Creation of fMRI Digital Reference Objects with Multiple Sources of Signal Variance

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Quantitative Imaging Biomarkers Alliance RSNA

BOLD fMRI as a Quantitative Biomarker

The aim of the QIBA fMRI technical committee is to establish quantitative standards for functional MRI including standards for reliable data quality control (QC). Such QC is critical for both research and clinical applications of fMRI. To this end, identifying sources of variance through creation and testing of standardized fMRI datasets (digital reference objects, DROs) with known "ground truth" will facilitate comparison of existing postprocessing methods and quantitatively assessing their ability to reliably recover fMRI signals in the face of noise and common signal artifacts. This new project will impact clinical, research and commercial applications of fMRI and provide DRO datasets for public use. Previous work by this committee has identified sources of variance in fMRI methodology. We have established metrics of reproducibility for one representative image analysis protocol. However, methods used for clinical fMRI typically vary from site to site and it is not known: (1) which methodological factors significantly affect reproducibility, sensitivity and bias, (2) which methods in current use are best for obtaining consistent quantitative results, or (3) how data processing methods impact clinical performance of fMRI as a biomarker of neuronal activity. The current project will address these issues. Your input to this process is invited (see comment sheet below).

Project Goals

Aim 1. Generation of fMRI Reference Data Sets and QA metrics

To provide a basis for comparing fMRI data processing and display methods, we will create a set of standardized fMRI reference datasets (DROs) with known "ground truth" related to the time-course, amplitude and spatial distribution of BOLD-like signals embedded in "noise". DROs will incorporate realistic brain activity signals as well as different types of noise and common fMRI signal artifacts.

Aim 2. Influence of Methodological Factors

There are a variety of fMRI image analysis methods in common clinical use, but little is know about their relative strengths and weaknesses. Aim 2 will use the DROs from Aim 1 to assess to what degree different analysis methods and potential sources of variance affect image reproducibility and quality. Seven independent clinical sites will process the DRO data sets and return their results for comparison. Post hoc tests will be used to identify specific sources of variance that most affect the results.

Approach

- Hand select samples of empirical fMRI datasets, noise and artifacts having realistic known signal qualities and noise/artifact features.
- Combine empirically sampled signals/noise with computationally modified or synthesized fMRI signals to create multiple sets of DICOM image DRO's having a range of controlled signal and noise characteristics (ground truth). Different DRO data sets will vary in the relative combination of sampled empirical signals combined with synthesized signals. Each DRO set will contain test-retest data having the same characteristics but independent samples of noise.
- fMRI characteristics of interest will include the signal timing, spatial distribution and profile of extended foci within the brain, signal-to-noise ratio and relative amplitude of specific artifactual signals (e.g. head motion).
- Resulting DRO datasets will be distributed to seven clinical sites for using different fMRI data post-processing sequences. Processed datasets will then be returned to host site for comparison and computation of quality metrics including reproducibility, sensitivity, bias, linearity and variance from "ground truth".
- To isolate and characterize individual sources of variance, the DROs will be processed through a standardized sequence in which individual computational steps will be manipulated to assess the degree to which it effects the quality metrics listed above.

QIBA Projects and activities have been funded in whole or in part with Federal funds from the National Institute of Biomedical Imaging and Bioengineering, National Institutes of Health, Department of Health and Human Services, under Contract No: HHSN268201000050C and HHSN268201300071C. Thanks to RSNA for their valuable support, to ASFNR and its members and to other QIBA committees for their valuable inputs and discussions.

Various Sources of Variance for creation of DRO