

Watching the brain going to sleep: A dynamic ICA approach

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Introduction

Independent component analysis (ICA) has recently gained broad interest in the field of fMRI as the method allows for hypothesis-free analysis of functional imaging data. Resting state networks can reliably be detected using ICA. Today, most research focuses on the default mode network (DMN), comprising cerebral regions with increased activity during rest as compared to specific tasks, and assumed to be linked to intrinsic awareness¹⁻³. Using sleep as an example of transient changes in brain activation, we propose a new iterative ICA to follow changes in the DMN integrity over time.

Methods

We followed the evolution of the DMN over 26.7 min (800 fMR images) in two individuals by a recursive ICA approach. For this, ICA was first cycled 650 times throughout the entire recording using a sliding window covering 150 images (5 min) with steps of 2 seconds (i. e. one image); from each cycle five candidate components possibly representing the DMN were extracted. In a second cycle, a continuous DMN stream was semi-automatically identified by comparing the current DMN at time t to the five candidate components of the next cycle at time $t+1$. Similarity was quantified as sum of the absolute values of a Z-score difference map. The component with the lowest difference score was selected and served as template in the next cycle. The process was visually supervised and corrected manually in cases of ambiguous components to preserve maximal continuity. Frames are combined to an animated graphics showing the development of the network in short movies.

Results

Iterative ICA as applied on individual subjects reproduced our previous findings of altered DMN integrity during nonREM sleep: 1. The DMN was clearly represented among the resting state networks throughout all vigilance stages. 2. (para-) hippocampal contributions retreated within S1. 3. Positively correlated mPFC and frontopolar areas were more strongly represented during wakefulness but remained detectable throughout all sleep stages. 4. The posterior cingulate and inferior retrosplenial cortex of the mid-posterior DMN node decreased in strength. 5. Lateral parietal areas were largely stable across all sleep stages. 6. During S2, transient contributions of middle and superior temporal gyrus were found. 7. Contributions of the thalamus were fluctuating with stronger contributions during wakefulness and SWS than during S1 and S2. Results were congruent with independently obtained groups statistical maps in a larger sample per individual sleep stage.

Discussion

Iterative ICA in individual subjects allows for continuous monitoring of brain networks undergoing dynamical changes in their structural composition. Transient alterations in network integrity due to shifts in vigilance or experimental interventions like drug administration can be easily detected and visualized by the proposed method.

References

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