Spatial normalization of fMRI results using study-based EPI and T1-weighted brain templates

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Introduction

Functional MRI (fMRI) has become a widely used method for localizing neuronal activities of the human brain. Spatial normalization to a reference coordinate space, e.g. using the Montreal Neurological Institute (MNI) brain template, is an essential step while analyzing fMRI data that involves multiple subjects (1). Individual impression of the spatial normalization can result in lessen fMRI sensitivity and/or localization errors of the activation foci in group analysis (2) (3). This can be caused by the morphological differences between the subject group and the template, and the inter-subject variations in brain structures. We have previously demonstrated that using a study-based (SB) template in the spatial normalization of echo-planar images (EPI) improves the sensitivity of group comparison (4). This study aimed to extend the SB template method to another fMRI spatial normalization approach that uses T1-weighted images and template.

Methods

Sixteen right-handed healthy volunteers (8 males) participated in this study. Functional MRI experiments were performed on a 1.5T MRI scanner (Gyroscan Intera, Philips). Subjects performed word generation task (generating as many words in given category such as "fruit" as possible with slight articulation), and motor task (performing right hand grasp-release at the frequency of 0.5 Hz.) consist of ON/OFF in 4 blocks. A single-shot T2*-weighted gradient-echo planar imaging (EPI) sequence was used with slice thickness = 5mm, TR/TE/θ = 3000ms/60ms/90°, FOV = 211 x 211mm and acquisition matrix = 64 x 64, covering whole brain with 24 contiguous axial slices. The anatomical MRI was acquired using a 3D T1-weighted gradient-echo pulse sequences with1x1x1mm^3. Two SB templates were used: (1) SB EPI (SB_{EPI}) template: created by spatially normalizing the first one EPI images in each subject to the MNI EPI (MNI_{EPI}) template provided in SPM2, and then smoothed the total 16 normalized EPI images with an 8-mm FWHM isotropic Gaussian kernel. Finally, the SB EPI template was composed by averaging these smoothed EPI images. (2) SB T1-weighted (SB_{T1}) template: created by spatially normalizing the T1-weighted images in each subject to the standard MNI T1 (MNI_{T1}) template smoothed and then averaged. The fMRI data pre-processing included realigned, spatially normalization and 8-mm smoothed. For spatial normalization of SB_{EPI}, SPM computes a transformation matrix between SB_{EPI} template and individual EPI images of each subject, and then applied transformation onto EPI images (SB_{EPI} method). For SB_{T1} template, SPM computes a transformation matrix between SB_{T1} template and the individual T1-weighted images that prior coregistrated to individual EPI images, and applied the transformation onto EPI images (SB_{T1} method). Image preprocessing and statistical analysis were performed using SPM2 software. Results were considered significant at a threshold of $p < 0.05$, corrected for multiple comparisons.

Results

Figure 1 and 4 demonstrated the activated volumes detected in SB_{EPI} and MNI_{EPI} template conditions (functional map were superimposed on SB_{EPI} images), SB_{T1} and MNI_{T1} template conditions (superimposed on SB_{T1} images) respectively. The results showed that the significantly activated volumes in SB template both in EPI and T1-weighted methods are generally greater than those from MNI template in each specific volume of interests in both task. In addition, the mean t-value of local maxima obtained by SB_{EPI} and SB_{T1} template increased 3% and 34%, respectively (fig. 2 and 3).

Discussion

The results obtained in this experiment confirmed our speculation that SB template efficiently reduced inter-subject variations than MNI template in both EPI and T1-weighted methods across all subjects. The proposed SB template with well-defined group characteristic makes it particularly useful for the group data that were expected large brain anatomical difference, such as aging or clinical patients. In addition, the SB method approach could reduce the number of subjects required for group analysis, provide the framework for more accurate functional localization, and allow researchers to better interpret results in clinical patients.

References

1. Friston, K.J. et al., *NeuroImage* 1999. 2. Brett, M. et al., *Nat Rev Neurosci*. 2002.
3. Argall, B.D. et al., *Hum Brain Mapp*. 2006. 4. Huang, C.M., et al., *NeuroImage* 2006 31(S1): S1926.

Fig. 1 Fig. 2 Fig.3 Fig. 4