2025 CBIC MRI Bootcamp Syllabus

Mike Tyszka
Caltech Brain Imaging Center

1. Basic NMR and MRI

1.1. Nuclear Magnetic Resonance (NMR)

- Nuclear Paramagnetism
- Quantum Spin Polarization
- Classical Bulk Magnetization
- The Classical Vector Model
- Relaxation
- Chemical Shift

1.2. Magnetic Resonance Imaging

- Frequency and Phase Encoding
- Slice and Volume Selection
- k-space
- Spin Echo
- Gradient Echo
- Pulse Sequence Diagrams

1.3. MRI Tissue Contrast

- Proton Density
- T_1-weighted Images
- T_2-weighted Images
- T_2*-weighted Images
- Flow and Motion

2. fMRI Pulse Sequences

2.1. Structural Imaging

- T1w MP-RAGE and MEMP-RAGE
- T2w SPACE
- Gradient Echo Fieldmap

2.2. Functional Imaging

- Requirements and tradeoffs
- Echo Planar Imaging (EPI)
- Multiband EPI
- SE-EPI Fieldmap

3. Practical MRI: Noise and Artifacts

- Systematic vs Physiological Noise
- SNR and CNR
- SNR efficiency and optimization
- External Noise
- Image Reconstruction Artifacts
- Fluid Flow vs Gross Motion Artifacts
- Susceptibility Artifacts

3.1. Quality Control

- MRIQC
- Quality metrics
- Phantom vs In Vivo QC

4. BOLD Functional MRI

4.1. The BOLD Effect

- Blood oxygenation
- Neurovascular Coupling
- Susceptibility Models for BOLD

4.2. fMRI Experimental Design

- Event-related fMRI
- Design Optimization

4.3. Preprocessing

- fMRIPrep
- Head Motion Correction
- Slice Timing Correction
- Image Registration
- Physiological Noise Estimation