Specialty area: Absolute Beginner's Guide to Neuroimaging Methods
Title: fMRI Analysis
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Highlights:
BOLD fMRI experiments generate vast amounts of noisy data
noise suppression and data analysis are crucial to unraveling neuronally induced BOLD signal changes
available approaches, tools, and basic steps in fMRI data analysis are described

Target audience: Clinicians and researchers with no previous experience in fMRI and fMRI data analysis.
Objectives: Recognize the presence of confounding factors in fMRI data and need for diligent data quality control, diagram the primary steps in functional MRI analysis, recognize conditions under which conventional approaches may be inappropriate.

Syllabus: Blood oxygenation level dependent functional MRI (BOLD fMRI) has become a powerful noninvasive technique for studying functional organization of the brain. A single BOLD fMRI experiment repeatedly (every two seconds or so for several minutes) acquires multi-voxel information of the whole brain at high spatial resolution (voxel volume order of a few mm cube) and therefore generates vast amounts of multichannel data. However BOLD fMRI data acquisition alone is not capable of elucidating neural activity from the collected data – fMRI data analysis is necessary. Even with recent MRI technology advances fMRI signal is very noisy, containing for example cardiac- and respiratory-related physiological noise, and may contain multiple artifacts that make it very challenging to detect and distinguish BOLD signals due to neural activity. Proper design of BOLD fMRI experiments, optimization of MRI acquisition parameters, use of the best hardware available, and concurrent collection of additional relevant information such as physiological waveforms may therefore significantly improve fMRI data quality and interpretation. Data analysis therefore plays a pivotal role in utilizing the capabilities offered by BOLD fMRI neuroimaging techniques to their full extent.

This presentation provides a very basic didactic overview of fMRI data analysis. Prerequisites for absolute beginners in fMRI will be enumerated and available software packages and online resources for data analysis will be named. Requirements and challenges of acquiring and managing data will be mentioned. Commonly used data processing steps in single-subject task-related block or event-related designs as well as task-free resting-state BOLD fMRI analysis will be enumerated and explained, with focus on a voxel-wise or univariate approach using a general linear model (GLM). GLM is the most commonly used, conceptually simple approach that implements standard statistics used in biomedical research. Because GLM can provide answers to many standard questions about data, a basic tutorial overview of this approach will be provided. Specifically, commonly used single-subject fMRI data preprocessing steps (image distortion, slice timing, and motion corrections, spatial smoothing and normalization), which also includes physiological noise suppression techniques, will be discussed. Next, in the context of task-related BOLD fMRI data, this tutorial will cover GLM model formulation, statistical inference of images, multiple comparison problems and solutions, contrast formulations, and statistical maps visualization. For the purpose of combining single-subject data and to test group hypotheses, the necessity for group analysis will be discussed. Approaches for resting-state BOLD fMRI data analysis where no specific task is involved – used to model and understand brain connectivity – will also be discussed on both the single-subject and group levels. For both task-related and resting-state BOLD fMRI data analysis, hints for how to start will be provided. As a practical starting point this tutorial will encourage utilization, understanding, and modification of existing fMRI data processing scripts that combine multiple analysis steps for an automatic and easy use.

fMRI data analysis by itself is a large and active field of research, driven by the need to understand and unravel information from the collected brain neuroimaging data. Besides voxel-wise univariate data analysis approaches, multi-voxel pattern analysis and machine learning approaches may be particularly well suited for formulating better models that may allow for new observational predictions. However it is important to remember and stay in close contact with the data being analyzed since the computer science mantra "garbage in, garbage out" applies for fMRI data analysis as well.

Take home messages: a) design your fMRI experiment well; b) use the best available hardware and optimize data acquisition parameters carefully; c) always stay in touch with your "raw" fMRI data and check for possible artifacts; d) don't blindly trust automatic data processing outputs; e) be critical to analysis results.