Understanding and Interpreting Functional Magnetic Resonance Imaging

Precision Health Boot Camp

Alexander Mark Weber

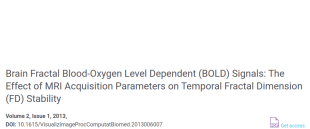
Department of Pediatrics, Division of Neurology
University of British Columbia

9:00 - 11:00 AM
August 9th, 2022

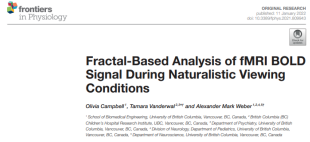
Preamble

A preliminary study of functional connectivity of medication naïve children with obsessive–compulsive disorder

Alexander Mark Weber [a], Noam Soreni [a,b,c,*], Michael David Noseworthy [a,d,e,f]

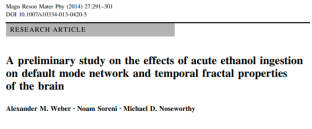


Brain Fractal Blood-Oxygen Level Dependent (BOLD) Signals: The Effect of MRI Acquisition Parameters on Temporal Fractal Dimension (FD) Stability



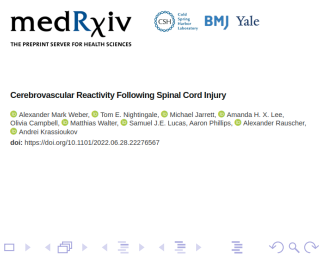
Fractal-Based Analysis of fMRI BOLD Signal During Naturalistic Viewing Conditions

Olivia Campbell [1], Tamara Vanderwal [2,3,4] and Alexander Mark Weber [1,4,5,6]



A preliminary study on the effects of acute ethanol ingestion on default mode network and temporal fractal properties of the brain

Alexander M. Weber · Noam Soreni · Michael D. Noseworthy



Cerebrovascular Reactivity Following Spinal Cord Injury

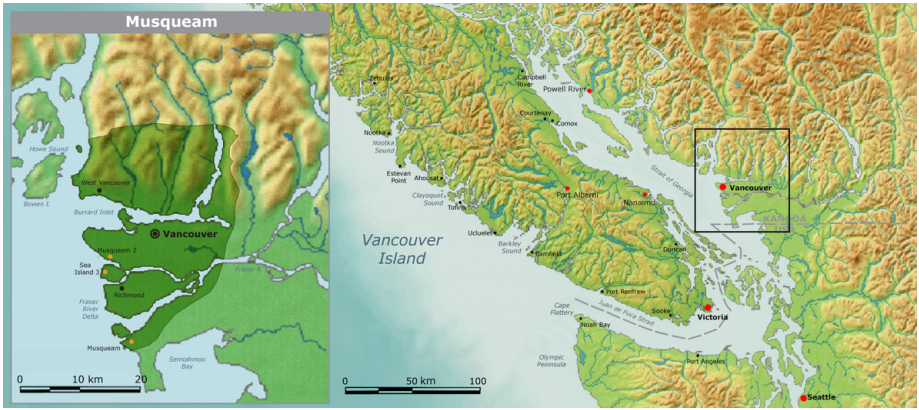
Alexander Mark Weber, Tom E. Nightingale, Michael Jarrett, Amanda H. X. Lee, Olivia Campbell, Matthias Walter, Samuel J.E. Lucas, Aaron Phillips, Alexander Rauscher, Andrei Krassioukov

doi: https://doi.org/10.1101/2022.06.28.22276567

Overview

Land Acknowledgement

I would like to acknowledge that we are gathered today on the traditional, ancestral, and unceded territory of the Musqueam people.



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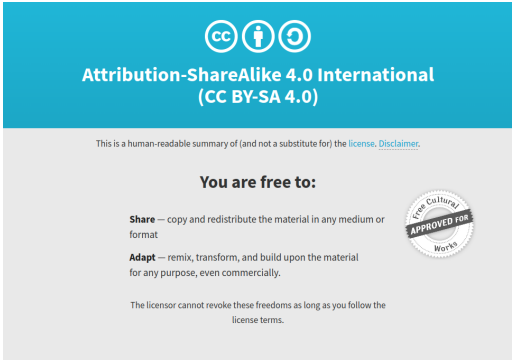

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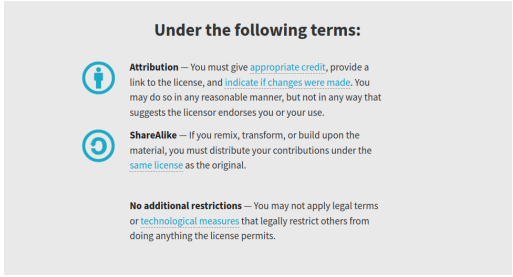

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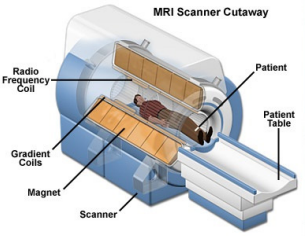
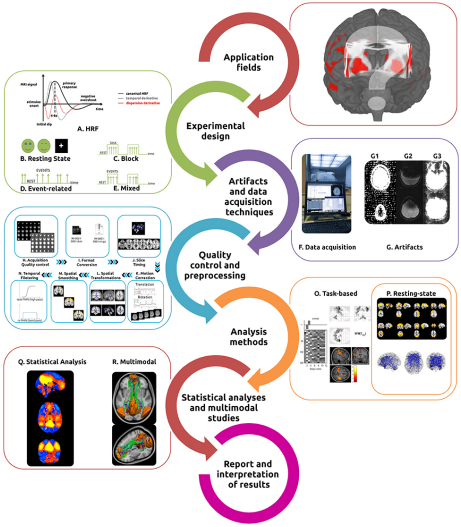
fMRI Overview



https://www.northwestradiology.com/blog/page/16/

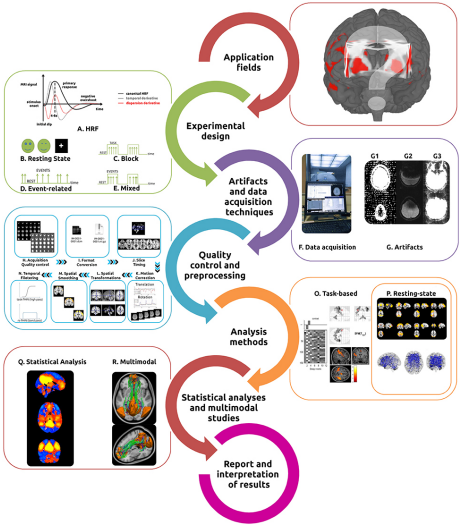
- **Magnetic:** Large magnet: 1.5 Tesla to 10 Tesla strength
- Earth's magnetic field is 0.00005 Tesla
- Our BCCHR Research MRI is 3T; 60,000x Earth's magnetic field
- **Resonance:** Uses radiowaves with frequencies that resonate with atomic nuclei (hydrogen, usually)
- **Imaging:** Converts spatial frequencies and phase into images

fMRI Overview



Soares et al. (2016) Front Neurosci, 10(515)

fMRI Overview



Soares et al. (2016) Front Neurosci, 10(515)

Lecture:

- MRI Physics
- Brain physiology
- fMRI acquisition
- Task vs Resting State fMRI

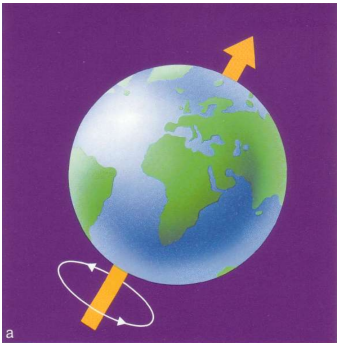
Tutorial:

- Get data from PACS; Copy over to Sockeye; Conversion
- BIDS
- Preprocessing using `fmriprep`
- Nuisance regression (two ways)

At the end of this session, students will be able to:

- Describe how MRIs produce and detect signal from the body
- Describe how brain activity can alter fMRI signals
- Describe the difference between task and resting state fMRI
- How to download data from open resources online to Sockeye
- How to run `fmriprep` on Sockeye to preprocess your fMRI data

MRI Physics Overview



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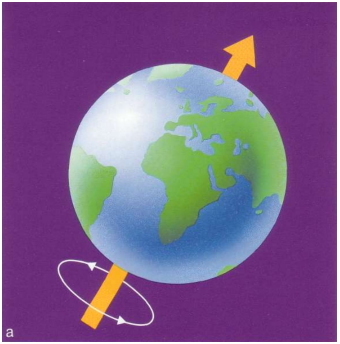

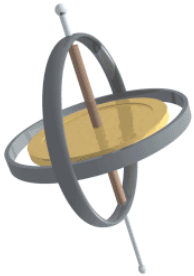

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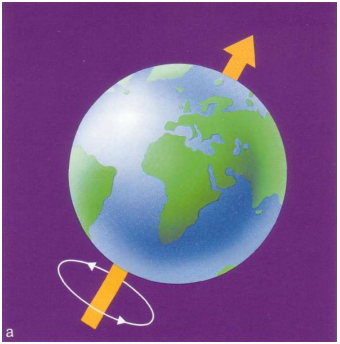

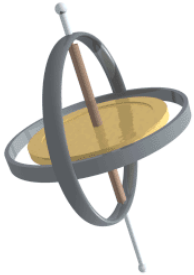

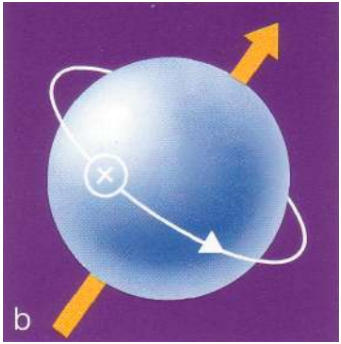

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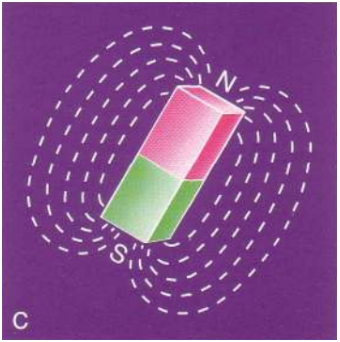

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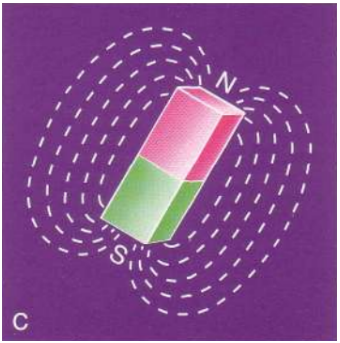

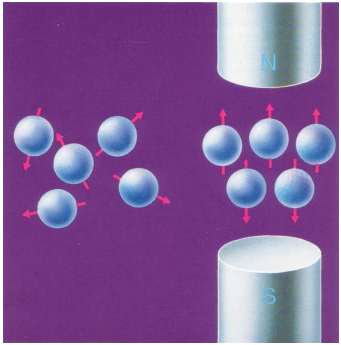

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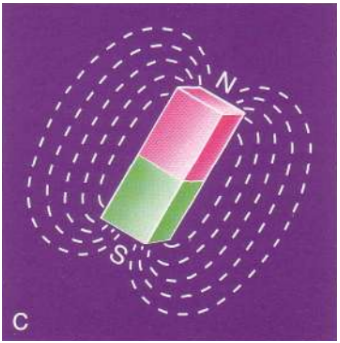

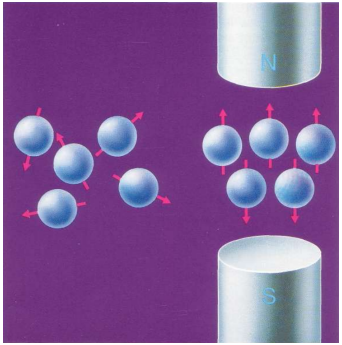

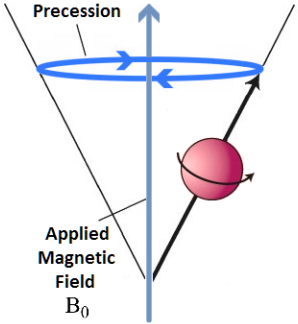

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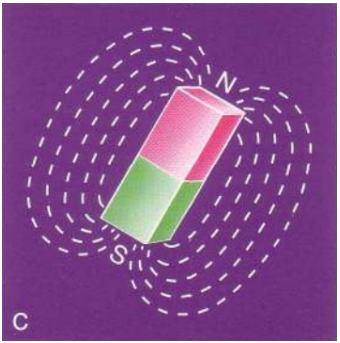

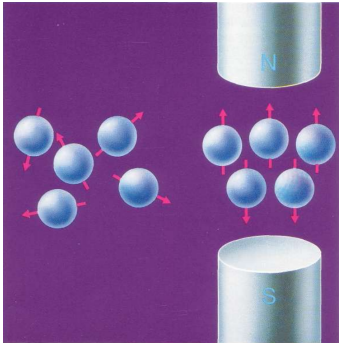

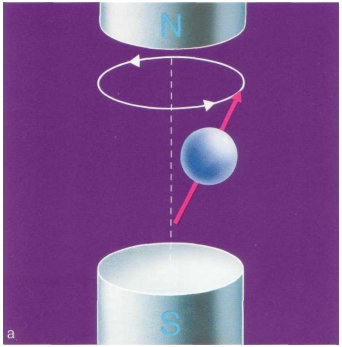

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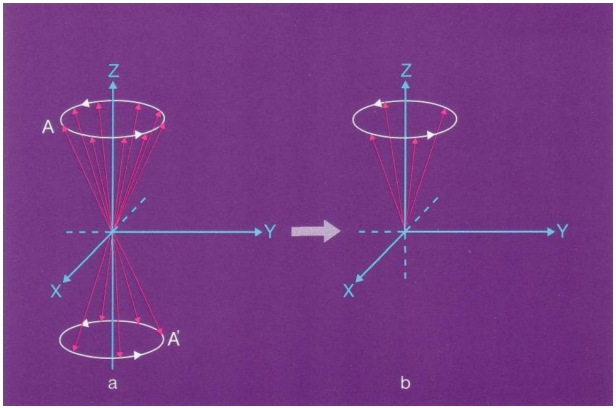

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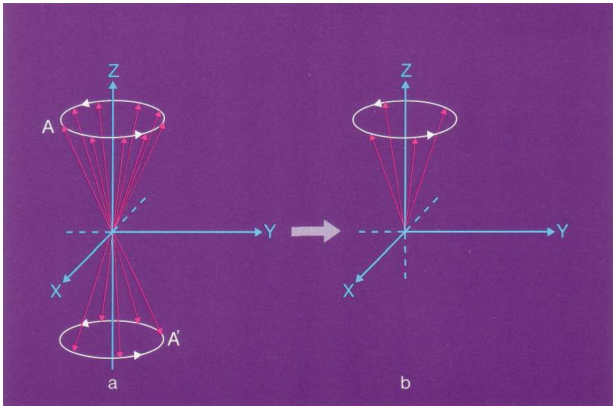

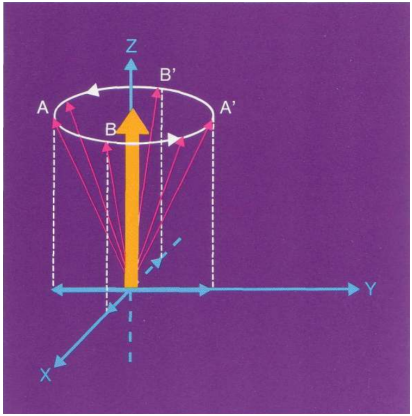

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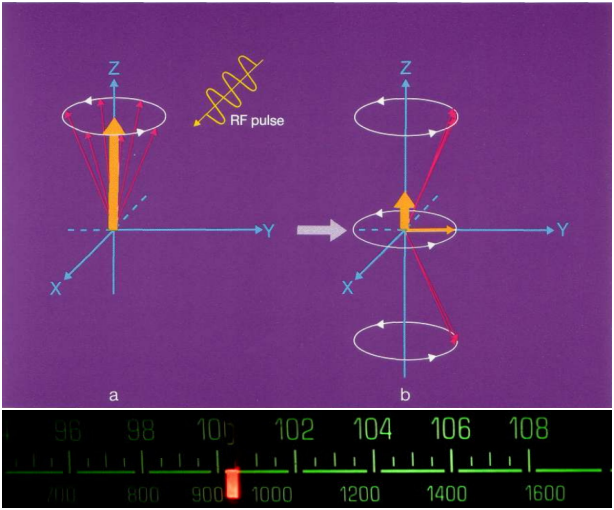

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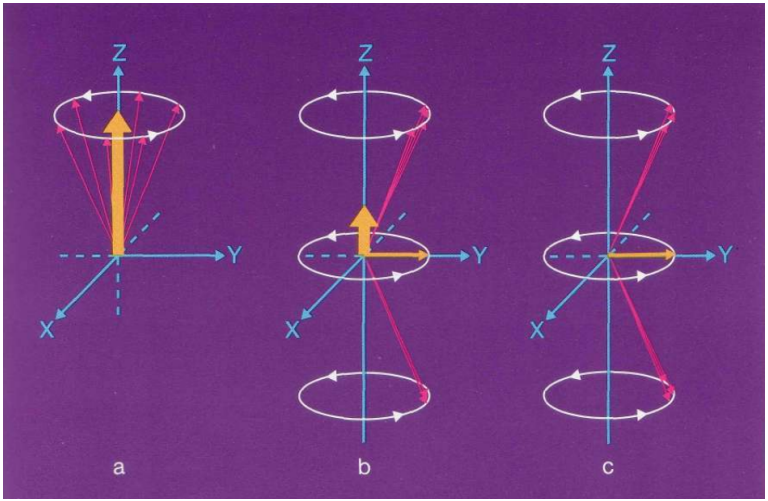
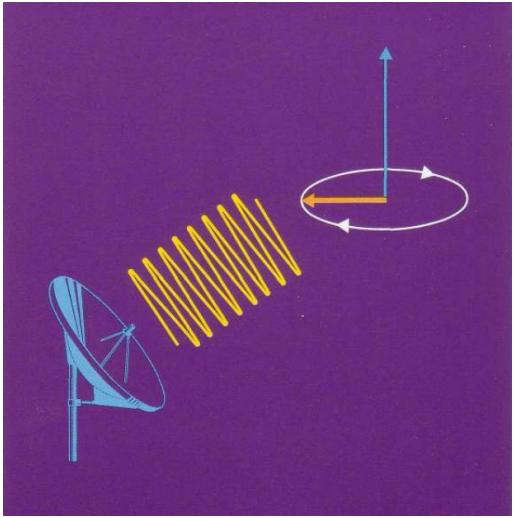
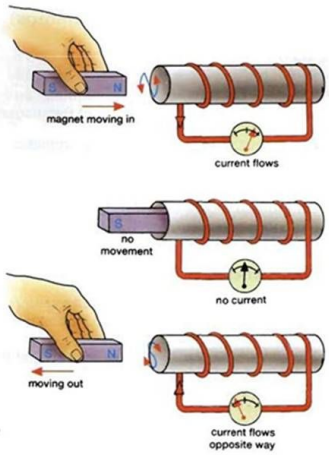


MRI Physics Overview

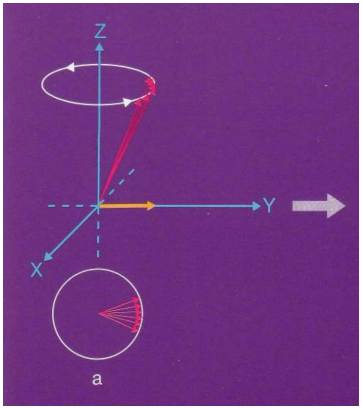


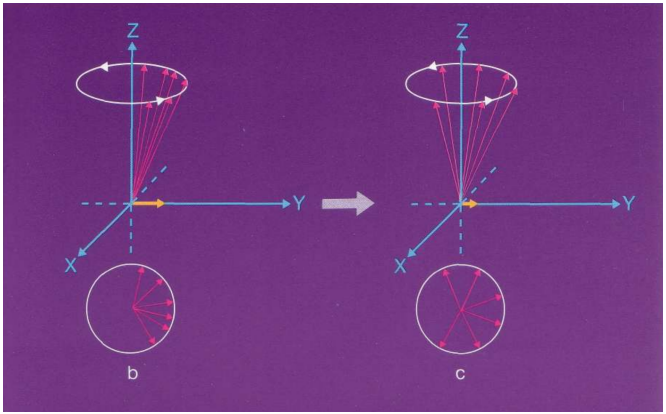


MRI Physics Summary

- Proton's have QM Spin
- When placed in a large magnet (MRI) these protons precess around the main magnetic field
- Some face up and others face down, many cancelling each other out
- If we send a RF pulse at the same precession frequency, we can put these protons in phase: we create a transverse magnetic field, and destroy the longitudinal one
- This transverse magnetic field can be measured thanks to Faraday's Law of Induction

T_2^* Overview

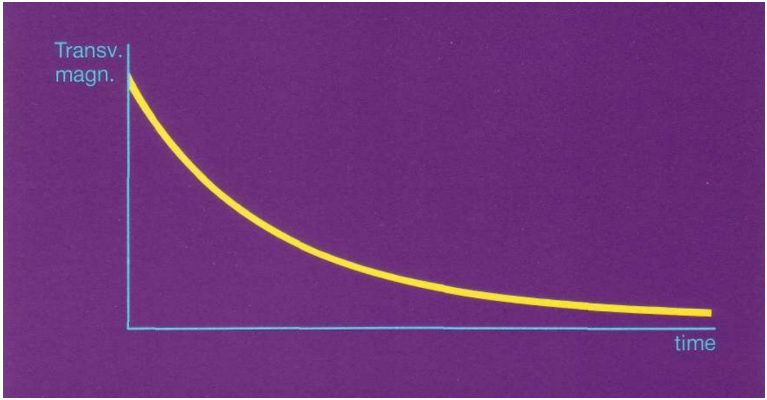




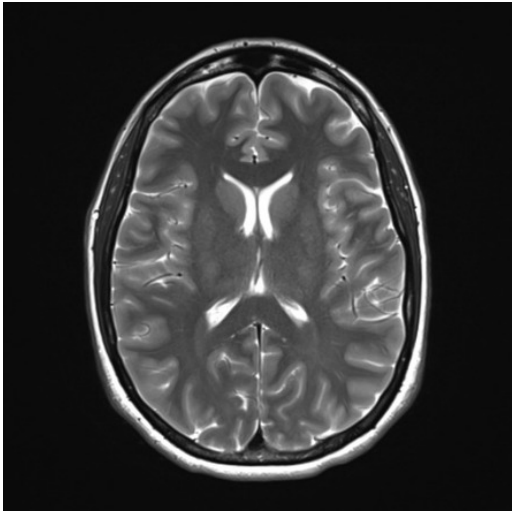
T_2^* Overview

T2 relaxation

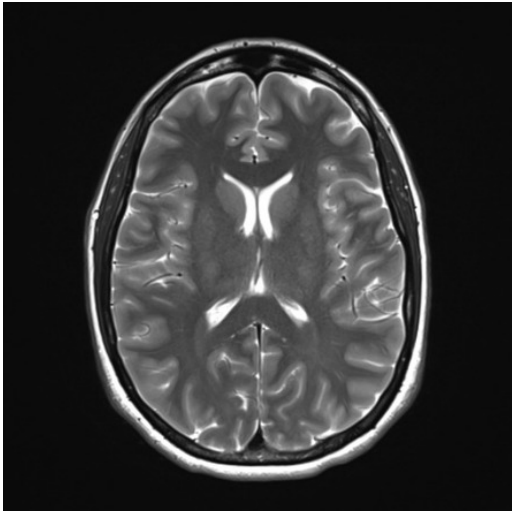
Also known as spin-spin decay: it is a time measure of the rate of decay caused by spin-spin interactions



T_2^* Overview



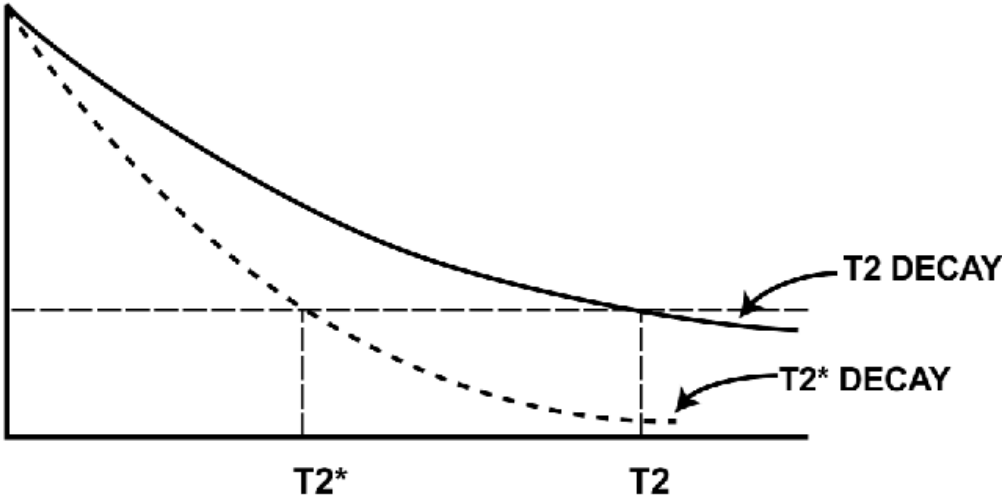
T_2^* Overview



T_2-weighted scan

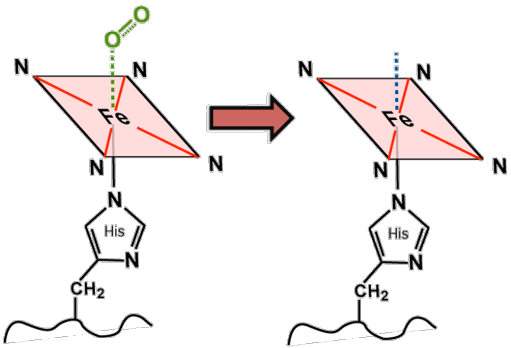
- Water is bright
- A mix of water/tissue is less bright (grey matter)
- Fatty tissue is dark (white matter)

T_2^* Overview



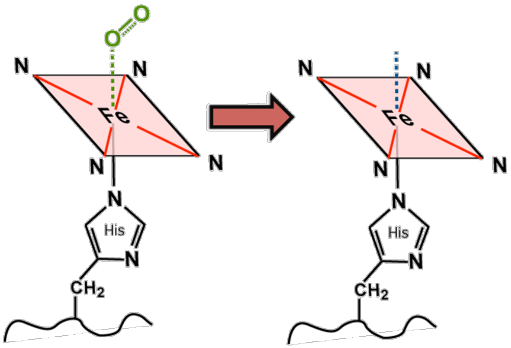
Chavhan et al. DOI: 10.1148/rg.295095034

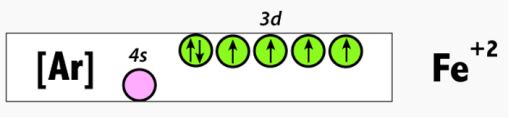
T_2^* Overview



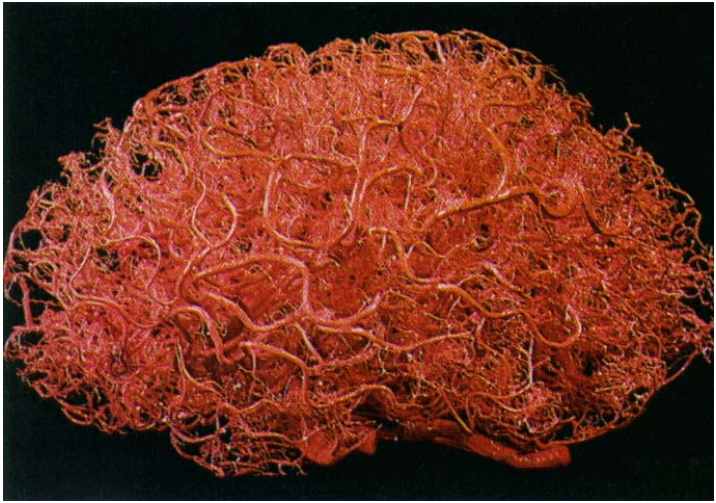
Oxyhemoglobin *Deoxyhemoglobin*

T_2^* Overview



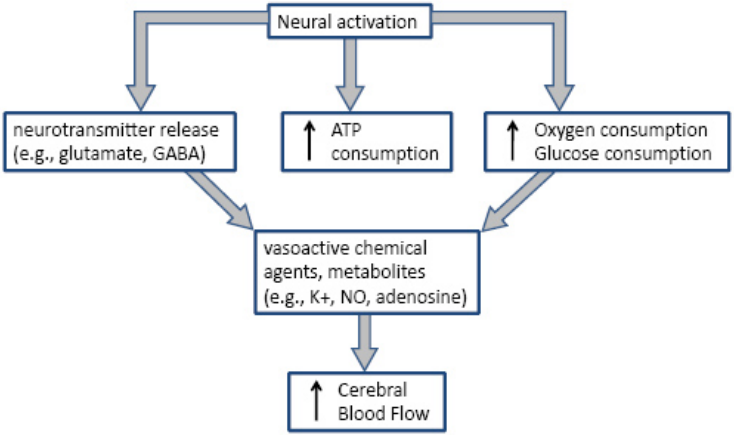


Neurovascular Coupling



Zlokovic, B. and Apuzzo, M. (1998). Strategies to Circumvent Vascular Barriers of the Central Nervous System. Neurosurgery 43, 877-878.

Neurovascular Coupling



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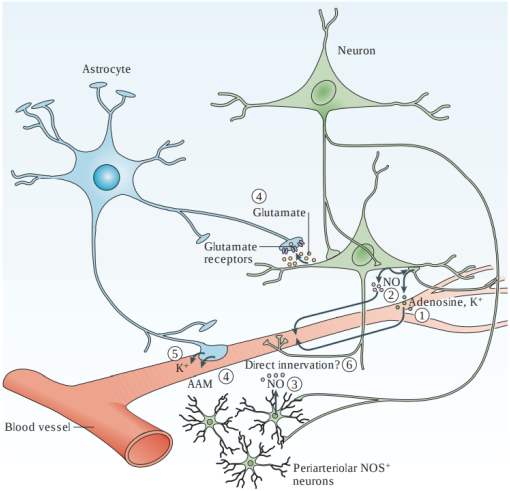
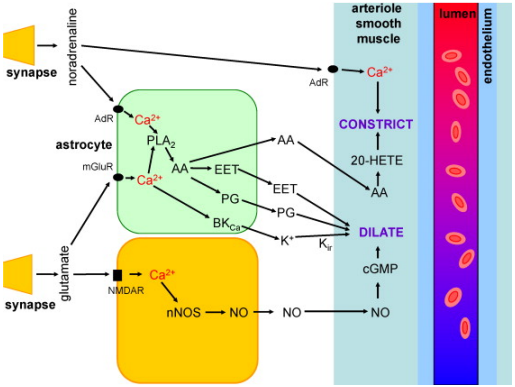


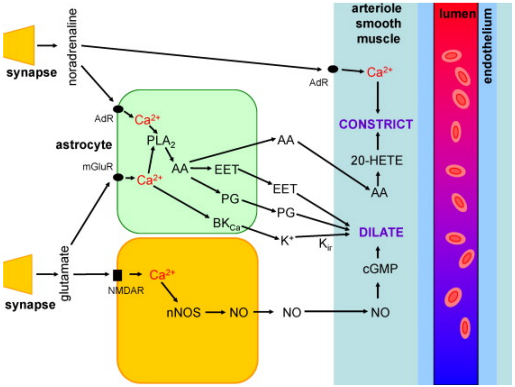
D'Esposito et al. (2003). Nature Reviews Neuroscience, 4

BOLD Effect



Harris et al. (2011). Developmental Cognitive Neuroscience, 1, 3

BOLD Effect



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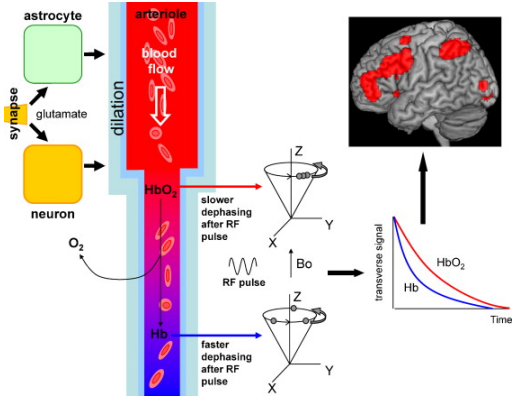
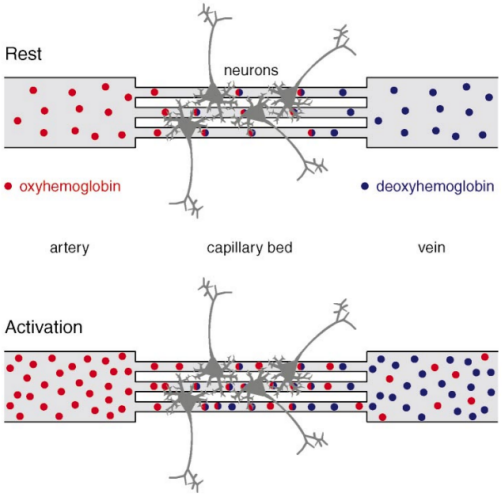


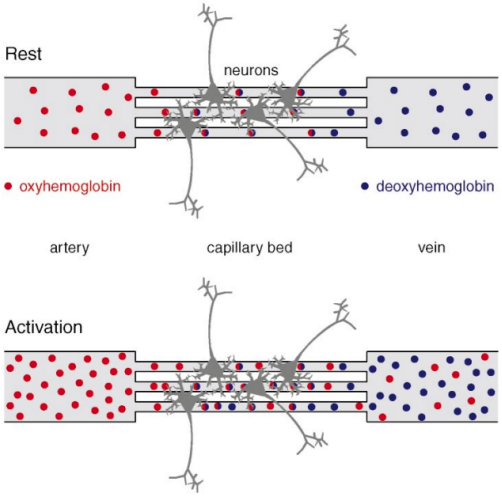
BOLD Effect



Dogil et al. (2002). Journal of Neurolinguistics, 15(1), 59-90

- Under normal conditions, oxygenated hemoglobin is converted to deoxygenated hemoglobin within the capillary bed at a constant rate

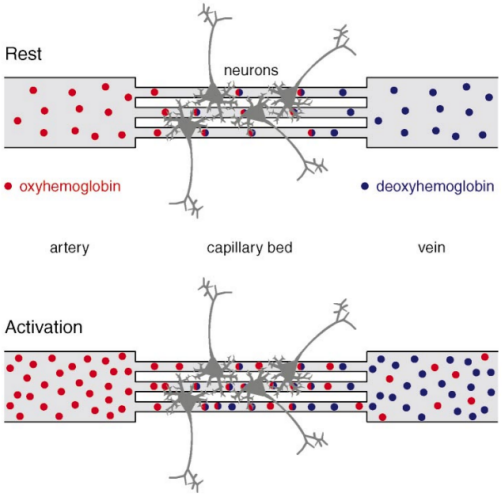
BOLD Effect



Dogil et al. (2002). Journal of Neurolinguistics, 15(1), 59-90

- Under normal conditions, oxygenated hemoglobin is converted to deoxygenated hemoglobin within the capillary bed at a constant rate
- When neurons become **active**, the vascular system supplies more oxygenated hemoglobin than is needed via an overcompensatory increase in blood flow.

BOLD Effect



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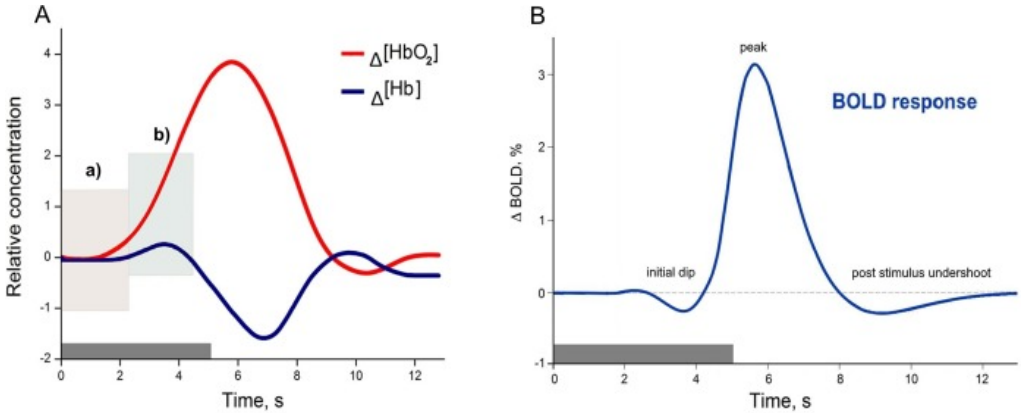
- Under normal conditions, oxygenated hemoglobin is converted to deoxygenated hemoglobin within the capillary bed at a constant rate
- When neurons become **active**, the vascular system supplies more oxygenated hemoglobin than is needed via an overcompensatory increase in blood flow.
- The result is a net **decrease** in deoxygenated hemoglobin and a corresponding **decrease in signal loss** due to T_2^* effects

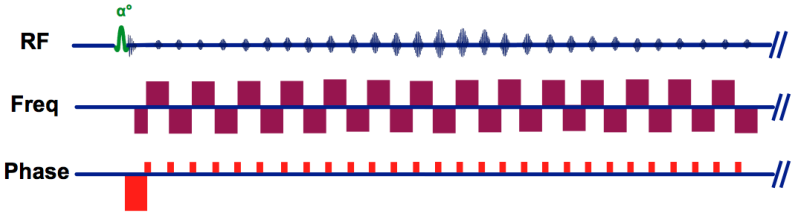
Hemodynamic Response Function

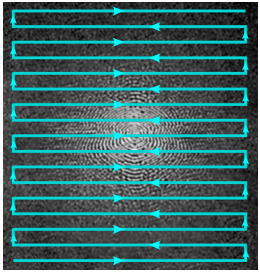


Sigita Cinciute (2019) PeerJ, Mar 25;7e6621

[Note: Please see work by Todd Woodward and others about how this shape should **NOT** be assumed]

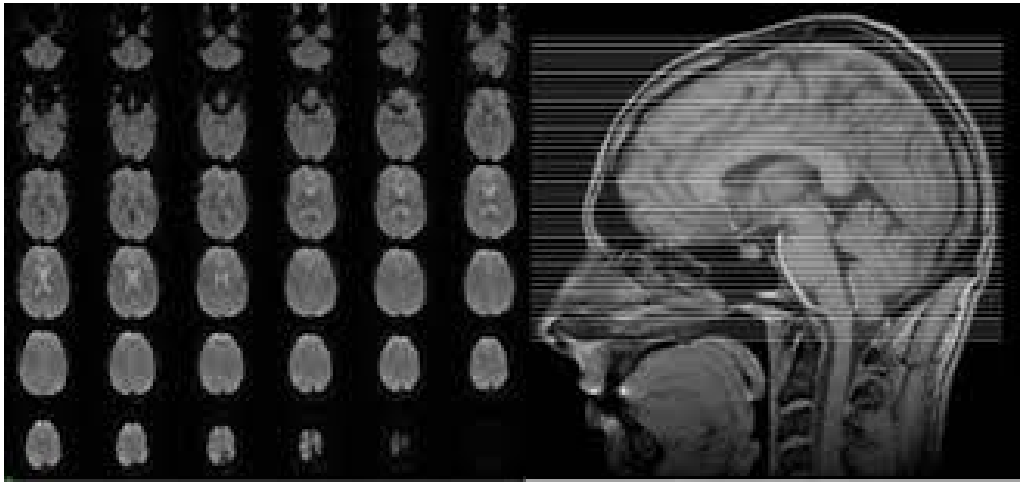
fMRI Acquisition



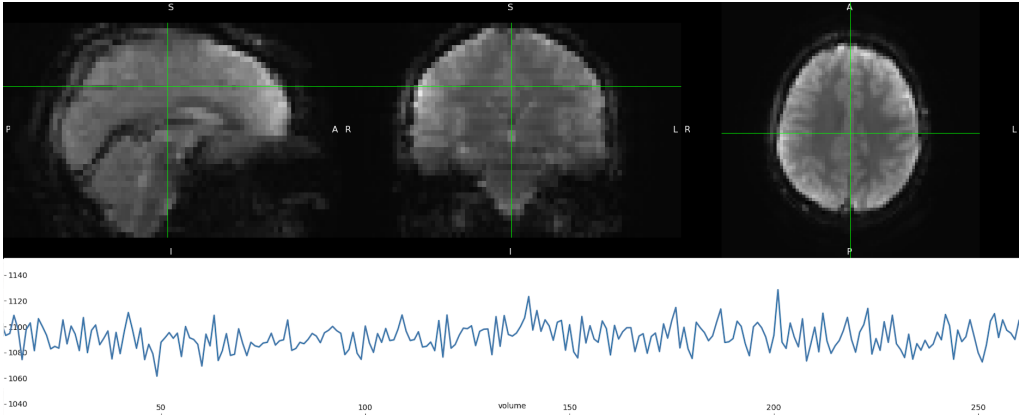


https://mriquestions.com/echo-planar-imaging.html

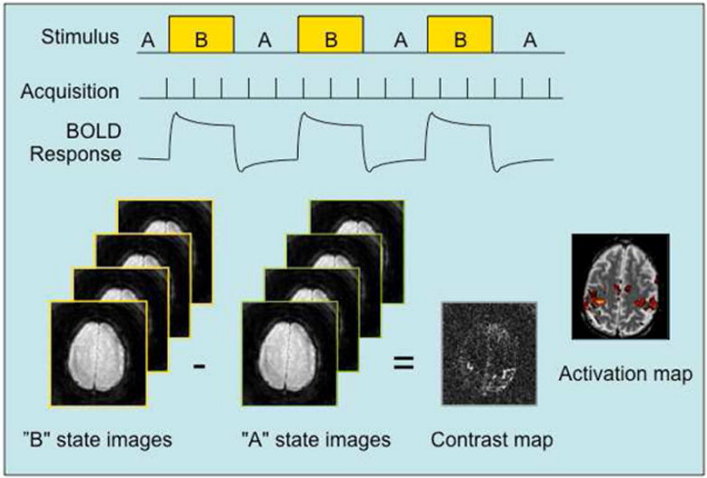
fMRI Acquisition



fMRI Acquisition

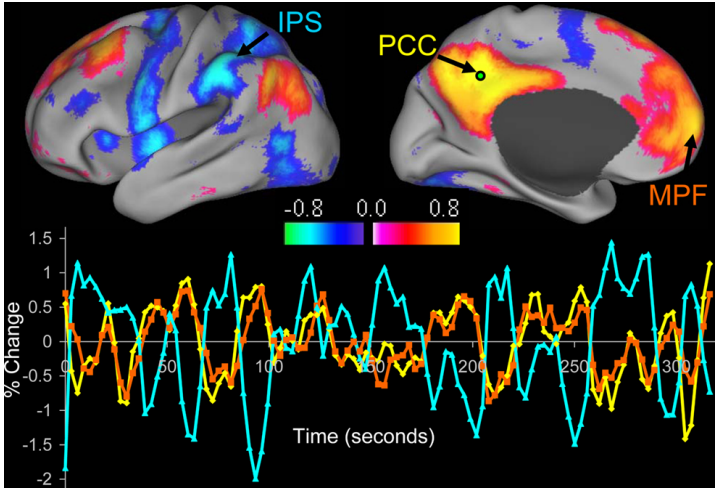


fMRI Acquisition: Task-based



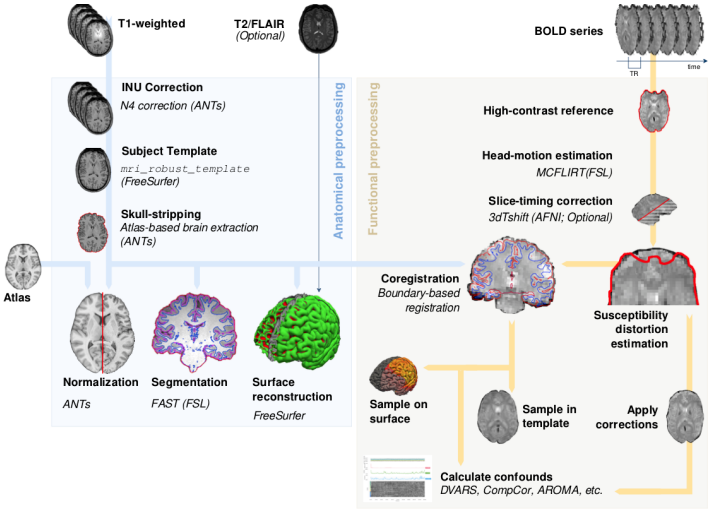
Gary Glover. (2011). Neurosurg Clin N Am, 22(2): 133-139

fMRI Acquisition: Resting state



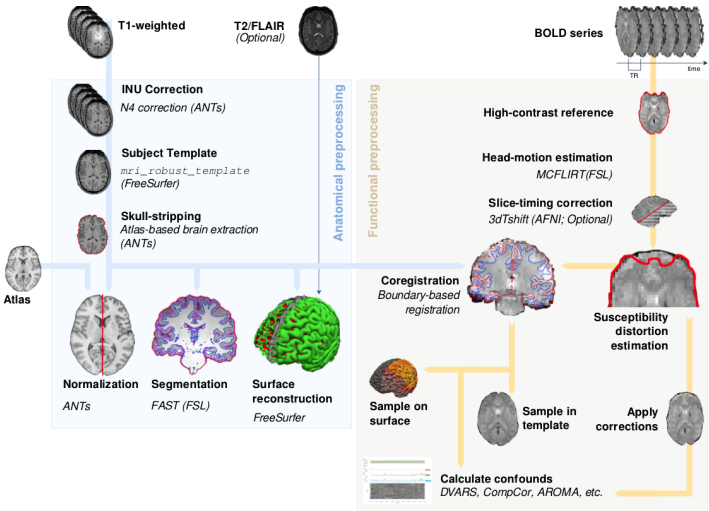
Fox and Greicius. (2010). Front Syst Neurosci, 4(19)

fMRI Analysis: Preprocessing



Markiewicz et al. (2018). OHBM Poster #2305

fMRI Analysis: Preprocessing



Markiewicz et al. (2018). OHBM Poster #2305

- Brain extraction
- Motion correction
- Slice-timing correction
- Susceptibility distortion correction
- Registration and Normalization
- Estimate noise/confounds
- Data quality check

Sockeye