

BOLD fMRI Resting State Activity and the Network of Default Mode Brain Function

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Introduction:

A number of BOLD fMRI studies have reported on the presence of ongoing activity in functionally related areas in absence of stimuli [1, 2]. These patterns have shown a spatial organization that suggests functional significance. In addition, some of this activity resembles the topography of the so-called “default mode” network, a region that increases its activity in absence of goal directed behavior [3]. In this study we explore the role of resting state activity for brain function, specifically whether they subserve conscious and cognitive processes and support activity attributed to a default mode of brain function. For this purpose, we performed simultaneous BOLD fMRI and EEG during varying levels of consciousness, including awake rest and light sleep.

Methods:

Simultaneous EEG and fMRI data were collected during a 60 minute experiment. Respiratory and cardiac signal were also monitored. Subjects (n=11) were instructed to keep their eyes open for 1 minute and then close their eyes, relax, and go to sleep if possible. Ten minutes before the end of the session a verbal command was given instructing subjects to open the eyes, and a contrast reversing checkerboard was presented.

BOLD fMRI was collected on a 3T (GE) scanner equipped with a 16-channel coil (Nova Medical) (single shot EPI, TE: 43 ms, TR: 6 s, burst mode, 28 slices, 1.7x1.7x3 mm³, gap 0.5mm, 600 volumes). EEG was collected using 40 channels on a Synamps2/Maglink system and analyzed with Scan4.3 (Compumedics). Sleep was scored for each subject based on the EEG data in intervals of 30 seconds by a sleep expert (TB). MRI data were normalized, band-pass filter to 0.005-0.1Hz, and respiration envelope and cardiac frequency regressed out. For each subject the amplitude of the fluctuations was then computed during wake (W) and stage 1 and 2 sleep (S) conditions. This was done by calculating the standard deviation on a pixel-by-pixel basis. A pooled variance t-test was performed for these two conditions on those subjects that showed W and S periods longer than 2 minutes. To test the effect of sleep on connectivity, correlations within the ‘default-mode’ network were computed for S and W conditions using a seed voxel in precuneus (Talairach coordinate: -5,-49, 40) based on reported studies [3].

Results and Discussion:

Six subjects showed S or W stages of more than 2 consecutive minutes each. In these subjects, significant increases in BOLD fMRI fluctuations were observed bilaterally in visual cortex (calcarine sulcus, cuneus and lingual gyri) and precuneus while decreases were seen in medial frontal gyri. A more lateralized effect –on the left hemisphere- was observed in STG, Inferior frontal gyrus and supramarginal gyrus (see figure 1). Correlations with the seed voxel showed the ‘default-mode’ network both in wake and sleep conditions (see figure 2). Furthermore, the correlation level in the default mode network was significantly increased during sleep. In summary, most brain regions, including the hypothesized default mode network, increase their activity during stage 1 and 2 sleep, suggesting that it is not specific to conscious and cognitive processes, including monitoring of the environment. A potential role is homeostasis, possibly including synaptic plasticity [4, 5].

Conclusion:

Low frequency fluctuations are maintained (or increased) during early sleep, arguing against ongoing conscious activity as origin of the fluctuations.

References:

- [1] Biswal, MRM 1995 ;
- [2] Greicius, PNAS 2003;
- [3] Raichle, PNAS 2001;
- [4] Huber, Nature 2005;
- [5] Tononi, Brain Res.Bul 2003

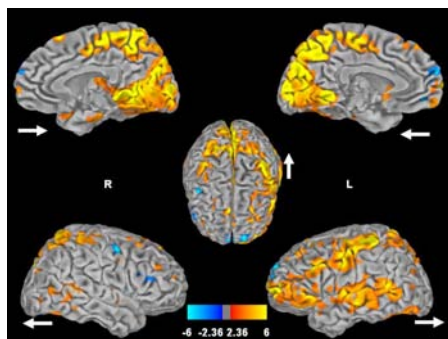


Figure 1: Comparison of the amplitude of fluctuations sleep vs wake for all the subjects. T values displayed.

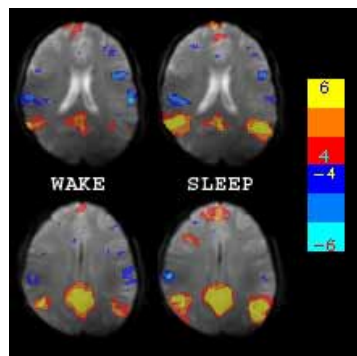


Figure 2: The ‘default-mode’ network during wake and sleep (stage 1-2). A correlation map was constructed for each subject, thresholded to $p < 0.05$, and combined across subjects. Scale indicates number of subjects where a particular voxel was significantly correlated with the seed. Positive and negative correlations included.