Can resting state measurements supplement task based fMRI for presurgical motor cortex mapping? A test-retest reliability study

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Introduction:

BOLD fMRI experiments during which the subject performs a specific task have become an increasingly valuable tool for presurgical mapping of areas of functional cortex in, for example, tumor- and epilepsy patients. This method requires active participation of the patient which can be difficult to achieve, for example, in children or in patients showing severe disease-related impairment. Therefore, the possibility of using resting state data would be of great value and mapping of the intrinsic motor network has recently been proposed as a promising alternative to task based mapping of motor functions (1-3). An important aspect in addition to mapping of relevant cortical areas is the robustness of the method. The aim of this study was accordingly to evaluate the test-retest reliability in detecting the intrinsic motor network from resting state data as compared to activation maps based on a bilateral finger tapping task. This was accomplished by use of a method proposed by Genovese et al. (4) and Noll et al. (5) for quantifying the reliability of the activation maps, yielding global measures of the probability of errors in the classification of voxels as active or inactive.

Subjects and methods:

The study was conducted using a Philips 3T Achieva MR system equipped with an 8 channel head coil. Functional data were acquired using a gradient-echo EPI pulse sequence. Five volunteers participated and each experiment consisted of five successive activation (task) sessions (fingertapping/fixation) interleaved with five resting state sessions (eyes closed). For the activation sessions a block paradigm was used with a block length of 30 s for both the fingertapping and fixation condition. Scan parameters for the activation sessions were TR/TE = 3000/30 ms, 3 mm isotropic voxels, 36 slices and 100 dynamic scans. For the resting state sessions, the scan parameters were TR/TE = 2000/30ms, 3 mm isotropic voxels, 33 slices and 300 dynamic scans. Prior to analysis, the data were realigned, slice time corrected and smoothed using a Gaussian kernel with FWHM = 6mm using SPM5 [http://www.fil.ion.ucl.ac.uk/spm/]. Data from one subject was excluded from further analysis due to excessive motion.

Data from the activation sessions were analyzed using SPM5, whereas the resting state data were analyzed using the Group ICA of fMRI Toolbox (GIFT) [http://icatb.sourceforge.net/groupica.htm]. The resulting statistical maps were thresholded at $p = 0.001$ (uncorrected for multiple comparisons) and at $z = 1$ for the activation and resting state data, respectively. In the resting state results, the motor network component was independently selected by two observers. In order to facilitate a voxelwise comparison between sessions, the thresholded statistical maps for each subject and session type (activation and rest data) were realigned. They were then used to create classification maps where each voxel was classified as active/inactive. Raw reliability maps were created from the classification maps in which each voxel in the investigated volume was represented by the number of replications (out of five possible) for which that particular voxel was classified as active. These maps served as input to a test-retest reliability estimate of the hit rate p_A (true positives), the false alarm rate p_I (false positives) and the proportion of truly activated voxels within the investigated volume λ (4,5).

Results:

Figure 1 shows individual parameter estimates for activation and resting state sessions (four subjects). Mean and standard deviations are summarized in Table 1. The true hit rate p_A was lower for resting state data and the false alarm rate p_I was generally higher. A larger fraction of the volume was typically classified as active from resting state data (higher λ), i.e. the intrinsic motor network encompasses a larger volume than the volume engaged by the bilateral fingertapping task. Figure 2 shows the raw reliability maps in an example slice representing the hand motor area for each subject. The spatial distributions of activated voxels determined from resting state data and activation (task) data appear similar, but large differences between subjects with respect to the reproducibility were observed. For subject 3, for example, a large number of voxels only showed activation in 3 out of 5 replications for the resting state data and almost no voxels were active in 5 out of 5 replications. For subject 1 on the other hand, the size and location of the area which was classified as active in 5 out of 5 replications was comparable to what was seen for the task sessions.

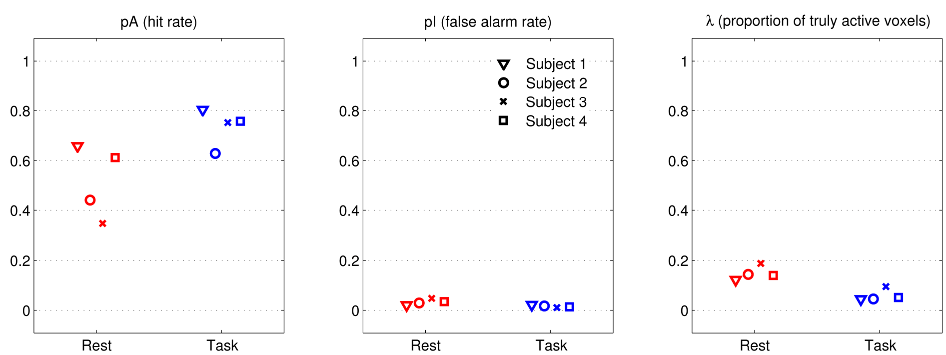

Fig.1: Reliability parameter estimates for four subjects

Table 1: Mean and standard deviations of parameter estimates

	p_A (mean/std)	p_I (mean/std)	λ (mean/std)
Task	0.736/ 0.075	0.016/ 0.005	0.059/ 0.024
Rest	0.515/ 0.145	0.033/ 0.011	0.148/ 0.028

Discussion:

The test-retest reliability of resting state data analyzed using ICA was found to be comparable to what is seen for a typical task based fMRI-experiment. However, large differences between subjects were also seen. This may have several causes such as difficulties to select the relevant ICA component or to set the threshold. ICA can be implemented in different ways and other types of analyses (e.g., seed based) could possibly render improved reliability. It is concluded that careful refinement in the acquisition and analysis of resting state data is needed to obtain a robust method for presurgical mapping of motor functions and that a method yielding quantitative measures of reliability, as shown in this study, appears to be useful.

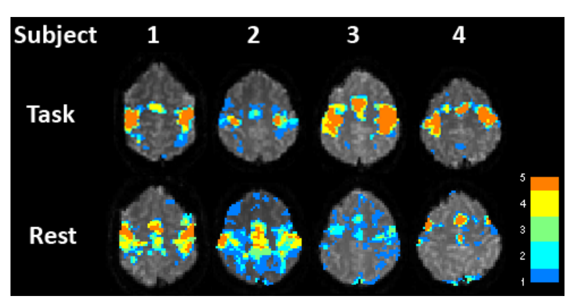

Fig.2: Examples of reliability maps for task and rest data

References:

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2. Kokkonen et al., MRI, 2009
3. Weibull et al., ISMRM 2008
4. Genovese et al., MRM 38:497-507; 1997
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