Methods and Software for fMRI Analysis for Clinical Subjects

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Introduction

Clinical subjects and children present a challenge for fMRI analysis because of the increased potential for head motions to affect the collected data. While modeling techniques have been described to reduce these effects, including corrections for small motions [1], large motions [2], rapid motions [3], noise spikes [4], and spontaneous deep breaths [5], no single software package addresses all of these artifact effects, which often co-occur in clinical subject data. In addition, it is difficult for a user to validate if a given method were successful for a particular subject. Our goals were to develop automated software tools that addressed all of the aforementioned artifacts, and to provide visualization tools to help users validate the results.

REFERENCES
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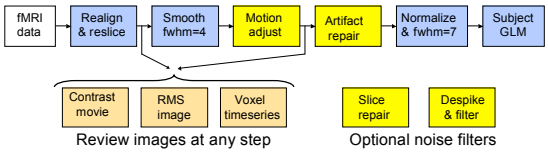
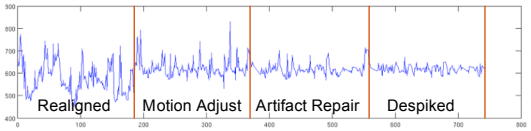
2.Grootoonk, et.al. 2000. Characterization of…, *NeuroImage* 11:49-57.
3.Lemieux, et.al. 2007. Modeling Large Motion…, *Mag.Res.Img* 25:894-901.
4.Cox, R.W. 1996. AFNI Software. *Comp. Biomed. Res.* 29(3): 162-173.
5.Birn, et.al. 2008. Respiration response function, *NeuroImage* 40:644-654.

Single Subject Pipeline

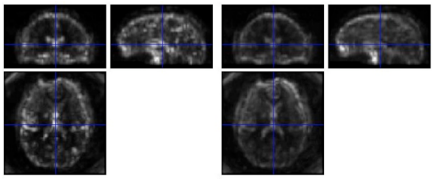


Motion causes up to 90% of the variance in fMRI data. Clinical subjects often cannot be rescanned, and noisy data sets may need to be processed as best as possible. Large motions may be outside the accuracy range of linear and quadratic motion regressors.

Approach: Use a motion adjustment algorithm that corrects the interpolation errors caused by realignment of large motions. Apply the correction before the GLM to avoid extra regressors in the design matrix. Three noise filters are provided: Artifact Repair for rapid motion and bad volumes, Slice Repair for bad slices, and Despike and Filter for voxel-wise noisy time series.



Time series of same voxel after four stages of processing

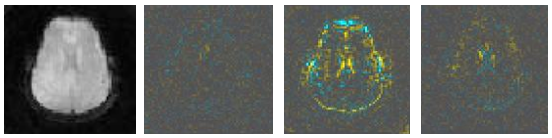


RMS fluctuation image: Before and after motion adjustment

Quality Check Data

Artifacts in the data may degrade the accuracy of single subject results.

Approach: Contrast Movie allows a user to view all data from all voxels with enhanced contrast. Bright yellow and blue correspond to a 16% change (positive and negative, respectively) in signal. Percent signal change is measured relative to mean image over a head mask.

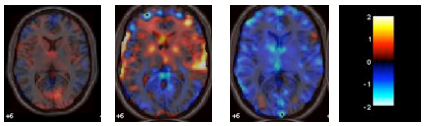


Base image Scan 49 - Base Scan 50 - Base Scan 51 - Base
Contrasts shown are from images of realigned, resliced data.

Group Level Review

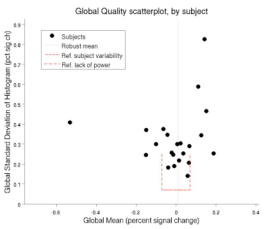
Block task designs are often required for cognitively impaired subjects and young children. These designs are more susceptible to confounds from task-correlated motion. Poorly analyzed subjects may invalidate a group study. Is there a better discard criterion than excluding all subjects with motions greater than 2 mm?

Approach: Quantify results into percent signal change to help detect unreasonable estimates. Provide easy tools to review and compare contrast maps from each subject. Measure the errors in subject estimates with a Global Quality score, and exclude subjects with high scores from the group analysis.



Low Motion High motion Deep breath [-2%,+2%]
Movie of single subject contrast estimates in percent signal change.

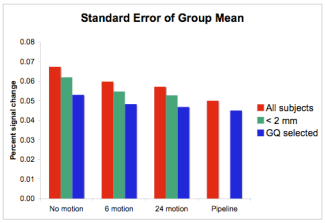
Each subject has a distribution of contrasts characterized by a mean and standard deviation. Outlier subjects had their results confounded by task-correlated motion or artifacts, and should be excluded from a group analysis.



Performance

Task-correlated motion or artifacts may reduce confidence in group statistical activation maps. Additional measures are required to evaluate performance.

Approach: Performance at the group level is measured by the standard error of the group estimate and by the replication of results across subjects. Good algorithms yield smaller standard errors. Small within-group errors will help improve discrimination between control and patient populations.



The pipeline algorithm yielded the smallest standard error for a group of subjects with bipolar disorder (24 subjects, red). The GQ selected subjects were better than a <2mm motion criterion, or using the full group, for every method (red->blue).

ArtRepair Toolbox for SPM

More than 500 pediatric and clinical subjects have been analyzed, including subjects with conditions such as fragile X, Turners and Williams syndromes, bipolar disorder, ADHD, depressive disorders, dyslexia, and post-traumatic stress disorder.

Over 900 software downloads (validated by user name) have been made by researchers in 20 countries.

Developed for SPM5 and SPM2. Compatible with SPM8.

SPM Extensions website or www.nitrc.org
or http://cibsr.stanford.edu

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