Development of the brain default mode network from wakefulness into slow wave sleep

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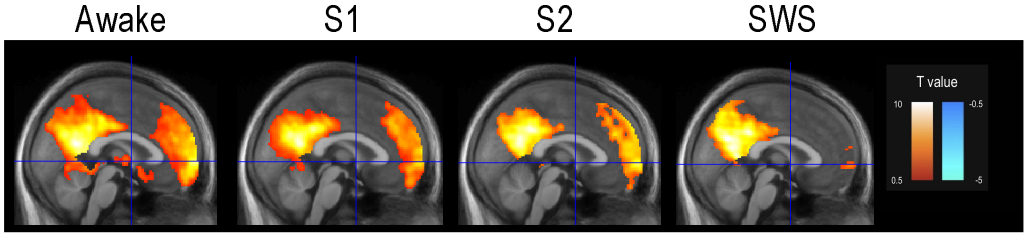
Introduction
During wakefulness the brain's default mode network (DMN) is engaged in internally directed awareness, while its anticorrelated network has been associated with externally directed awareness[1]. Whether the DMN is preserved throughout sleep is of particular interest, as sleep is characterized both by reduced capacity to process external information and by reduced self-awareness. Vigilance associated changes of DMN integrity have to date only been studied in early light sleep[2].

Methods
Using fMRI/EEG recordings of 94 sleep epochs gained from 25 subjects we investigated vigilance related changes of the DMN during wakefulness and all non-REM sleep stages. These included 28, 24, 24 and 18 epochs of wakefulness, S1, S2 and Slow Wave Sleep (SWS), respectively. The DMN was automatically detected using ICA and selection criteria given by Greicius et al.[3] The Z-map of each epoch was forwarded to voxelwise analysis in atlas space using one-way analysis of variance. Areas of significantly decreased or increased contribution to the DMN during sleep (S1, S2 and SWS) as compared with wakefulness were determined by differential T-contrasts (wakefulness>sleep and wakefulness<sleep).

Results
Functional connectivity in the DMN revealed dynamic alterations throughout non-REM sleep in the posterior cingulate and retrosplenial cortices, anterior thalamus, and bilateral parahippocampal, inferior temporal and medial prefrontal/frontopolar cortices. Parietolateral anticorrelated activity retreated stepwise.

Discussion
Results provide first evidence that the DMN persists as a functional unit throughout all human non-REM sleep stages including slow wave sleep, yet with systematically changing regional contributions. Vigilance correlated decreases of the retrosplenial cortex and posterior cingulate contribution to the mid-posterior DMN node are highly plausible as different lines of evidence suggest the posterior cingulate, precuneal and retrosplenial cortices to constitute key nodes in a neural network of consciousness[4]. Early retraction from the DMN during S1 observed for the bilateral parahippocampal and right inferior temporal gyrus may represent a critical determinant for the degree of (para-)hippocampus connectivity to the DMN. The fact that episodic memory reports are more frequent in awakenings arising from sleep onset light sleep than from SWS[5] is an interesting parallel that may be hypothesized to be a behavioural correlate of our finding. Reduced coupling of frontal and parietal neuronal activity during sleep is a phenomenon similarly observed in neurophysiological recordings[6]. As vigilance and consciousness are closely correlated under physiological conditions, we postulate that coupling of the mPFC to the posterior DMN node is critical for vigilance and/or conscious cognitive processing.



Group statistical maps (p_{voxel}(FDR)<0.005, k>40) as obtained from 28, 24, 24 and 18 five-minute epochs of wakefulness, S1, S2 and SWS, respectively.

References:

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