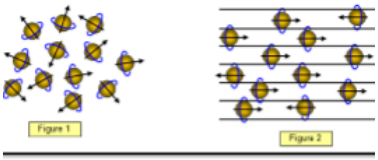
PSY3180 Neuropsychology Notes

Week 1: Introduction to Neuroscience Methods

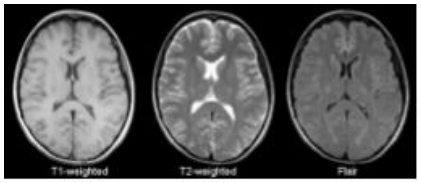
The Brian Imaging Revolution

- Post-mortem limited:
  - No experimental control
  - Waiting until patients are deceased
- Imaging provides access to the brain in-vivo (whilst in persons head functioning normally)



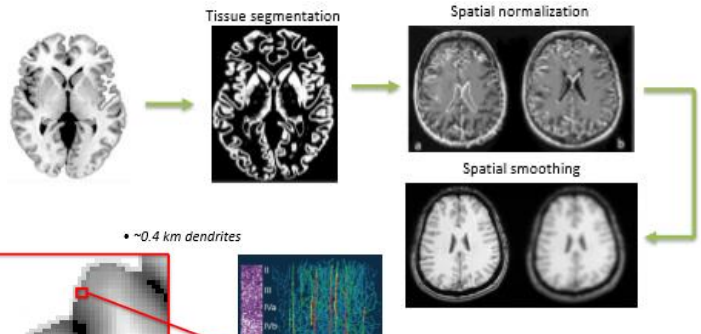
Basic MRI Physics

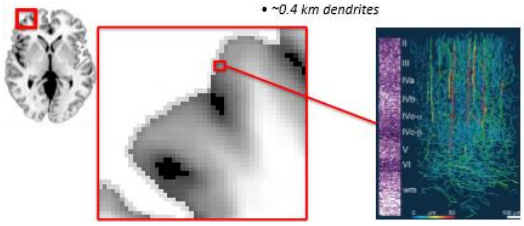
- RF pulses (energy) causes spinning hydrogen atoms to dephase
- When the RF pulse stops, hydrogen return to the original aligned position with the magnetic field
- MRI measures how hydrogen returns to original position which gives us our images



Structural MRI (T1)

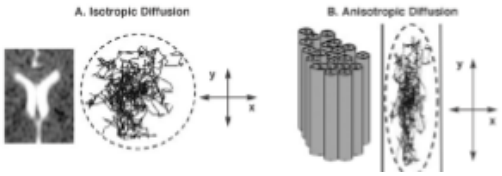
- Highly detailed, static image of the brain
- Used to examine properties of brain structure
- Often used clinically to diagnose gross pathology
  - Tumours
  - Bleeds
- Morphometrics
  - Examine the 'size' and 'shape'
  - Caveats
    - A single 3x3x3mm voxel
      - ~20-30 thousand neurons
      - ~1 billion synapses
      - ~4km axons
      - ~0.4km dendrites





Diffusion Weighted MRI

- Basic DWI Physics
  - DWI measures the diffusion of water throughout the brain
  - Without constrain, water diffuse randomly in all directions (isotropic)
  - With constrain, diffusion is directional parallel to constraining barriers (anisotropic)
  - White matter fibres create such constraints



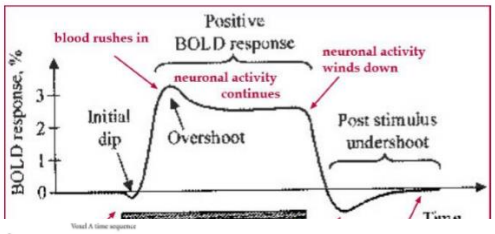
To Diffusion Tensor Imaging (DTI) to Tractography

- Tracks ARE NOT axons
- Tractography is only an approximation of underlying white matter, a wiring map of the brain
- Determines which grey matter is physically connected
- Cross fibres
- Undirected – not sensitive to efferent/afferent connections, not sure if signals sent to A or sent to B

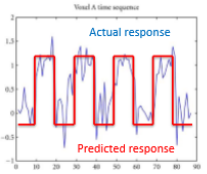
Functional Magnetic Resonance Imaging (fMRI)

- Basic fMRI Physics
  - Imaging brain 'states' or 'function' instead of structure
  - Snapshots of the brain that can be out together to develop a time series of neural activity
  - Neurons need oxygen to operate

- Oxygen is supplied via the bloodstream
- The ratio between oxygen-rich and oxygen-poor blood in a given voxel is read by MRI
    - More neuronal firing = more blood flow = greater contrast
- This contrast is the basis of the Blood-Oxygenation-Level-Dependent (BOLD) signal



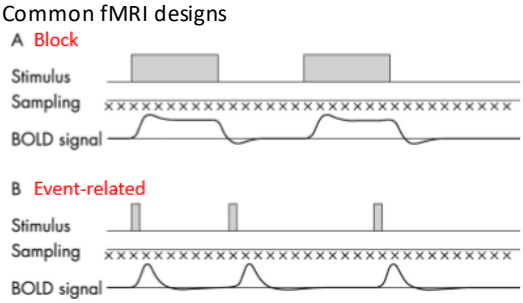
- fMRI Models
    - Every voxel has an associated time series
    - fMRI response is modelled using the General Linear Model (GLM)
    - A good match implies activity in vowel related to stimulus



$$Y = X\beta + \varepsilon$$

Activity in a voxel — Predictor — Weight — Error

- Common fMRI designs



- Caveats
    - Blood flow is not neuronal activity
    - Increased BOLD may reflect all kinds of neural activity
    - Relatively poor temporal resolution

Resting-State fMRI

- The brain represent 2% of body weight, but accounts for 20% of oxygen consumption
- Task-evoked activity accounts for <5% of the brain's energy consumption; possibly as low as 1%
- ~80% of energy consumption is devoted to neural signalling
- Resting state fMRI is the spontaneous fluctuations in BOLD activity while the brain is not engaged in a task
    - Is often quantified using
        - Seed-based connectivity
            - > Involves taking a region of the brain and pulling out the time series
            - > Correlate the timesseries from a region of interest again the time series of the rest of the brain
            - > Gives us an SPM which quantifies the extent to which the time series in our region of interest predicts BOLD activity around the rest of the brain (resting state functional connectivity)
        - Independent component analysis (ICA)
            - > Takes all the independent time series and looks for independent components that relate in all of the time series
            - > Provides map for resting state networks

Electroencephalogram (EEG)

- Measure the electrical potentials produced by neuronal firing
- Electrodes attached to scalp
- Three common modes of analysis
    - Event-related potentials (ERP)
    - Time-frequency analysis
        - How the power of the frequencies changes across different sites and different conditions
    - Source reconstruction
        - A projection of signals learnt from the scalp onto the brain
        - Make a prediction of where on the surface of the brain the EEG signals originated from

Magnetoencephalogram (MEG)

- Measures the magnetic fields produced by neuronal firing
- Similar modes of analysis to EEG
    - Event-related potentials (ERP)
    - Time-frequency analysis
    - Source reconstruction

EEG vs MEG

- Complementary modalities
    - EEG sensitive to parallel electric currents