Measurement & Signal

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How does the scanner work?
How does the scanner work?

- Step 1: Place an object/subject in a big magnet
- Step 2: Apply radio waves
- Step 3: Measure emitted radio waves
fMRI Components
Magnetic fields align hydrogen protons

Body is composed of 70% water

Magnetic field Aligns hydrogen protons

MRI machines have two primary gradients of magnetic
T1 Relaxation/Recovery

Before RF Pulse

After RF Pulse

— Functional Magnetic Resonance Imaging 3e, Figure 3.12
T2 Decay

Before RF Pulse

After RF Pulse

FUNCTIONAL MAGNETIC RESONANCE IMAGING 3e, Figure 3.11
RF pulse sequence for frequency and phase within a slice
TR & TE

TR: repetition time - time between excitation (RF) pulses
TE: echo time - time between excitation pulse and data acquisition
T1 Recovery

A graph showing T1 recovery, with an excitation pulse at 90° and longitudinal magnetization (arbitrary units) on the y-axis and time (s) on the x-axis.
T1 recovery and T2 Decay

(A) Longitudinal magnetization (arbitrary units) vs. Time since excitation (s)

(B) Transverse magnetization (arbitrary units) vs. Time since excitation (ms)
Optimal parameters for T1 weighted

To maximize differences in tissue contrast for T1 weighted image you need a shorter TR and a very short TE
Optimal parameters for T2 weighted

To maximize difference in tissue contrast for T2 weighted image you need a longer TR and shorter TE
2D Frequency Information converted into images

(A) + + =

(B) + + =

(C) Center of k-space

Image of a block
Corresponding k-space representation
Image of rotated block
Corresponding rotation of k-space frequencies
K-space & image space
Images

T1-weighted

T2-weighted

T2*-weighted
What is BOLD?
The brain is active at rest

At rest the brain accounts for 11% of cardiac output and 20% of energy consumption.

Alavi and Reivich, 2002, Raichle, 2010
Rodent brain energy budget

- Postsynaptic potentials: 37.5%
- Action potentials: 15.8%
- Resting potentials: 15%
- Presynaptic transmitter release: 3.8%
- Transmitter recycling: 3%
- Housekeeping: 25%
Blood Oxygenated Level Dependent (BOLD) signal

Oxygenated hemoglobin is diamagnetic
Deoxygenated hemoglobin is paramagnetic
BOLD Signal

Source: Doug Noll’s primer
Blood oxygenation and T1/T2
Stimulus presentation changes BOLD in visual cortex

Kwong et al., 1992
(A) BOLD signal amplitude

- Peak
- Rise
- Fall
- Initial dip
- Undershoot

(B) Plateau

- Rise
- Fall
- Initial dip
- Undershoot

FUNCTIONAL MAGNETIC RESONANCE IMAGING Jr, Figure 7.10
Hemodynamic Response Function (HRF)
Sampling resolution
Assume HRF is Linear and Time Invariant
Scaling & Superposition
Do BOLD responses summate linearly?
HRF Nonlinearities
What exactly is BOLD Measuring?
BOLD Correlates
Negative BOLD signals

Single unit vs fMRI

Mukamel et al., 2005 Science
BOLD appears to be measuring postsynaptic neural activity

Ferenczi et al., 2005 Science