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Coupling of sleep spindles with respiration in the human sleep

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INTRODUCTION

Coupling of sleep spindles with cortical slow waves and hippocampus sharp-waves ripples is crucial for sleep-related memory consolidation.[a] Recent literature evidenced that **nasal respiration modulates neural activity in large-scale brain networks in humans at rest.[b] In rodents, this respiratory drive strongly varies according to vigilance states**. [c,d] However, no study has examined whether sleep oscillations are respiration-modulated in humans. In this work, we **investigated the influence of breathing on sleep spindles during non-rapid-eye-movement sleep stage 2 (N2) in humans.**

METHOD

Full night polysomnography of **twenty healthy participants** were analysed. **Spindles and slow waves** were automatically detected during N2 in all (N=11) EEG channels. Fast and slow spindles were separated through a frequency threshold manually set for each participant according to the bimodal distribution of their frequencies The **respiratory cycle detection** was performed using nasal pressure signal, and timestamps were converted into phase angles according to the relative time of occurrence during their corresponding breathing cycle (0° = onset of inspiration). **Spindle-related sigma power as well as spindle and slow waves events were analysed according to the respiratory phase.** Circular statistics were computed on angles provided by spindle onsets and slow-wave negative peaks. The non-uniformity of the distribution of angles as a function of the respiratory phase was assessed using the Rayleigh test.

RESULTS

We analysed 230 ± 31 (mean ± SD) min of N2 epochs per participant. Considering all channels, 5543 ± 2739 spindles were detected per participant (density = 2.2 ± 1.4 spindles/minute/channel/participant, mean duration = 0.88 ± 0.30 s, mean frequency = 13.4 ± 0.7 Hz). A total of 2834 ± 1353 slow waves were detected per participant (mean duration = 1.25 ± 0.29 s, mean frequency = 0.84 ± 0.19 Hz, negative-to-positive peak mean amplitude of 127 ± 49 μV). Participants respiration cycles lasted on average 3.77 ± 0.45 s corresponding to 1,57 ± 0.18 s of inspiration and 2.19 ± 0.3 s of expiration.

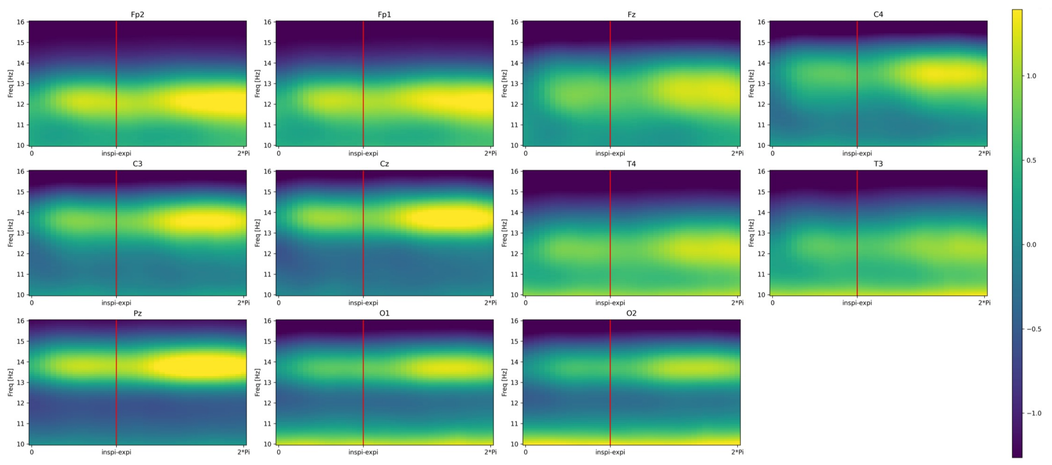
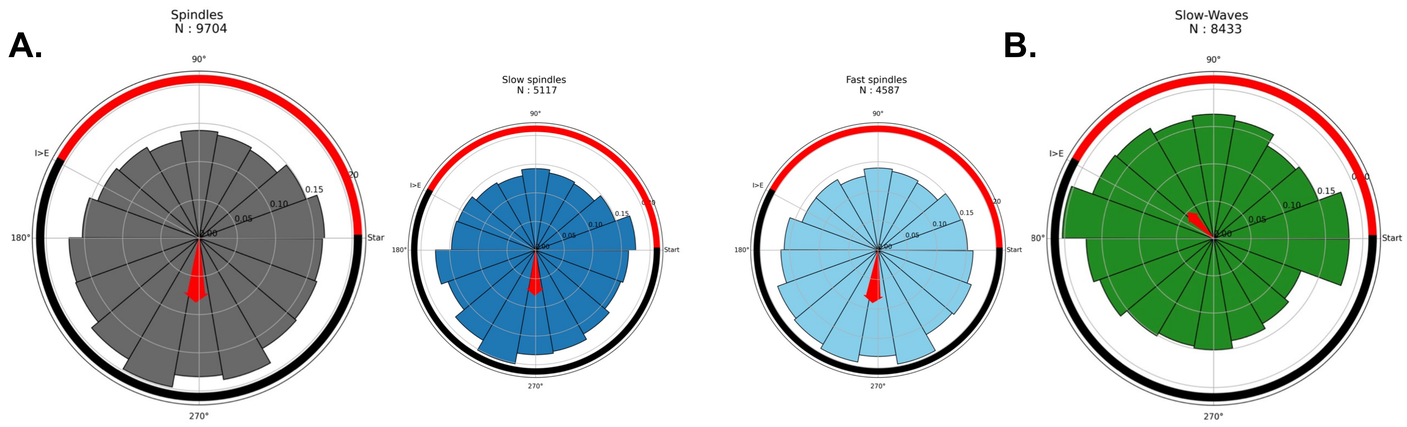


Figure 1. Mean respiratory phase-frequency map of the sigma band power (n=20 subjects).
Power matrix of each subject and channel has been z-scored before averaging. Note that spindle frequency is lower in anterior (Fp1, Fp2) than in posterior (C3, C4, Cz, Pz) channels.
Sigma power is higher during the expiratory phase. Respiration phase is expressed in radians from 0 to 2Pi, beginning from inspiration and ending before the next inspiration. Red vertical line shows the transition point between inspiration and expiration.

We found a **significant coupling between both slow and fast spindles and the respiration cycle in almost all channels, with enhanced sigma activity (Figure 1) and probability of spindles occurrence (Figure 2) during the middle part of the expiration phase** (mean vector length 0.084 and angular value 267° in Fz, p<0.001). A different coupling was observed for the slow waves which were rather distributed around the two transitions of respiration phase with a main peak at the inspiration-to-expiration transition (mean vector length 0.049 and angular value 135° in Fz, p<0.001) **(Figure 2)** .

Figure 2. Spindle (A) and slow waves (B) events occurrence according to respiration phase (20 subjects)
Spindle onsets and slow-wave negative peaks were considered as timing events. These events were labelled with the phase angle of occurrence according to breathing cycle and distributed in 18 equal phase bins of respiration (20° per bin). Inspiration and expiration phases are indicated by the red and black lines respectively. A red arrow indicates the mean angular direction, and its length depends on the resultant mean vector length that is represented on the circular ticks



CONCLUSION

Our findings suggest that breathing cycle influences the dynamics of brain activity during non-rapid-eye-movement sleep. This body-brain coupling may enable sleep spindles to synchronize with other sleep oscillations and facilitate information transfer between distributed brain networks, thus playing a role in sleep-related cognitive functions. [e]

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