Scanner Differences In the Smoothness of fMRI Images: Implications for Multi-Center Studies

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Introduction:

The FIRST-BIRN (FBIRN) project is composed of a team of 11 universities studying brain dysfunction with fMRI in schizophrenia. Although fMRI techniques are widely used, comparing data across laboratories has been a challenge due to scanner hardware and software differences. One goal of the FBIRN project is to characterize the quality and sensitivity of fMRI data collected at the 11 sites and to study the impact of possible inter-site differences on pooled group studies. Toward this end, we have evaluated the inherent smoothness (spatial correlation) of the fMRI images. Below, we report substantial, highly significant inter-site differences of smoothness and discuss these in relation to inter-site differences in fMRI sensitivity using a simple motor/visual task.

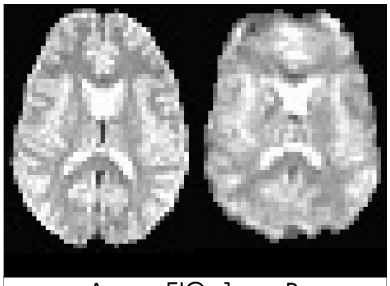


FIG. 1

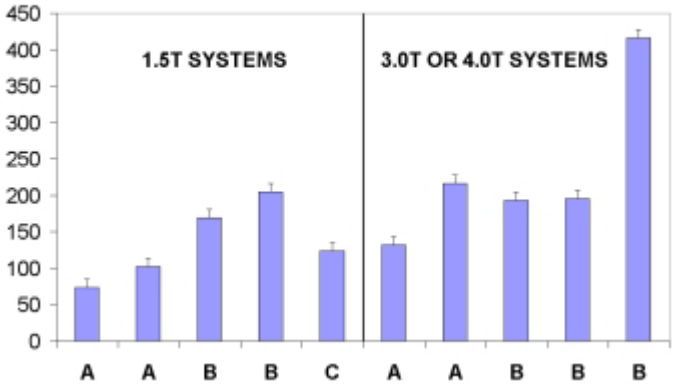
Methods:

The ten FBIRN sites reported on here have a variety of MRI scanners (5 GE, 4 Siemens, 1 Picker) and field strengths (6@1.5T, 3@3.0T, 1@4.0T). Six use a standard single-shot EPI sequence, three use a spiral sequence, and one uses a double echo single-shot EPI sequence.

Five volunteers traveled to 10 sites and had identical fMRI studies performed. All the sites used a 3000 msec TR with 35 axial slices. The TE for 1.5T was 40 msec and for 3T was 30 msec. The (nominal) voxel size was 3.44 X 3.44 X 4.00 mm.

The smoothness was measured on unaltered images (no additional smoothing was applied prior to this step) with the AFNI program 3dFWHM. It measures the extent of spatial correlation corresponding to each axis as a Gaussian FWHM (Forman et al., 1995; Xiong et al., 1995). We calculated an effective voxel volume (EVV) by multiplying FWHM_x * FWHM_y * FWHM_z , as measured by the 3dFWHM program and compared the sites on this measure.

FIG 2: Effective Voxel Volume by Site



The sensorimotor task is described in a companion abstract by the same first author. In the present study, only the bilateral finger tapping activation of motor cortex was evaluated. A block design was used. The square wave was convolved with several hemodynamic response functions. FMRI time series analysis was performed with AFNI using conventional approaches.

Sensitivity to the BOLD effect in motor cortex was assessed by varying the threshold (Pearson r) to optimize the match of activation patterns across sites within a subject (see companion abstract by the same first author). The thresholds were linearized prior to statistical analysis.

Statistical analysis assessing inter-site effects were performed with Mixed Model ANOVA (SAS Proc Mixed) with subject as a random effect and site and field strength as fixed effects.

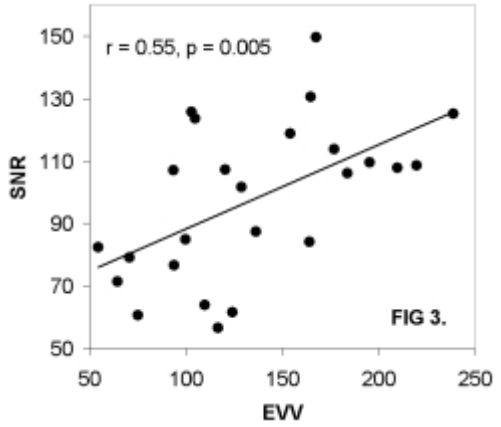


FIG 3.

Results:

There were highly significant inter-site differences in apparent smoothness (Figure 1, A and B – same subject, different 1.5T scanners) and the EVV across sites (Figure 2, "A", "B" and "C" index manufacturers), even between 1.5T scanners. The F value for site was 64.4 (df = 9, 40, $p < 0.0001$). After removal of the outlier (far right), F was 18.8 ($p < 0.001$). 3.0T systems had significantly higher EVVs than 1.5T systems (F=12.1, df = 1,39, $p < 0.0013$). Within 1.5T scanners, the site effect was also statistically significant (F=39.1, $p < 0.0001$). The measured signal-to-noise ratio (SNR) of 1.5 T data appeared to increase linearly with smoothness (Fig. 3). There was also a significant relationship between fMRI sensitivity and EVV (Fig. 4).

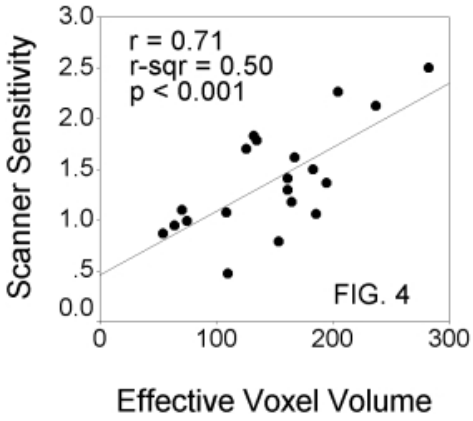


FIG. 4

Discussion:

There are important "site" differences in smoothness of raw FMRI images from the 10 fBIRN sites. These differences may be related to imaging method (EPI vs. spiral), gradient performance, image reconstruction method, reconstruction filter settings, and field strength. These differences in smoothness may affect the SNR of the fMRI data and contrast-to-noise ratio from of activation maps from the different sites and will have to be taken into account in order maximize cross-site comparability of fMRI results (Parrish et al., 2000).

References: Forman SD et al. Magn Reson Med, 33:636-47, 1995; Parrish et al. Magn Reson Med., 44:925-32, 2000; Xiong J et al. Human Brain Mapping, 3: 287-301,2000.