Basics of Functional Magnetic Resonance Imaging

How MRI Works

- Put a person inside a big magnetic field
- Transmit radio waves into the person
  - These "energize" the magnetic field of the **H**ydrogen nucleus in water (**H_2O**)
- H_2O magnetic energy comes back out as very weak radio waves, which are measured by a radio receiver (RF coil)
- Frequency of these radio waves is tuned by changing the magnetic field while they are being received (gradient coil)
- Frequency changes let images be created

Basic MRI Concepts - 1

- **TR** = time between reading data out from same location in the brain
  - Smaller TR is faster imaging
- **Slices** = images are usually made in thin slices, which must be put together to make up a 3 dimensional volume
  - It usually takes about 50-100 ms to get the data for one slice image
  - To cover the whole brain = about 30 slices that are 3 mm thick $\Rightarrow$ TR is 1.5 to 3.0 seconds
  - Slower than the heartbeat; Faster than breathing
- **Voxel** = smallest 3 dimensional unit of imaging

Basic MRI Concepts - 2

- **TE** = how much time it takes between the radio wave transmit that starts the image, to the ***center*** of the image data acquisition
- For functional MRI at 3 Tesla, one big problem is image "dropout" (dark regions) in brain regions near air
  - Nasal sinuses ⇒ dropout in medial frontal lobe
  - Ear canals ⇒ dropout in temporal lobes
- Possible solutions (or palliatives):
  - Thinner slices
  - Make TE as short as possible

Basic MRI Concepts - 3

- Functional MRI runs MRI scanners very hard
- Small problems with the scanner hardware can cause problems with the high speed images that are used for FMRI
  - **Echo Planar Images** = **EPI**
  - These small problems might not show up in slower images that are used for medical purposes
  - It is important to check the EPI image quality of your scanner very often by scanning a "phantom" object and looking at the amount of noise
  - If the noise increases some day, you need help!

What is Functional MRI?

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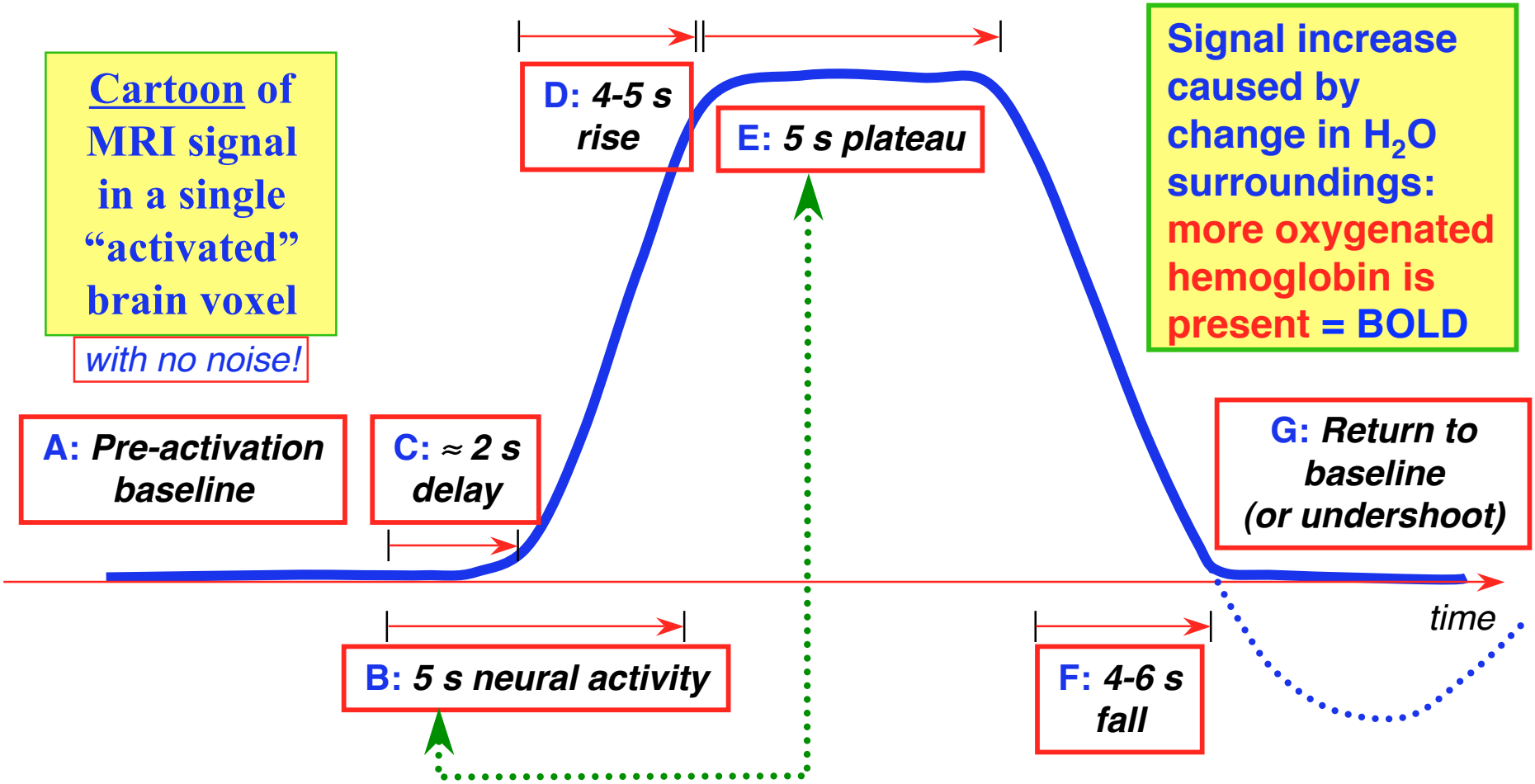
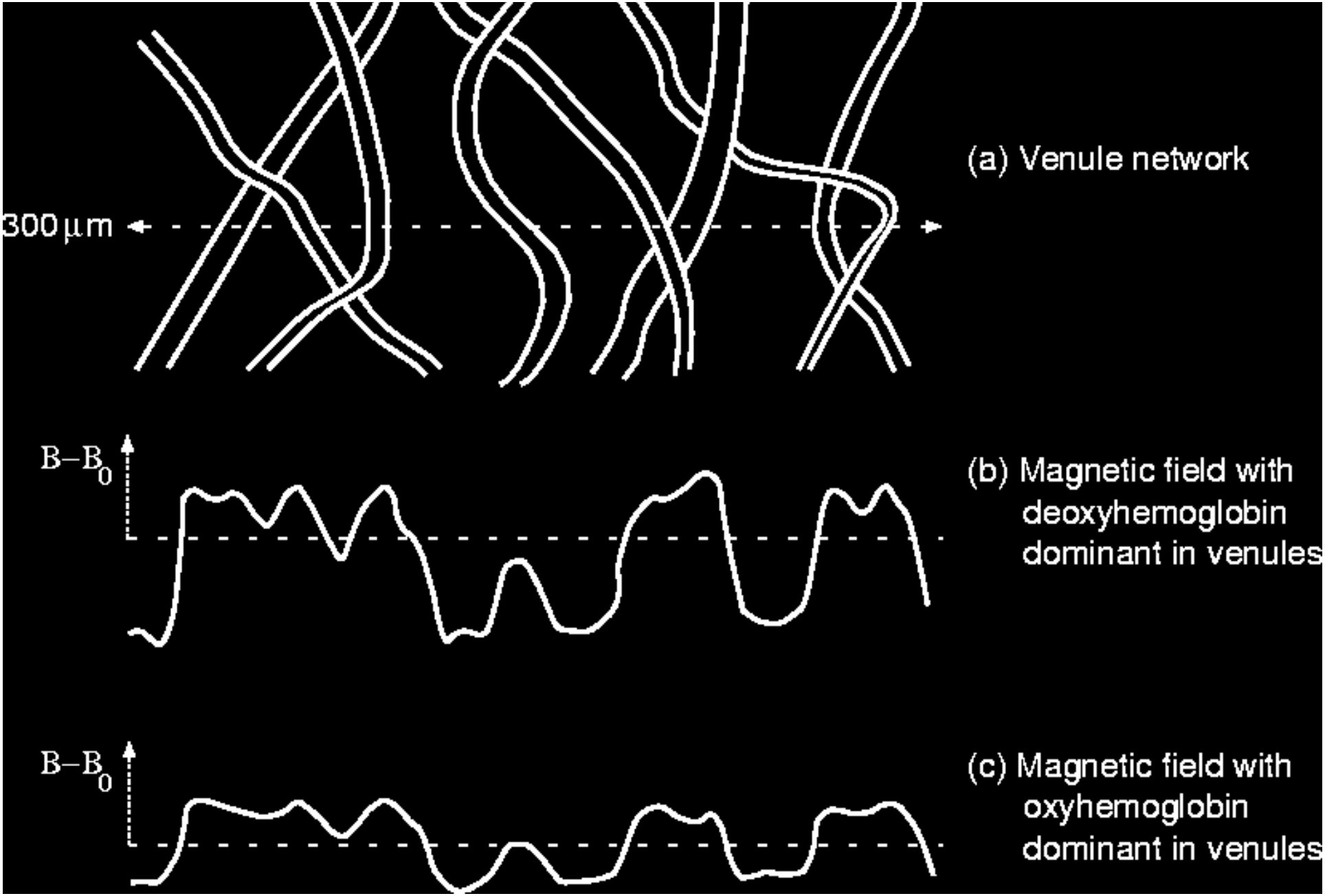
- 1991: Discovery that MRI-measurable signal increases a few % *locally* in the brain after increases in neuronal activity (Kwong, *et al.*)



Cartoon of Veins inside a Voxel



FMRI = It Takes a Team

- FMRI is complicated
  - MRI physics and engineering and operation
  - Stimulus equipment design and operation
  - Design of experiment
  - Analysis of data: **AFNI**, **SPM**, **FSL**, **BrainVoyager**
  - Understanding the results of the analysis
- FMRI research center needs
  - MRI physicists or engineers
  - Statistical experts for data analysis
  - Computer experts
  - Plus psychologists and brain scientists!

What Kinds of Questions Can Be Answered with Functional MRI?

Task Based FMRI

- To find out information about brain processing of short (1-30 second) stimuli or tasks
- Locations in brain that are more or less active in different tasks
  - and correlations between activation fluctuations
- Dependence of neural activation strength (BOLD effect) on task parameters (pain level; face type; …)
- Dependence of neural activation on subject parameters (age; disease; …)

Type of Stimuli or Tasks

- Short visual or auditory (sound) inputs
  - Faces / Houses ; Musical tones ; Words
- Decision tasks
  - Same face? Tones up or down? Animal?
- You may not care about actual task
  - You might care about the CONTEXT in which the task appears
  - Faces: task is MALE or FEMALE but context is **angry** or **fearful** face

Groups of Subjects

- Can look for differences in activation parameters between group of subjects
  - Patients and "normals"
  - Genotypes
- Differences in
  - Activation magnitude
  - Inter-regional activation correlations
  - Correlation of activation with covariates

Hard Tasks for FMRI

- Anything that requires subject to speak
  - One word or sound can be OK
  - Requires censoring out MRI volumes during subject speech — jaw motion is bad for images
- Anything that uses subtle sounds (music)
  - Scanner is very loud
  - One solution: silent period between scans
- Very long duration tasks (learning; drugs)
  - Hard to tell long activation changes from MRI signal drifting up or down
  - Not impossible, but requires special analysis

My Advice: Start Small

- Do some simple experiment that you KNOW will give results with FMRI
- Then increase complexity to get closer to what you really want to do
- Do NOT start with your first FMRI experiment being something very complicated and subtle!

FMRI Connectivity

- Looking for MRI signal fluctuations that are correlated (vary up and down at same times) in different spatial locations
- Can be based on task FMRI or based on "resting" FMRI
- Hot new word: **Connectome**
- We have a couple of talks about connectivity analyses in AFNI
- Data analysis methods are more variable than for task-based FMRI

Brain "Reading"

- Trying to find out what the brain is doing from the FMRI data
  - Is the subject looking at a face or at an elephant?
- Multi-Voxel Pattern Analysis = **MVPA**
- Training data:
  - To build up different patterns of brain data for different types of brain functions
  - Support Vector Machines = **SVM**
- Then apply patterns to new brain data to estimate what subject is doing
- The limits of MVPA are still being researched