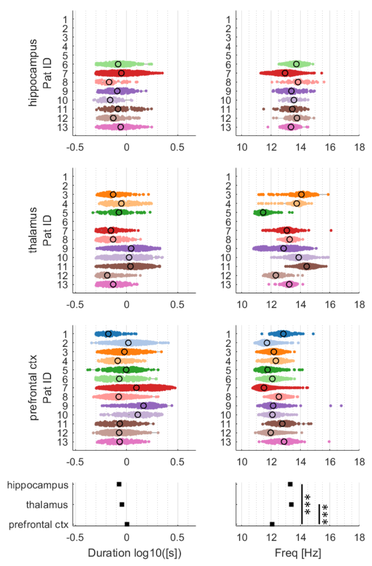


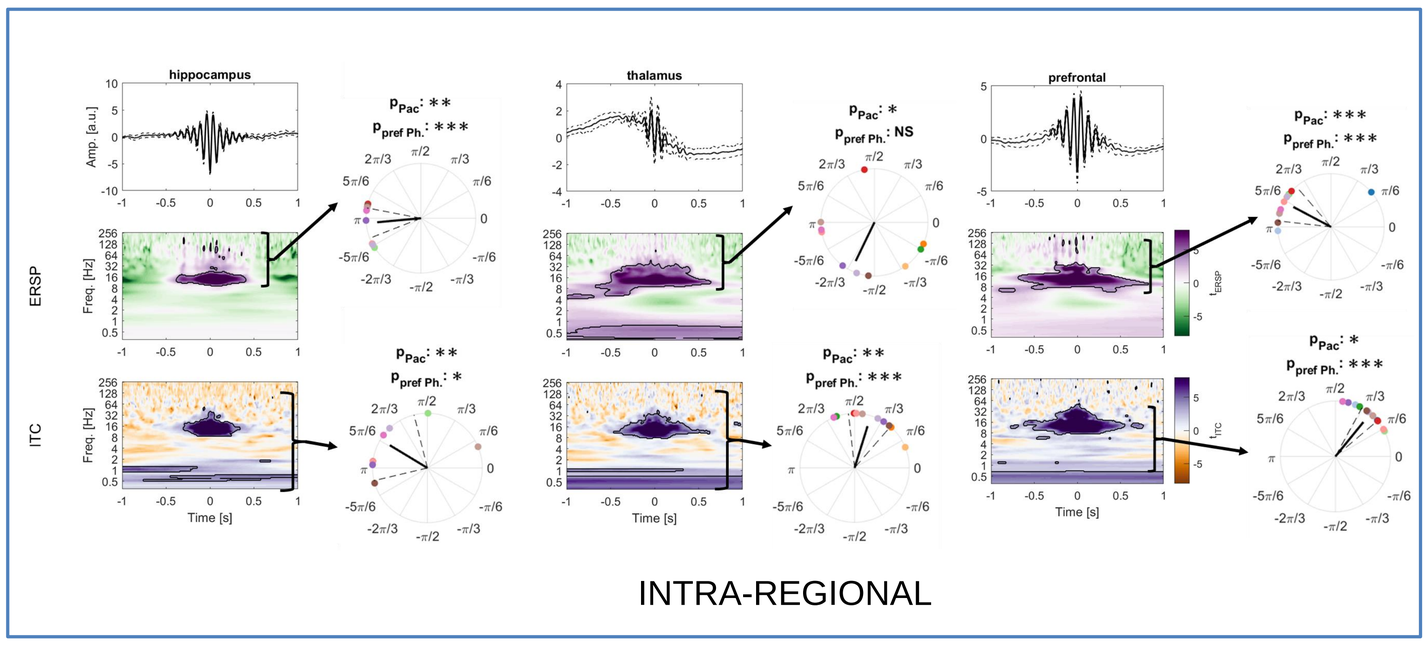


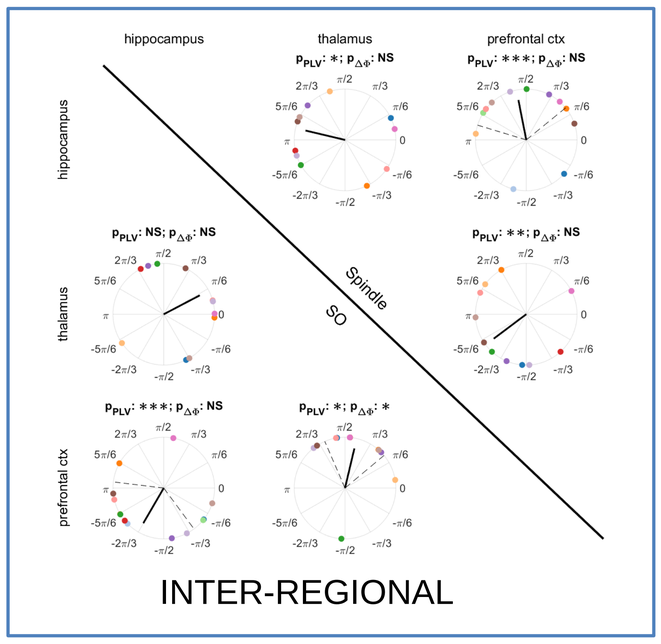
RESULTS

We found no difference in spindle duration (about 0.8s) between the three regions. Prefrontal spindles are slower than those in the thalamus and hippocampus (12Hz vs 13.5Hz) with a high variability in the thalamus.

Intra-regional spindle-aligned analysis:The ERSP showed, in all three regions, increased power in the ripple band during the spindle troughs when triggered on the local spindle trough. ITC revealed a local phase-locking in slow oscillations (below 1 Hz) during spindles in each region. PAC was significant between spindles and ripples, and between spindles and slow oscillations in the three regions. Inter-regional analysis: PLV between spindles were significant between the three regions, whereas PLV between slow oscillations were significant between the hippocampus and the prefrontal cortex, and between the thalamus and the prefrontal cortex, but not between the thalamus and the hippocampus.





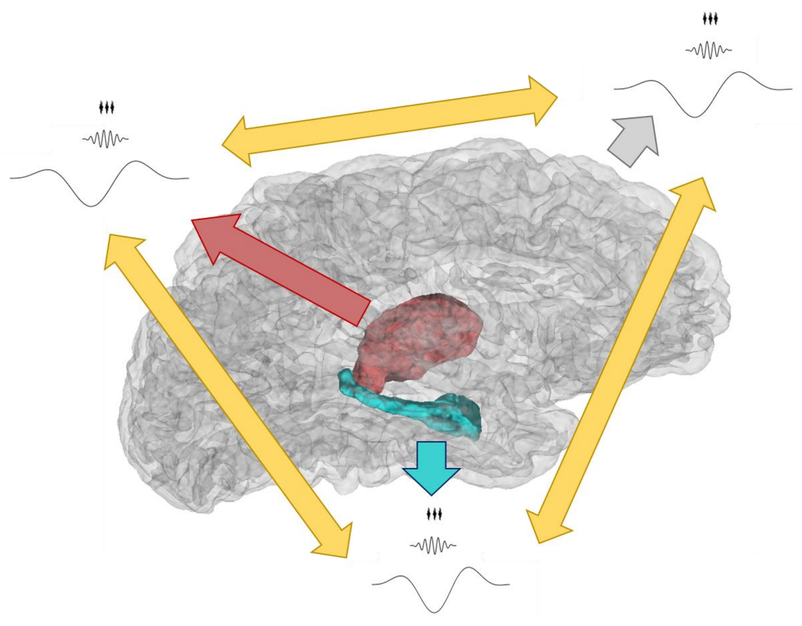


CONCLUSION

Our results show an intra-regional SO-spindle-ripple coupling in each region (prefrontal, hippocampus, and thalamus).

They also show an inter-regional coupling between i) slow oscillations and ii) spindles.

This intra-regional and inter-regional coupling may be a key mechanism of some physiological functions occurring during NREM sleep such as memory consolidation.



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