Out of Body/Out of Mind:
Scanner artifact detection in open access resting state fMRI.

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Introduction

Functional MRI data is susceptible to scanner and other artifacts that diminish the sensitivity to detect functional brain signals. These sources of data contamination include physiological and transient equipment artifacts such as gradient heating and radio-frequency channel arcing. The objective of this project was to develop a method to detect scanner-generated artifacts using out-of-body (out-of-head) MR signals.

Methods

The Explore-Remove-Scanner-Noise (ERSN) software was developed to detect and characterize MR signal outside the head and use it as a regressor to minimize unintended signal components in the fMRI data.
The software performs the following steps:

1) motion corrects the brain signal (using FSL MCFLIRT);
2) isolates the head and neck signal from non-tissue (out-of-head) voxels using FSL BET along with custom software;
3) defines a mask that contains non-tissue signal within the image space;
4) identifies ICA components using FSL MELODIC that come from the non-tissue signal;
5) generates a diagnostic plot which helps to identify volumes containing unwanted signal characteristics (this plot is called the "Scanner Noise Envelope");
6) algorithmically determines the number of temporal spikes in the ICA components; these components contain a substantial increase in background/out-of-body MR noise and the volume with the spike is labeled as a suspect volume;
7) filters out unwanted ICA components using FSL_regfilt.

This procedure was applied to 649 fMRI resting-state scans with a TR of 2.0 seconds from the Autism Brain Imaging Data Exchange dataset.
(ABIDE, http://fcon_1000.projects.nitrc.org/indi/abide)

The software is open source and available at https://github.com/IBIC/ibicERSN.

* FSL: Smith, Jenkinson, Woolrich, et. al.,
Advances in functional and structural MR image analysis and implementation as FSL. NeuroImage, 23(S1):208-19, 2004

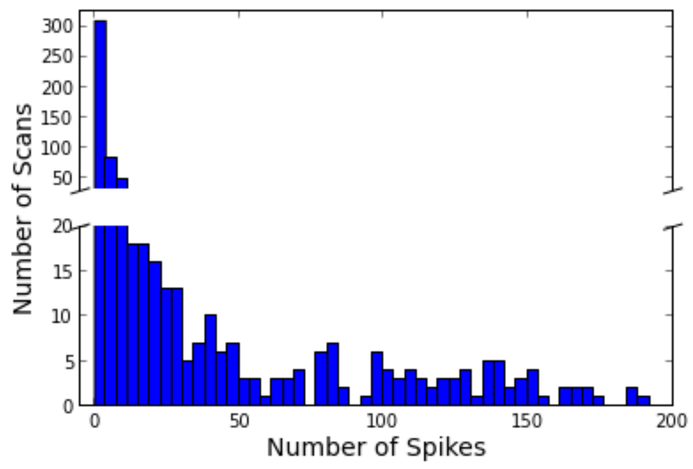


Figure 1: Histogram of out-of-body MR spikes

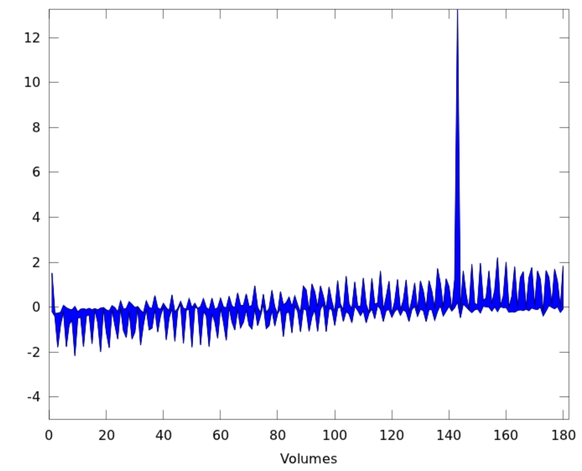


Figure 2: "Scanner Noise Envelope" showing large changes in scanner performance as a function of time during fMRI.

Results

Software ERSN identified one or more suspect volumes in 47% of the 649 ABIDE scans tested. As indicated in figure 1, the number of within-scan suspect volumes varied from 1 to 192 (X axis, total N=649). Figure 2 shows an example of a "Scanner Noise Envelope" generated by ERSN which highlighted volume 143 as a suspect volume in an fMRI multi-volume scan. Figure 3 is the display of the ICA component time course that contains the spike shown in Figure 2. Figure 4 shows the spatial distribution of the scanner noise within the out-of-body mask caused by the spike at volume 143. Note that a single slice in this volume has large noise signals

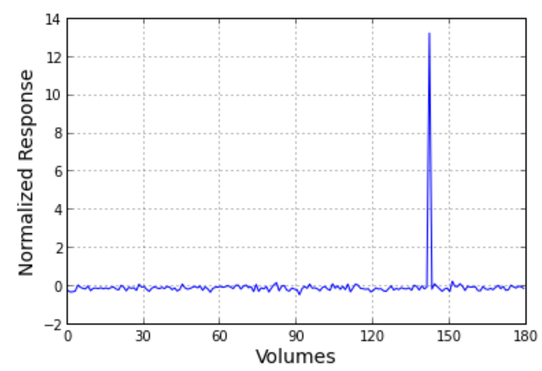


Figure 3: Time course of a spike ICA component within the out-of-body mask.

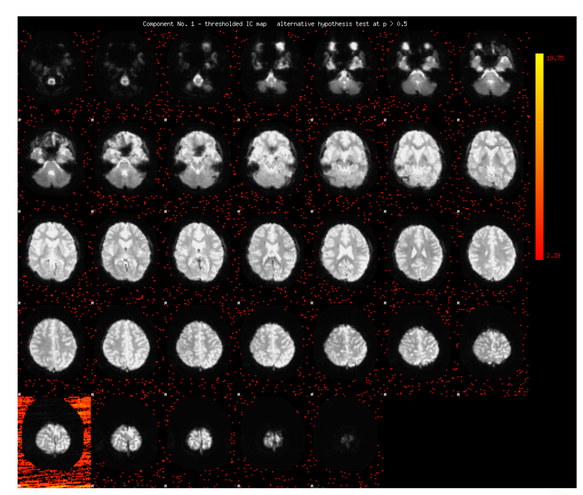
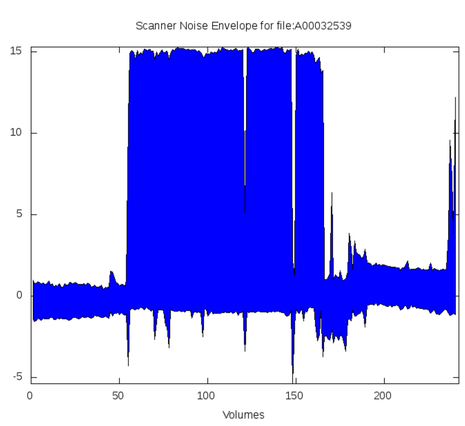


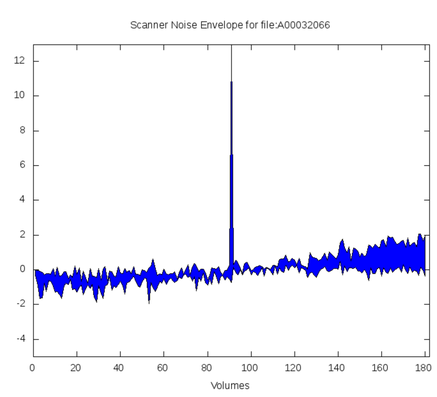
Figure 4: MR signal from the out-of-body masked volume. The noise characteristics are consistent with a scanner / equipment generated artifact.

Conclusions

The ERSN procedure may be useful in diagnostically testing the quality of an fMRI scan. The ERSN Scanner Noise Envelope allows the user to quickly determine if any volumes have a noise signature that needs to be examined. This test of the ABIDE data: 1) validated the usefulness of ERSN as a preliminary diagnostic tool that can be easily implemented as a standard quality-control procedure; and 2) demonstrated that there was a wide range in the quality of an example publicly available fMRI data set. The procedure is designed to have a very high sensitivity to changes in scanner noise profile. Further research is required to determine the extent to which the identified noise issues impact fMRI statistical results. A refinement of the procedure would be to automatically separate motion artifacts from scanner-related noise using a clustering algorithm that identifies the noise characteristics; however, the current implementation allows for visual separation of these contributions by examining the spatial characteristics of the noise profile.



"Problem" goes on / off

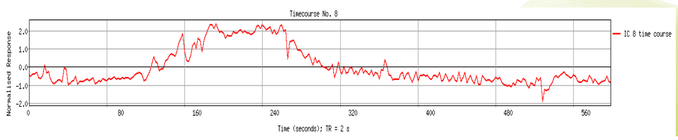


Middle volume only

Current research focus

What (if anything)do these plots indicate about the scanner

Very slow stabilization: Impact on intensities?



Scanner instability: Impact on intensities?