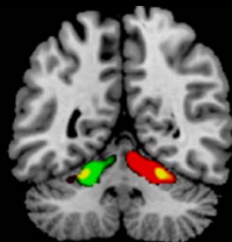


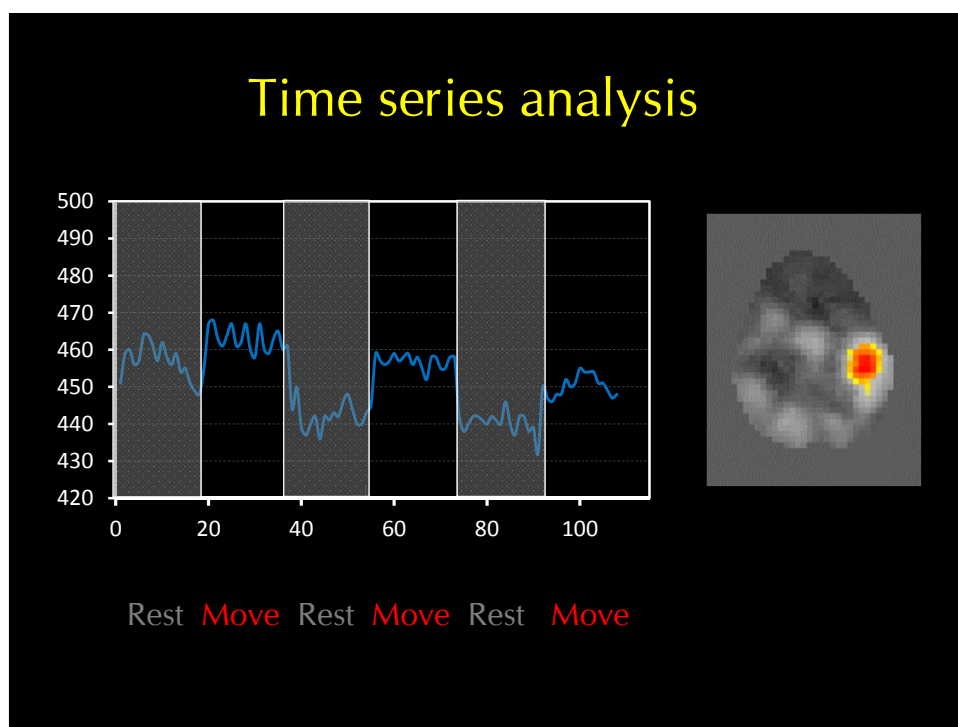
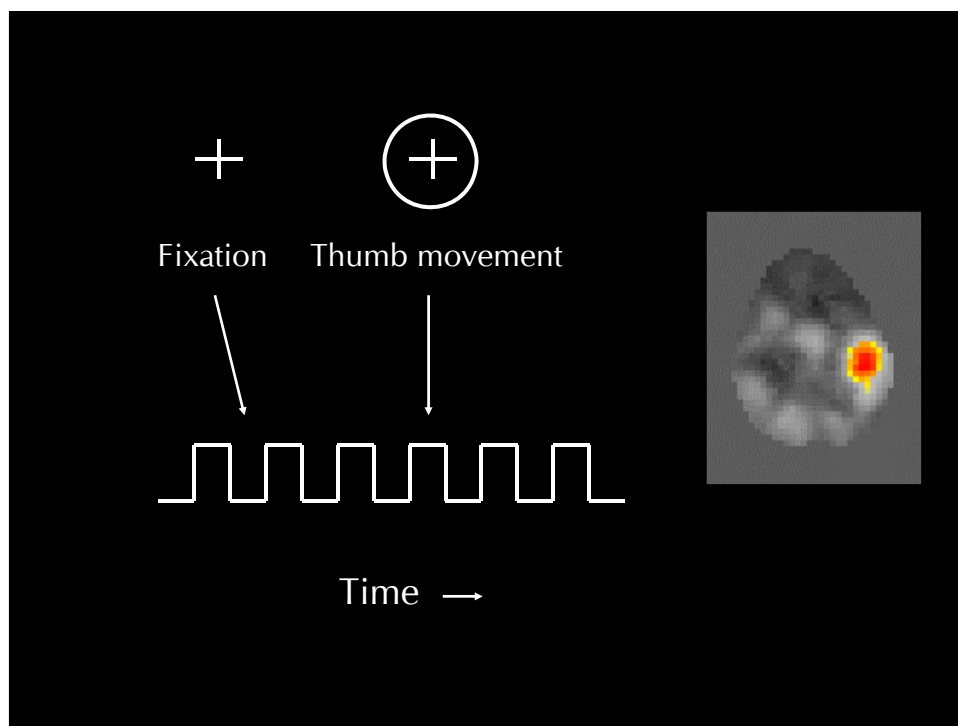
Principles of Functional Neuroimaging : Measurement, Design and Analysis

Overview: Planning a fMRI Study



Functional Neuroimaging Study Components

- Measurement
- Design
- Analysis
- Reporting



- Research questions and hypotheses
- Meta-analysis
- Sample selection
- Task design
- Study design
- Power analysis
- fMRI data acquisition
- fMRI data preprocessing
- fMRI quality assurance
- Python and nipy
- Task-related fMRI data modeling – individuals and groups
- Resting state fMRI data modeling – individuals and groups
- MVPA and machine learning
- Critical thresholds for inference
- Structure/function integration
- Reporting results

Functional neuroimaging research questions and hypotheses

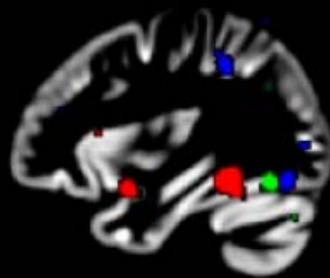
- Physiology
- Perceptual mechanisms
- Cognitive mechanisms
- Movement mechanisms
- Practice effects

Clinical functional neuroimaging research questions and hypotheses

- Pathophysiology
- Diagnosis
- Intervention effects
- Disease as a model system

Meta-analysis

- Meta-analysis in clinical research
 - Summarization
 - Study planning
- Meta-analysis techniques in neuroimaging

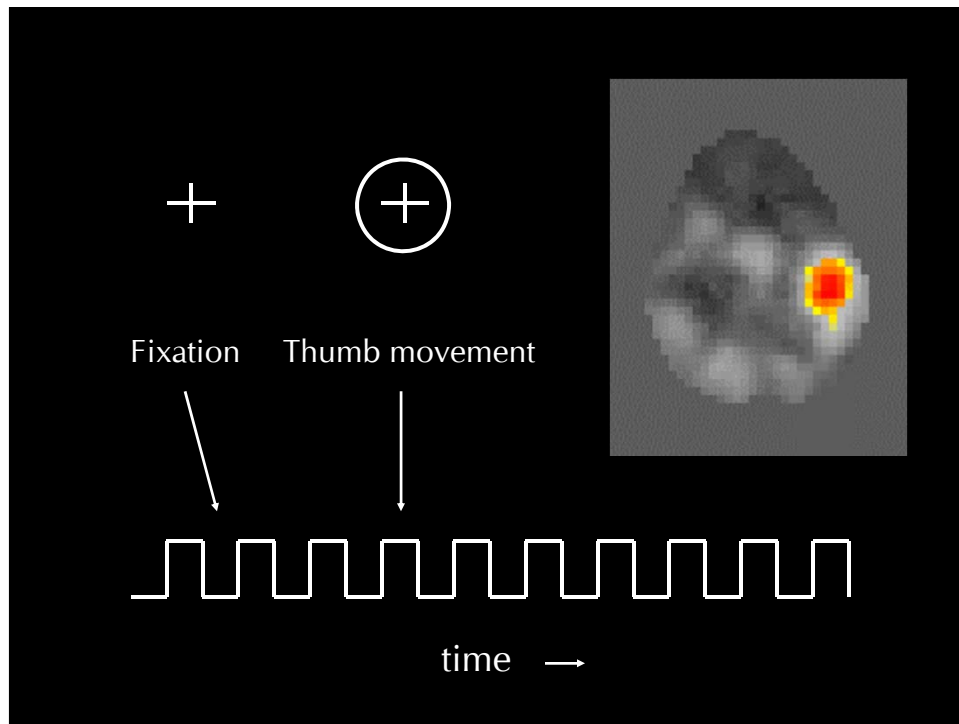


Sample selection

- Random samples and samples of convenience
- Inclusion criteria
- Exclusion criteria - medical issues, smoking, drug use
- Psychometric testing
- Neurologic and psychiatric testing
- The uses of covariates

Task design

- Block designs
- Event-related designs
 - Periodic
 - Stochastic
- Mixed Designs
- Parametric design
- Adaptation design
- Sensitivity and efficiency
- Subtractive logic

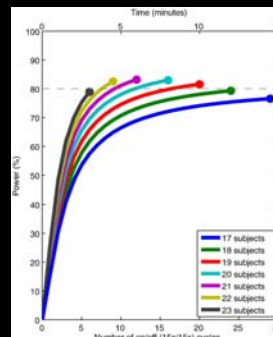


Study design

- Case study design
- Group design
- Fixed vs. random effects
- Within and between group effects
- Randomized designs
- Quasi-experimental designs
- Factorial designs
- Parametric designs
- Inclusion of covariates

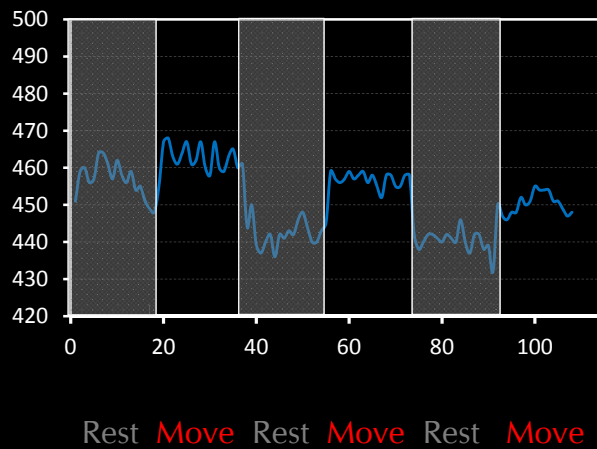
Power analysis

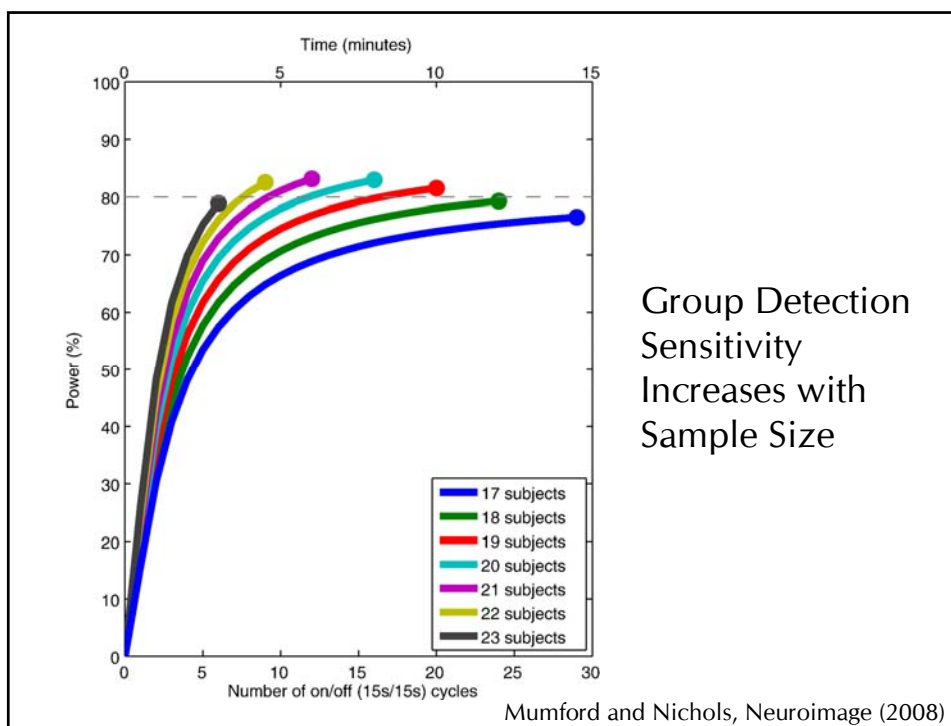
- Goals
- Requirements
 - Effect size
 - False positive rate
 - Sample variability
 - Desired power



Effect size

mean (Move) - mean (Rest) / std dev (Rest/Move)





Functional MRI data acquisition

Sensitivity in functional neuroimaging is a spatiotemporal compromise.

- Spatial considerations
- Temporal considerations

Functional MRI data acquisition: Spatial

- Field strength
- Head coil
- Sequence type - EPI, spiral
- Echo time
- Flip angle
- Voxel dimensions
- Slice angle
- Field map
- Whole vs. partial head coverage

BOLD-Contrast Increases with Static Field Strength

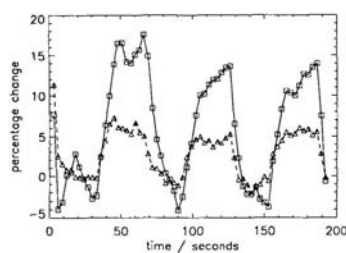
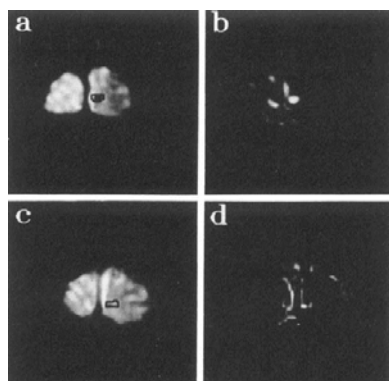
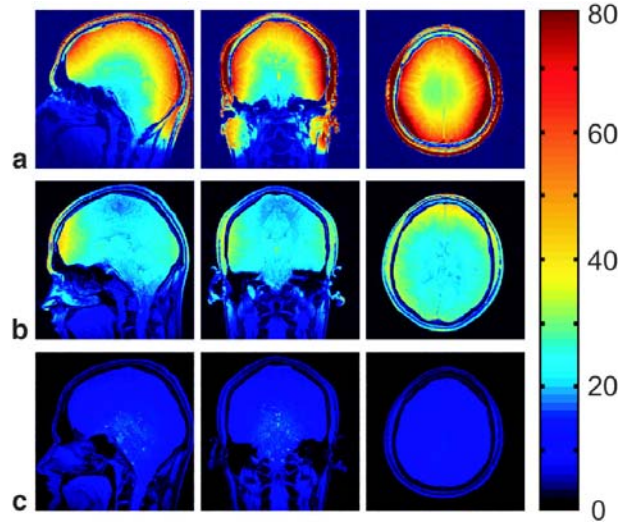


FIG. 2. Plot of fractional change in 4 T (squares) and 1.5 T (triangles) EPI image intensity versus time in the eight-voxel regions of interest in the visual cortex shown in Fig. 1, for a volunteer experiencing alternate 30-s periods of rest and photic stimulation. Details of acquisition for the 4 and 1.5 T data are described in the caption for Fig. 1.

Turner et al., MRM (1993)

SNR Increases with Coil Density



Wiggins et al., MRM (2006)

Voxel Volume

- field of view (FOV)
- matrix size
- slice thickness

Signal strength is proportional to voxel volume.

$$1 \times 1 \times 1 \text{ mm} = 1 \text{ mm}^3$$

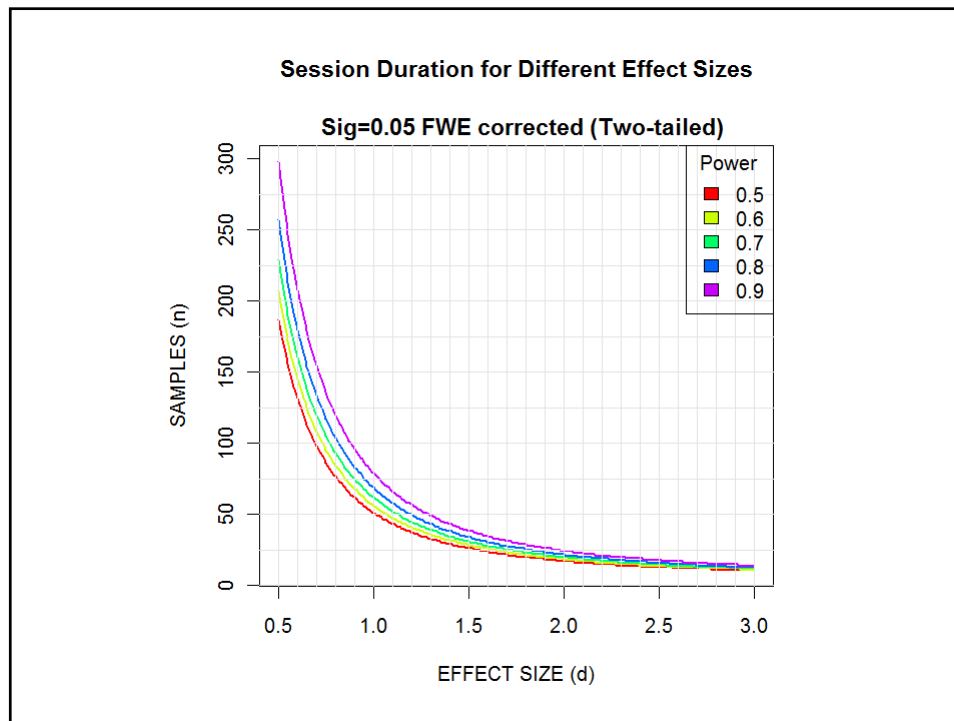
$$2 \times 2 \times 2 \text{ mm} = 8 \text{ mm}^3$$

$$3 \times 3 \times 3 \text{ mm} = 27 \text{ mm}^3$$

Voxels should be isotropic.

Functional MRI data acquisition: Temporal

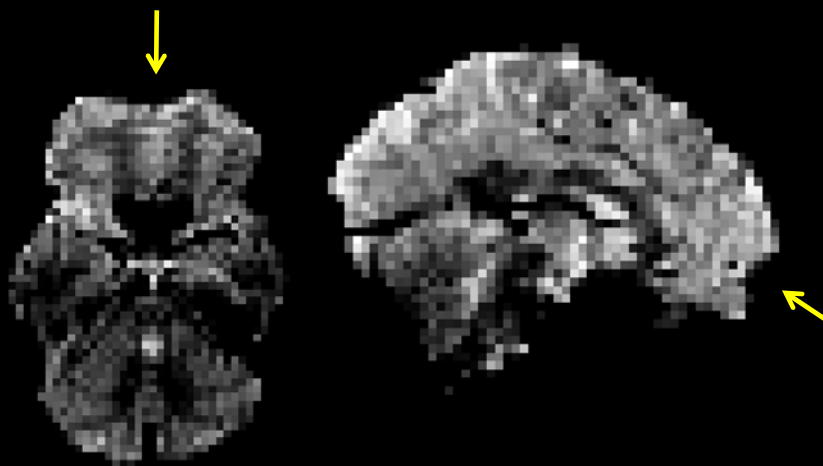
- Slice acquisition order
- Repetition time
- Session length
- Fixed vs. distributed temporal sampling
- Sparse temporal sampling
- Noise source recording
- Prospective motion correction



Functional MRI quality assurance

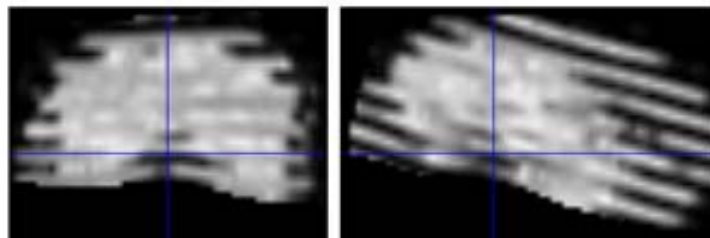
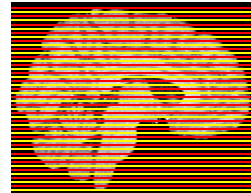
- QA for images
- QA for time series
- QA in individual models
- QA in group models
- Outliers in regression and correlation

Signal Dropout and Geometric Distortion



Head Motion Can Cause Intensity Artifacts in Interleaved Acquisitions

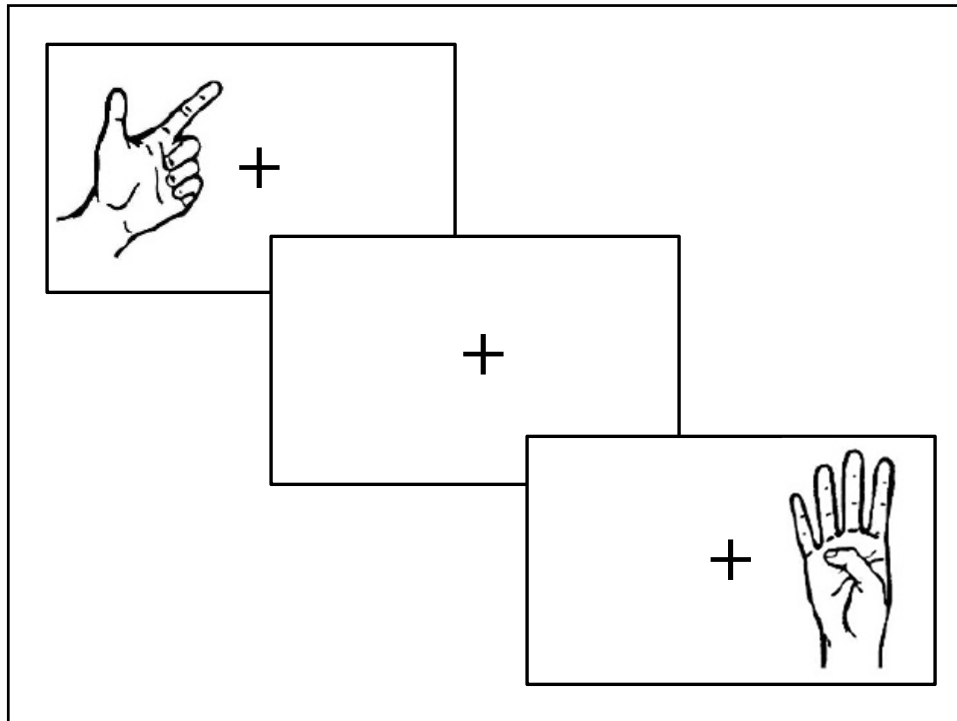
These artifacts are caused by intra-scan motion and spin-history effects



Whitfield-Gabrieli

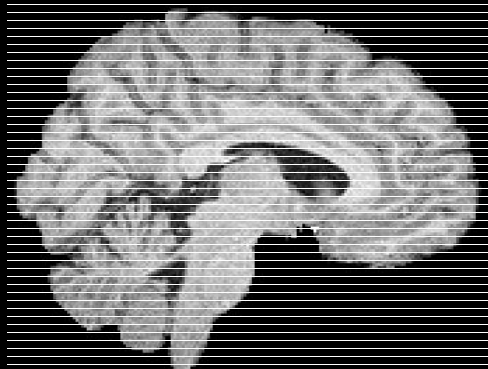
Functional MRI individual modeling

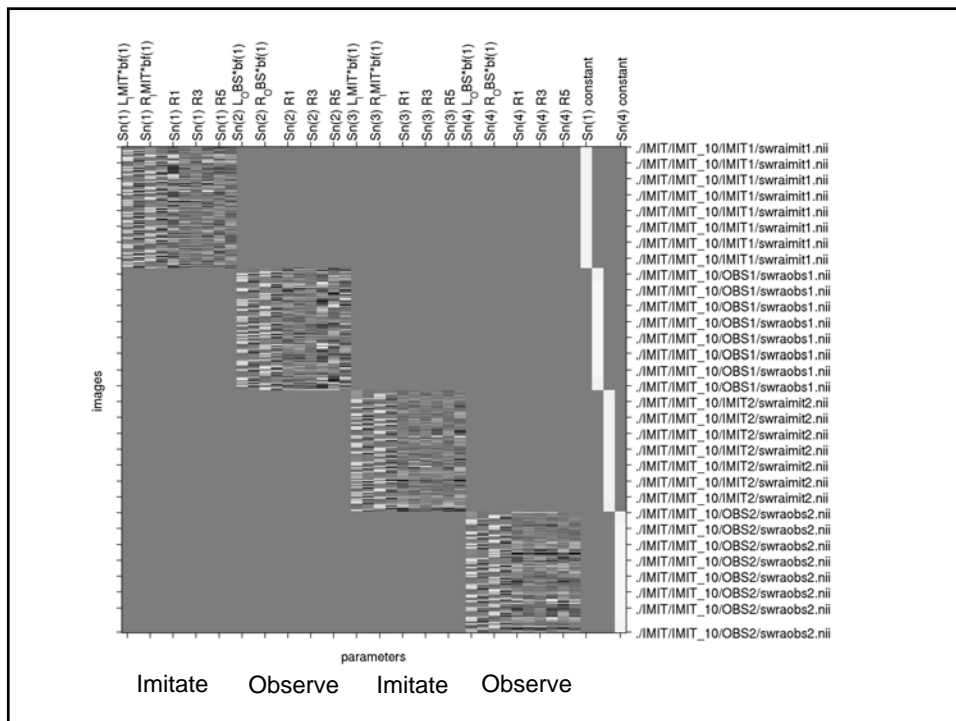
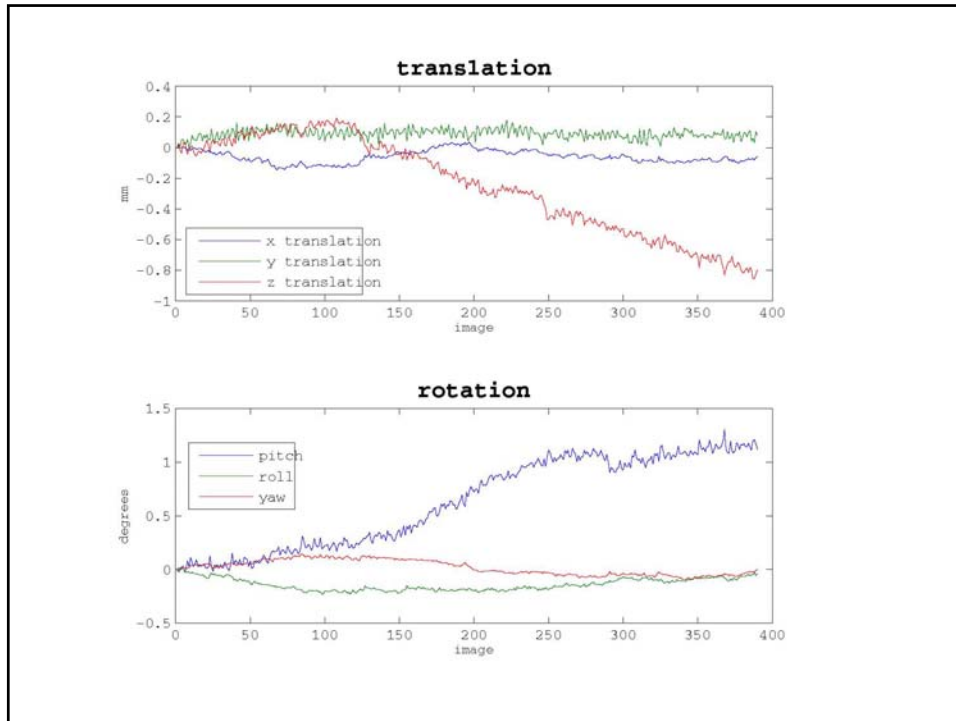
- Regression models
- Physiological noise reduction
- Temporal autocorrelation correction
- Inclusion of covariates
- Contrast specification

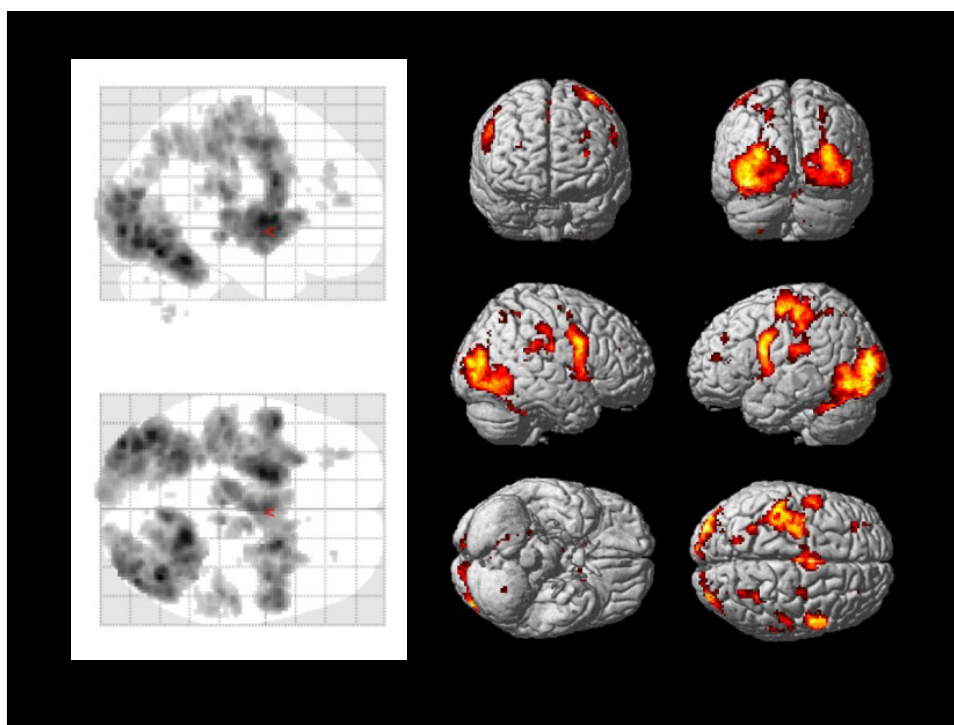
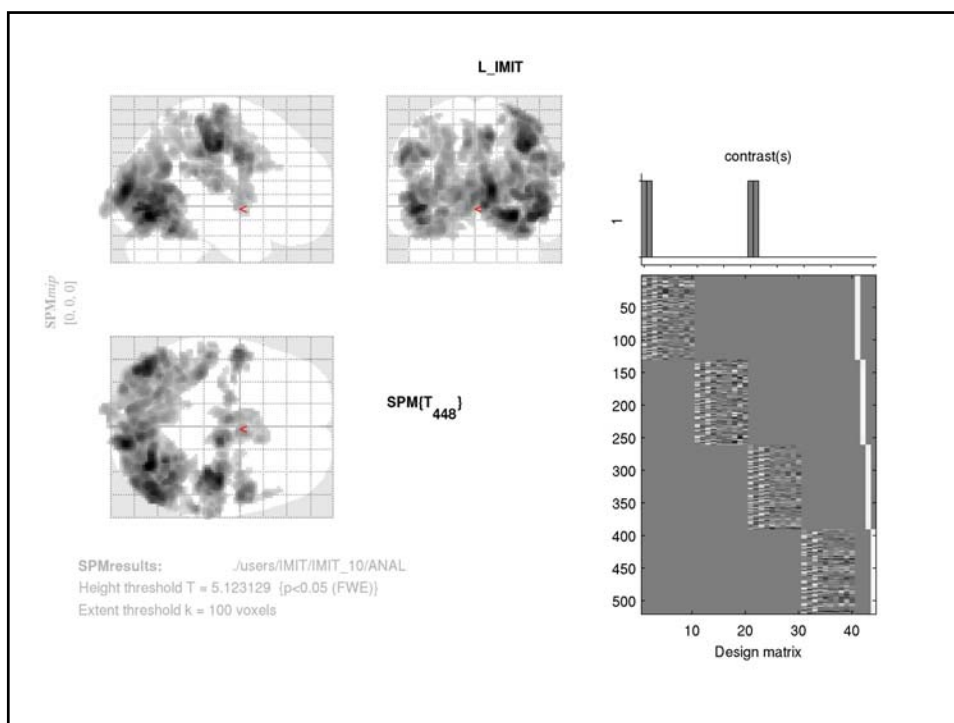


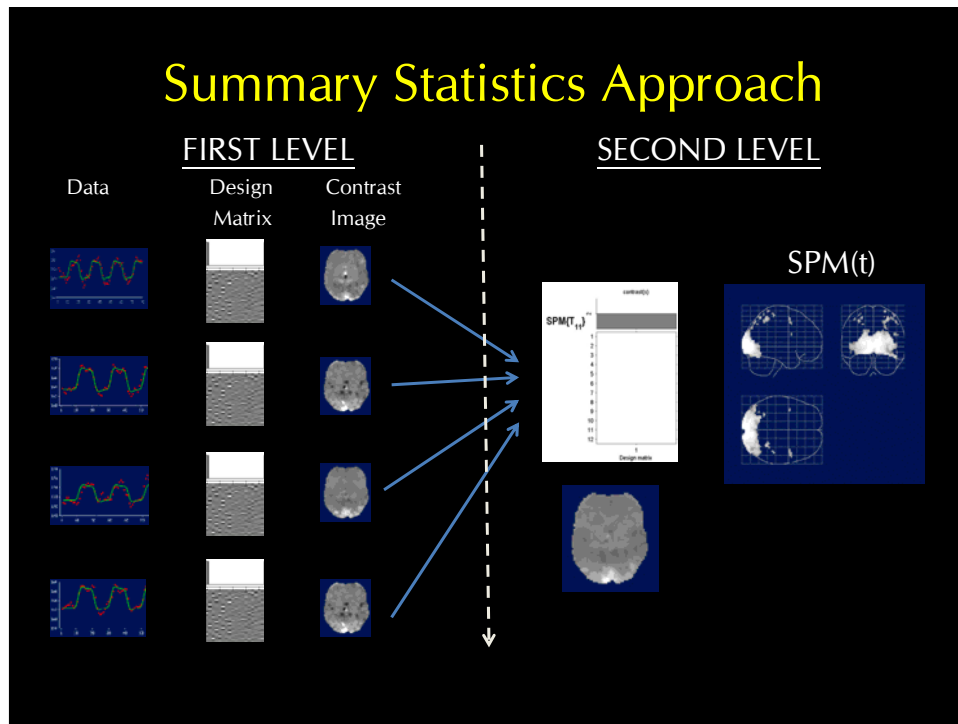
Data Acquisition Details

- BOLD-contrast using echo planar imaging
- 3.0 T system
- 32 channel head coil
- GRAPPA acceleration
- 58 axial slices per volume
- TE 30 ms
- TR 3510 ms
- 2.5 mm³ voxels







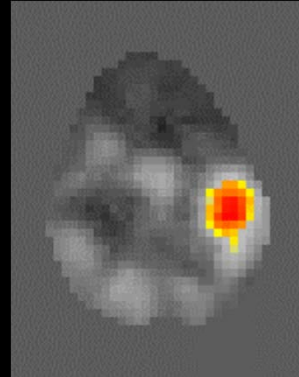


Functional MRI group modeling

- Regression models
- ANOVA models
- ANCOVA models
- Within and between group factors
- Repeated measures
- Inclusion of covariates

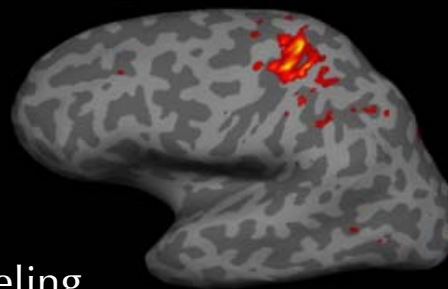
Critical thresholds for inference

- Correction for multiple comparisons
- Bonferroni correction
- Family-wise error control
- False discovery rate control
- Gaussian random field theory



Structure/function integration

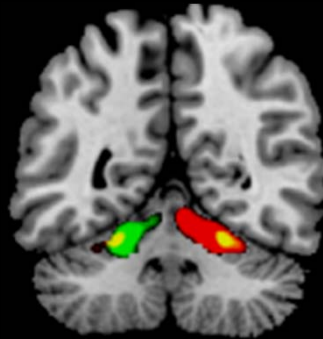
- Localization
- Anatomical labeling
- Visualization



Reporting results

- Choosing an audience
- MAGIC criteria
- Structure of a neuroimaging paper
- How to describe the methods
- How to report results
- Effective figure presentation
- Revisions and resubmissions

- Research questions and hypotheses
- Meta-analysis
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- Task design
- Study design
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- Task-related fMRI data modeling – individuals and groups
- Resting state fMRI data modeling – individuals and groups
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Course lectures, readings, exercise:
http://neurometrika.org/MITfMRI_Spring2012