Retrospective Quality Assessment of fMRI Data

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Introduction fMRI presents challenges in terms of scanner performance and stability which frequently exceed the specifications covered by commercial manufacturer quality assessment (QA) and preventative maintenance. To address these requirements, QA methods specific for fMRI have been proposed as part of the research protocols at several imaging centers (1,2). Weisskoff first described methods to assess the temporal SNR of fMRI timeseries data for the evaluation of scanner stability(3). The majority of fMRI QA methods have focused on using phantom scans, since such measures are expected to have relatively uniform signal, and predictable noise characteristics. In vivo fMRI data presents additional challenges due to the presence of physiologic noise, tissue based contrast variability, subject motion, and actual actual BOLD-based signal fluctuations. Recently, Stocker et al described a QA methodology for both phantom and human subjects (4). Here we describe a method for retrospective QA on a large collection of fMRI sessions spanning several years of experiments at a single imaging site.

Parameter	dx	dy	dz	slices	plane	TE	TR	flip	BW	reps	sequence
Value	3.00	3.00	3.00	20	axial	30	3000	90	2605	100	ep2d_bold
Tolerance	10%	10%	10%	>19	-	10%	10%	1%	10%	>99	-
Units	mm	mm	mm	-	-	ms	ms	°	Hz/pix	-	-

Table 1. Acqusition parameters used to select fMRI data for Q/A processing

Methods Imaging data from a 3T Siemens Trio scanner was culled from the data servers of the Center for Functional Neuroimaging (CfN) at the University of Pennsylvania (http://cfn.upenn.edu). Software was developed in the IDL programming language to crawl the disk drives for original Dicom image data from fMRI sessions. Only the header content of the Dicom images was used to identify eligible images; no additional information (e.g. stimulus paradigm, subject reponses) was considered. The program found all functional scans (gradient-echo EPI) whose acquisition parameters matched a template image. The match was applied using a list of parameters and associated tolerances (Table 1). Only scans meeting the tolerances for all specified parameters were selected for QA analysis. For each fMRI timeseries data set selected, an automated voxel mask was generated and the following metrics were computed from the masked voxels:

tSNR	the average voxel temporal SNR, after linear detrending.
Spikerate	the percentage of time points for which the time derivative of the detrended global signal exceeds 1% of the global signal mean (%).
Drift	the slope of the best linear fit to the global time signal (%/TR)
Rerr	the mean voxel-wise squared difference between each timeseries image and the first image.

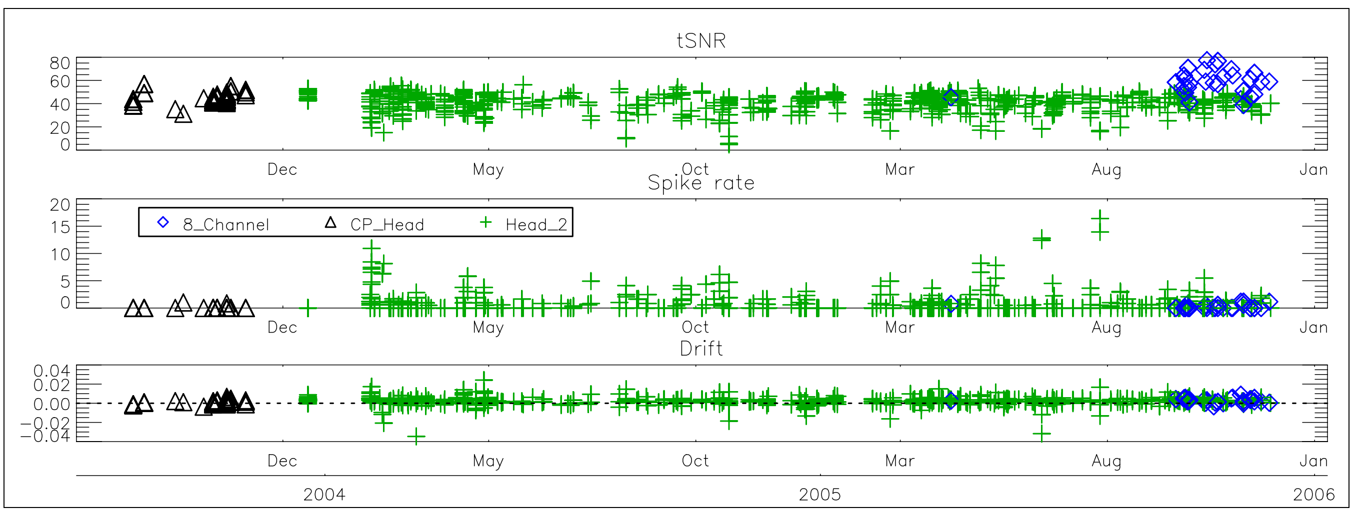

Figure 1. QA metrics for tSNR, global signal spike rate and drift versus date of scan. Points are categorized by receiver coil type.

Results The QA metrics from 959 functional data sets spanning 2.5 years of experiments are shown in Fig. 1. The addition of an 8-channel headcoil clearly produced increased tSNR compared with two other quadrature head coils. Periods of increased spike rate are also evident. Overall global signal baseline drift did not appear to have a particular trend. Correlation plots of tSNR vs. Spikerate and absolute Drift vs. Spikerate are shown in Fig.2. Both showed moderate, though opposite, correlations (r=-0.58 and r=0.42, respectively), indicating that those metrics are not entirely independent as might be expected.

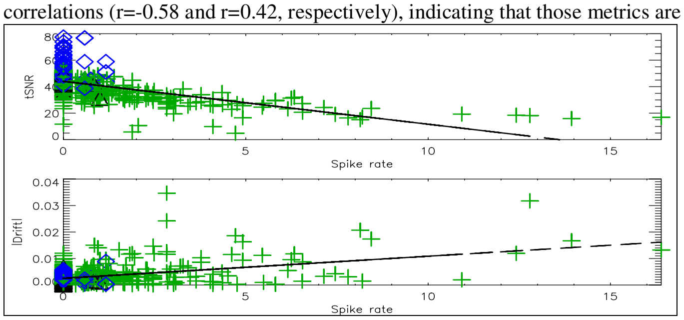

Figure 2. Correlation of tSNR (top) and |Drift| (bottom) versus Spikerate.

Discussion An automated QA system was developed which allows for retrospective analysis of in vivo fMRI data series. The system selects for data sets acquired with similar acquisition protocols, so that QA metrics may be compared across experiments. Due to the large volume of data and the requirement of automation, activation paradigms and subject responses were not considered or compensated for. Such sources of variability notwithstanding, the results obtained revealed relatively stable scanner performance over the course of several years. For example, the benefits in tSNR from a multi-channel head coil was readily apparent. The greatest source of image quality variability was spike rate. Moreover, spike rate correlated with decreased tSNR and increased estimates of baseline drift. Automated image QA should be considered a standard component of fMRI analysis and data management.

References

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