Scanner Quality Assurance for Longitudinal or Multicenter fMRI Studies

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Introduction The FIRST (Functional Imaging Research Schizophrenia Testbed) Biomedical Informatics Research Network (fBIRN) program is the first-ever large scale, multi-center fMRI study of schizophrenia (http://www.nbirn.net). The fBIRN project will pool fMRI data from each of the 11 participating sites to enable the acquisition of a large and diverse study population in a modest time period. To maintain scanner stability, periodic quality assurance (QA) scans are performed regularly at each of the sites. This report compares measures of image stability across 10 of the participating scanners (comprising 5 1.5T, 4 3.0T, 1 4.0T; Siemens, GE, Picker).

Methods For longitudinal fMRI studies, it is important to periodically monitor scanner performance to assure that stability, geometric accuracy, signal to noise ratio (SNR) and other characteristics remain accurate and consistent. Constancy is even more important when data from multiple scanners are being compared or combined both initially and over extended periods of time, such as in the fBIRN project. QA methods developed at Stanford University were adapted for fBIRN. The most important of these examines scanner stability but also derives SNR and is presented here.

Data Acquisition The weekly stability test uses the fBIRN fMRI scan protocol with a 17 cm diameter agar phantom (35 axial, 4 mm contiguous slices, 22 cm FOV, 64x64 matrix, TE 30ms/40ms (3T-4T/1.5T), TR 3000ms, 200 time frames, 10 minute scan time, EPI or spiral). The agarose gel phantom was doped with NaCl to present RF loading typical of a head and was preferred over water to avoid swirling artifacts. *Analysis* Only timeseries data from the central slice (18) is used for analysis. Image intensities are measured for each time frame in the series using a 20x20 ROI centered in the image. The RMS fractional fluctuation is calculated after quadratic detrending, and drift is obtained from extrema of the trend line (Fig. 1, top). The Fourier spectrum is calculated (Fig. 1, middle). A 'Weisskoff analysis' (1) is performed using ROIs with sizes varying from 1x1 to 20x20, as shown in Fig. 1, bottom. In this analysis, the standard deviation (STD) should decrease as √(number of voxels in ROI) if the noise is uncorrelated. System instabilities from RF or gradient sources tend to cause low spatial-frequency image fluctuations, which are manifested as cross-correlation between voxels. This in turn causes STD to depart from linear dependence on 1/(ROI width) and hit a floor as the ROI size becomes larger, as shown in Fig. 1 (cf. with dashed line). Note that the top plot is performed with the largest ROI size, intentionally picked to represent the system limited (rather than SNR limited) noise. In addition, the signal to fluctuation noise ratio (SFNR) is measured by an ROI in a map made from (timeseries mean image)/(timeseries standard deviation image). Finally, the SNR is calculated from noise measured with an ROI in the noise image obtained by subtracting the average of the even time frames and average of the odd time frames and dividing into the mean signal.

Results Figure 2 shows stability measures from a weekly scan set obtained at initiation of the fBIRN project, demonstrating substantial variability across the 10 scanners. SNR (not shown) varied from 65 to 220 and was correlated with field strength ($R^2 = 0.58$) but not stability ($R^2 < .000003$). As a result of these data, service of several of the fBIRN scanners was initiated in order to increase the stability and SNR. On-going scans have shown improvement after service.

Conclusions Periodic QA methods are important for sites performing longitudinal or multicenter fMRI studies, as in the fBIRN project. Timeseries stability and SNR are particularly critical, and deviations from normative values can indicate that system service is required.

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1. Weisskoff RM. Magnetic Resonance in Medicine 1996;36(4):643-645.

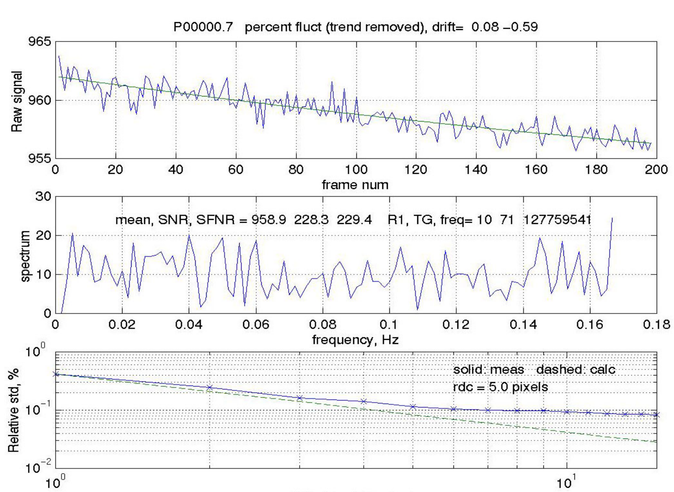

Fig. 1. Stability plots for 3T scanner at Stanford.

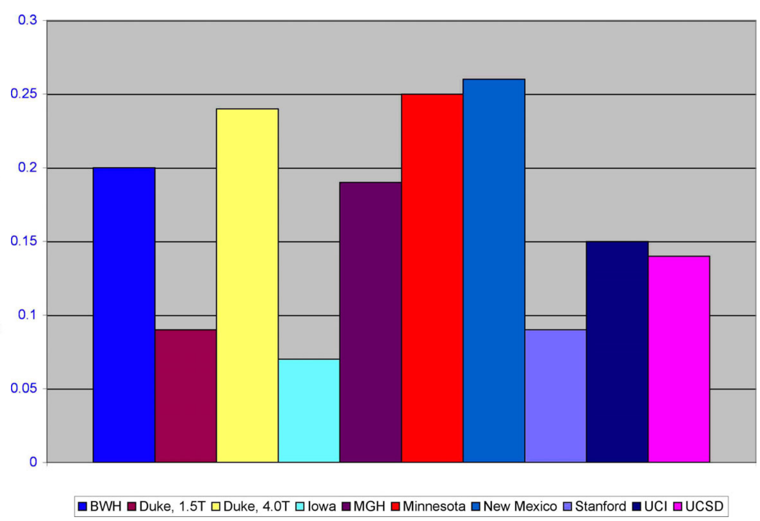

Fig. 2. Stability results (% fluctuation) for 10 scanners for one week.