TEMPORAL DYNAMICS OF THE DEFAULT NETWORK: EVIDENCE FROM HIGH-TEMPORAL-RESOLUTION RESTING-STATE FMRI

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Introduction: Resting-state functional magnetic resonance imaging (R-fMRI) has become a powerful tool for the investigating of brain connectivity architecture[1]. Connectivity patterns are usually estimated based on the assumption that functional coupling between brain regions is highly dependent on static anatomical connectivity; therefore the coupling is relatively stable over time. However, neurophysiological evidence suggests that function networks could dynamically integrate to support both internally and externally oriented cognition. These transient interactions among brain regions may not be fully captured by the hemodynamic responses sampled at a low temporal resolution (usually TR=2~3s). A multiband echo-planar imaging (multiband-EPI) technique has recently been developed for acquiring fMRI data with a 4-8 fold increase of sampling rate compared to a conventional EPI sequence while keeping the same spatial resolution[2]. With the high temporal resolution (TR=645ms, voxel size 3x3x3 mm^3) R-fMRI data, the dynamic states of the brain networks may be better assessed.

Materials and method: The multiband-EPI-based mR-fMRI dataset used in this study was publicly available from the INDI (http://fcon_1000.projects.nitrc.org/indi/pro/eNKI_RS_TRT/FrontPage.html). Eleven healthy subjects (4 females, age 30.2±9.6 years) without obvious brain atrophy and significant head motion were included. All mR-fMRI data were scanned on a Magnetom Trio 3T (Siemens AG, Erlangen, Germany). For each subject, there were two mR-fMRI sessions on separate days (TR=645 ms, TE=30 ms, flip angle=60°, 40 slices, multiband accelerate factor=4, FOV=222×222 mm^2, voxel size=3×3×3 mm^3, 900 frames each session).

The pre-processing steps include: 1) removing the first 10 frames 2) slice timing correction 3) head motion correction 4) spatial smoothing with Gaussian kernel, 6mm full width half maximum 5) removing the linear trend and regressing out 9 covariance parameters including global signal, white-matter signal, ventricle signal and 6 head motion parameters 6) projecting the volumetric data from each individual's natural space to the standard surface space (fsaverage) using Freesurfer pipeline.

For each subject, we extracted the pre-processed data from the DMN-based on a functional network template derived from 1000 normal subjects[3]. For each time point, a vector was constructed based on signal extracted from each vertex within the DMN. Then all vectors in each session were clustered into several groups using k-means algorithm. The number of groups was optimized according to the Davis-Bouldin index. In each group of vectors, the t-statistic value of each vertex was calculated across all time points to create a temporal state of DMN. The t-values with p>0.01 were set to 0.

Results: The brain images were clustered into 10 states (Fig. 1). These clusters could be largely replicated in the second scanning session. In some states, sub-divisions of the DMN showed opposite activation pattern, and this spatial distribution could be flipped in other states. For example, in MS7, the posterior cingulated cortex ventral medial prefrontal cortex, inferior parietal lobule and prefrontal cortex showed higher activity than the dorsal medial prefrontal cortex and lateral prefrontal area. The opposite pattern was found in MS8.

The dwelling time of every state was accessed over all subjects (histograms of the two sessions were shown in Fig.2a and Fig.2b, respectively). Most states last for about 1~3 TRs (645 ~ 2580 ms) but some states could last for as long as over 20 TRs,

Conclusions: The multiband/slice-accelerated EPI can provide high temporal or spatial resolution. With this new technology, the temporal dynamics within the DMN and the behavior of its subsystems can be observed. This technology shows great potential in investigating the dynamic interaction between brain regions.

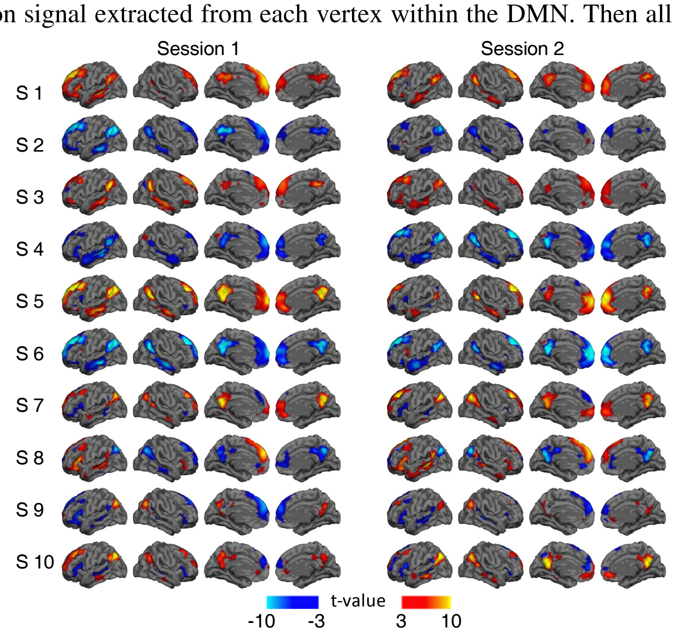

Figure 1. DMN topographies of each state obtained from the two mR-fMRI sessions of one patient (ID: 3315657).

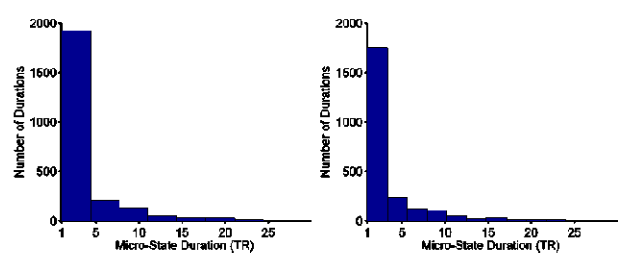

Figure 2. Histograms of the states' time duration. (a) session 1 (b) session 2

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