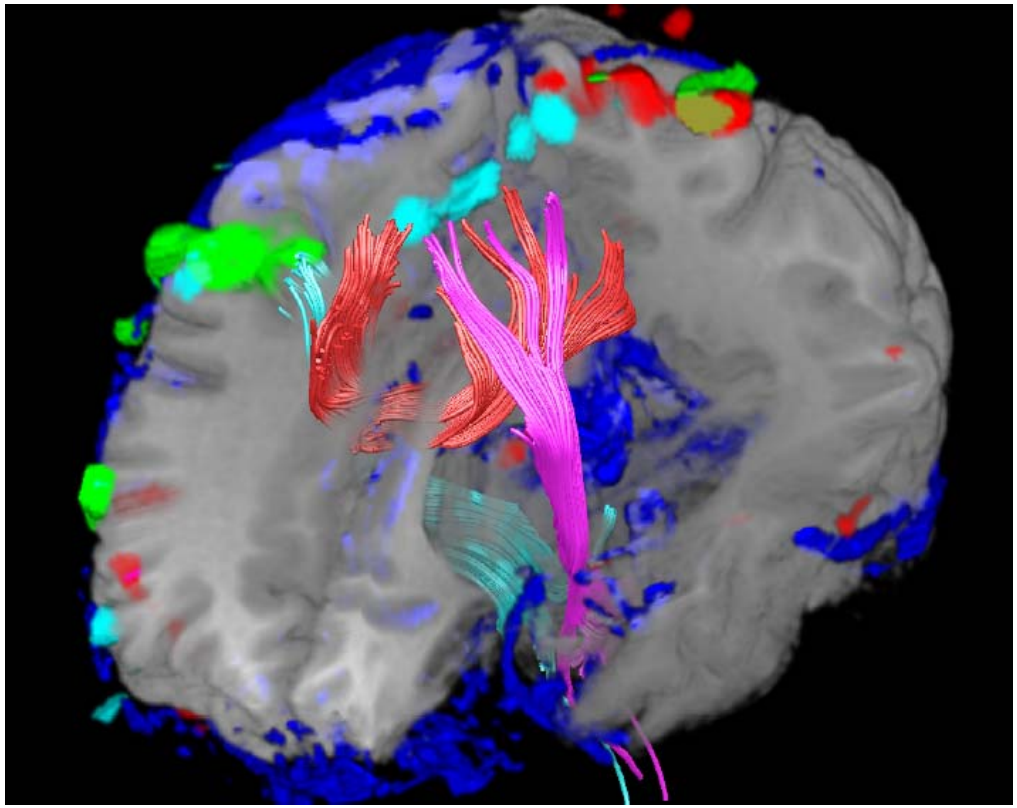
Neuroimaging of Speech and Language processes with MEG and fMRI

Susan Bowyer Ph.D.
Medical Physicist
Department of Neurology
Henry Ford Hospital

www.megimaging.com

Integrated Imaging of the Brain

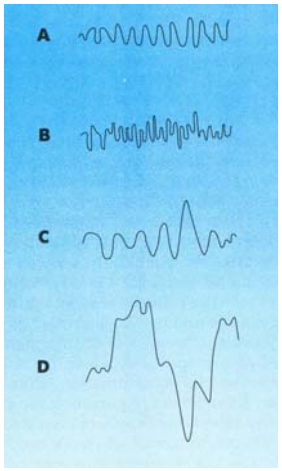
This image displays the fiber tracks, several functional areas, the vasculature and the underlying anatomy. On the right we can see the cortical spinal track (cyan) projecting from the left hand motor region (green).



Hardenbergh et. al “Integrated 3D Visualization of fMRI and DTI tractography” 2006 HBM, conference

Functional Imaging Techniques

Electroencephalography EEG



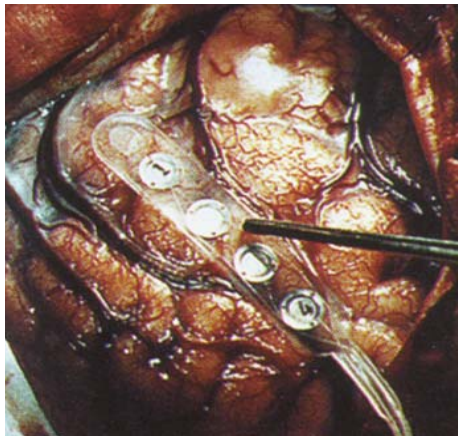
Alpha (8-12 Hz)

Beta (13-30 Hz)

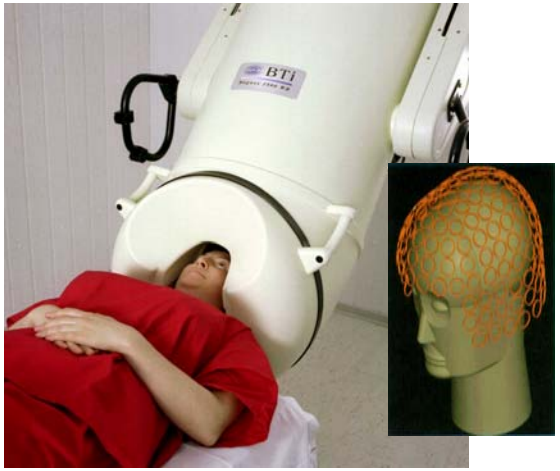
Theta (4 - 8 Hz)

Delta (< 4 Hz)

Gamma (> 30 Hz)



Electroencephalography ECoG



Magnetoencephalography MEG

Sources of MEG and EEG

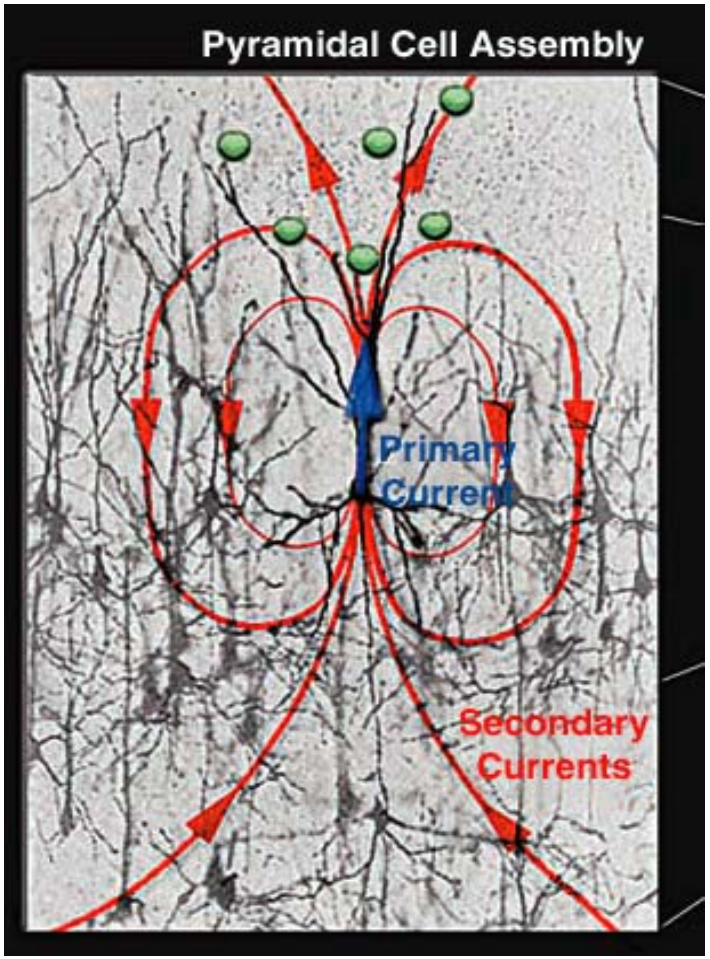
- MEG signals primarily arise from intracellular current flow in pyramidal neurons

  Called - Primary Currents

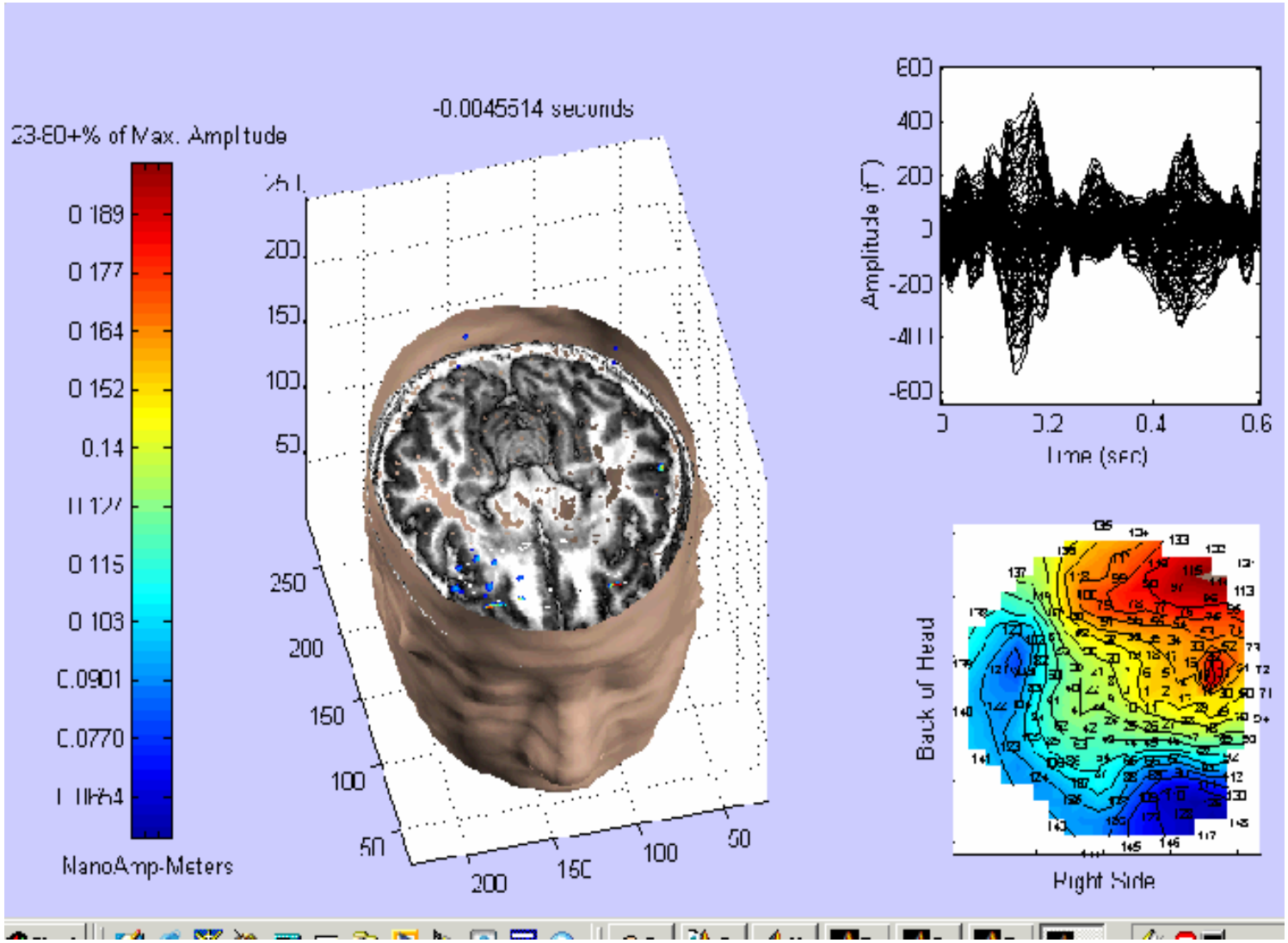
- EEG signals primarily arise from extracellular current flows

  Called - Secondary Currents

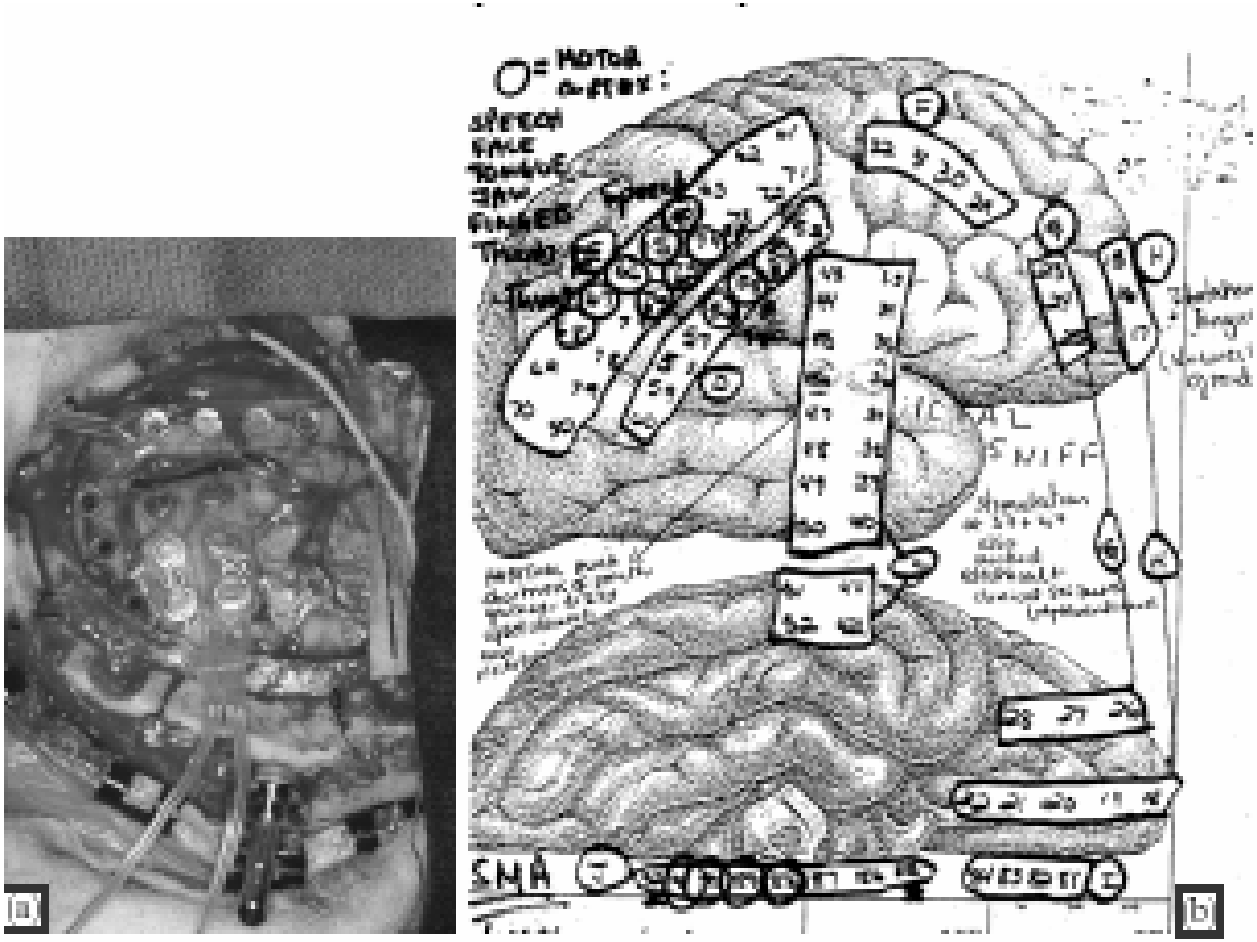
- Secondary Currents cancel in MEG due to symmetry



Time Evolution of Language Processing

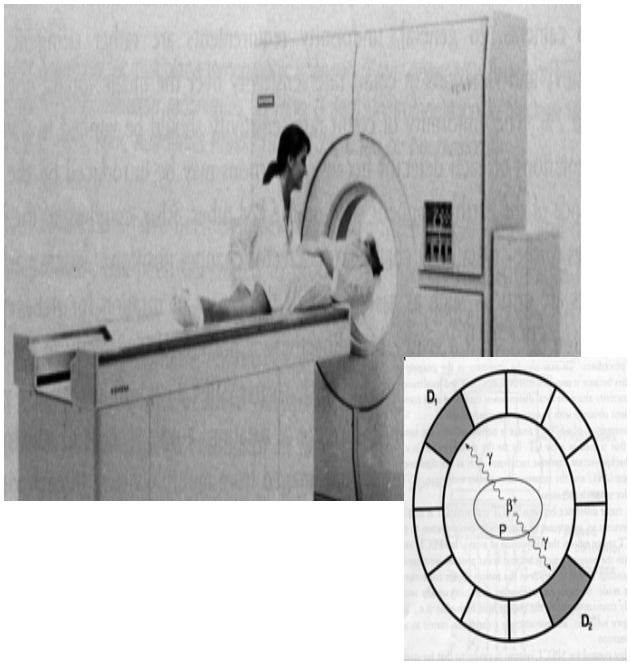


Electrocorticography Localization



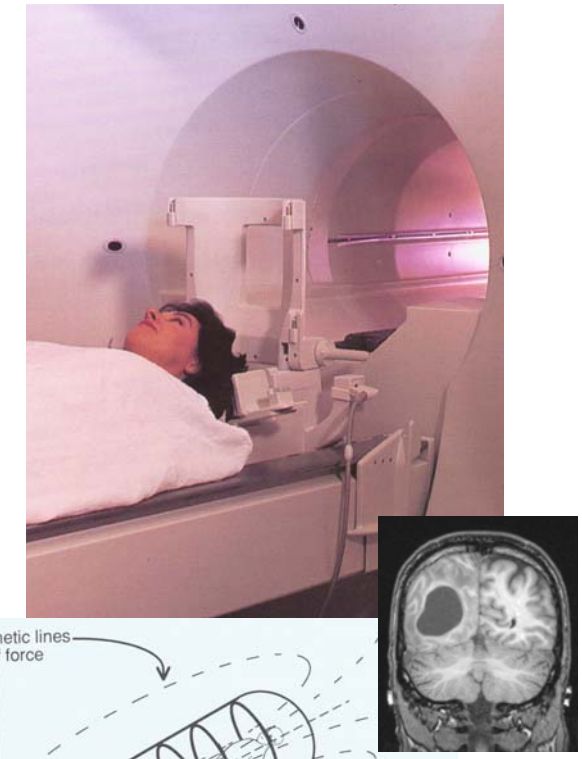
Subdural electrodes placed on cortical surface.
Typical 2D views of the brain diagram used to mark the electrode locations and hand written schematic results of the brain mapping tests.

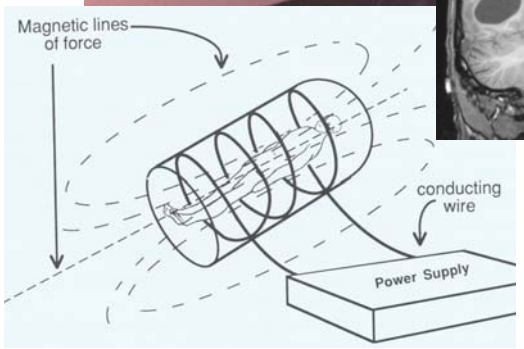
Functional Imaging Techniques



A technique for measuring blood oxygenation of specific tissue during a task.

Both techniques overlay Pixel activation onto an MRI scan

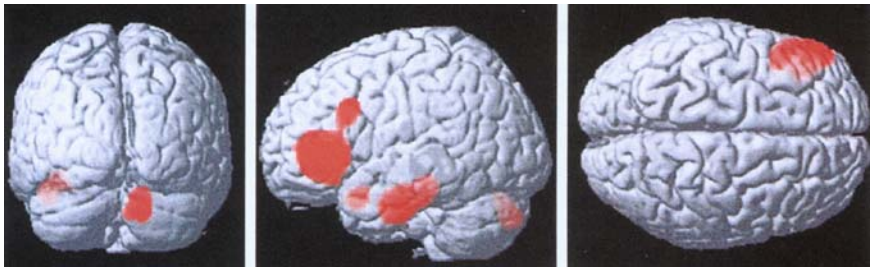




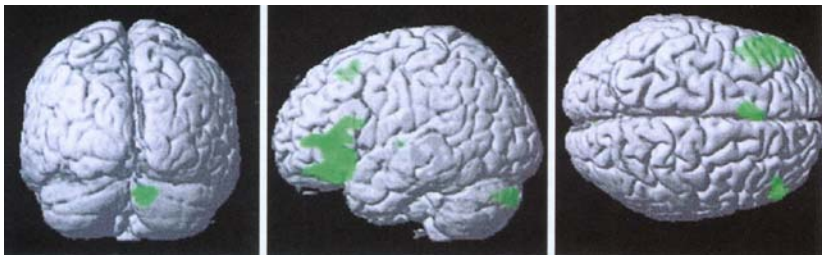
A technique for studying the metabolism of the brain, by using positron-emitting isotopes ^{11}C, ^{13}N, ^{15}O, and ^{18}F labeled molecules in solution and injected into a subject.

Combined fMRI and PET

fMRI

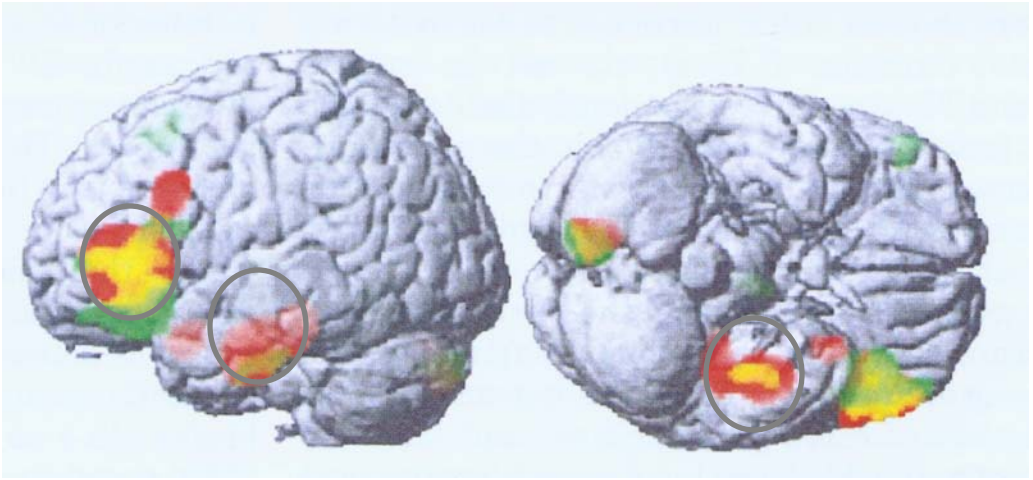


PET

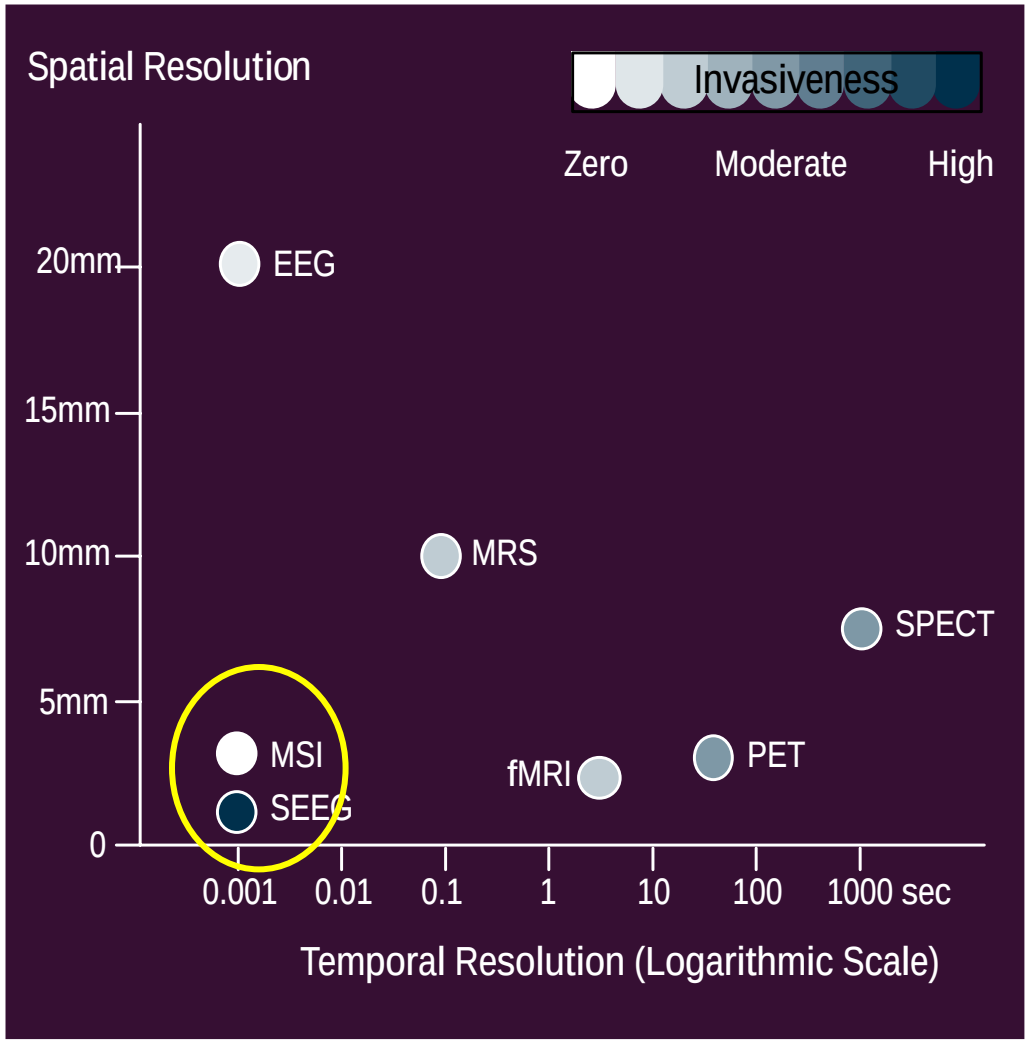


Semantic-Letter categorization comparison task

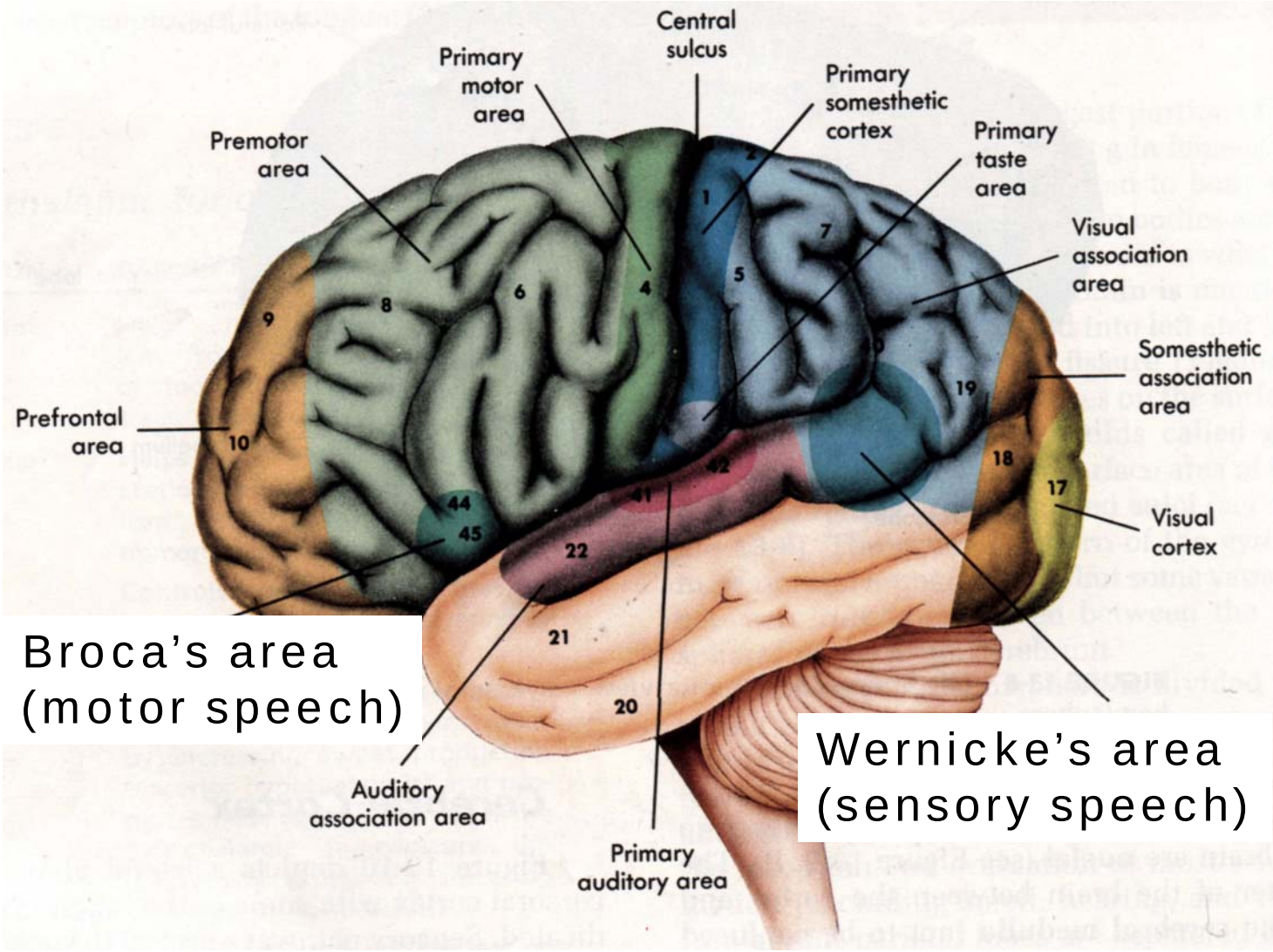
Yellow color is where fMRI and PET results overlap

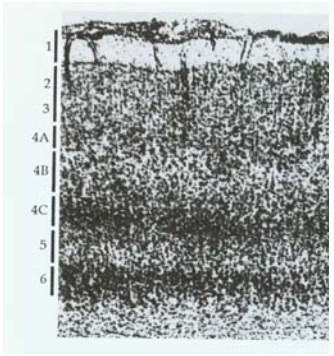


Spatial and Temporal Resolutions for Various Functional Imaging Modalities

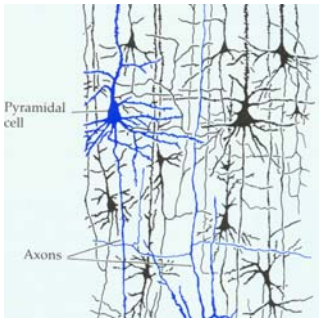


Localization of Language Areas





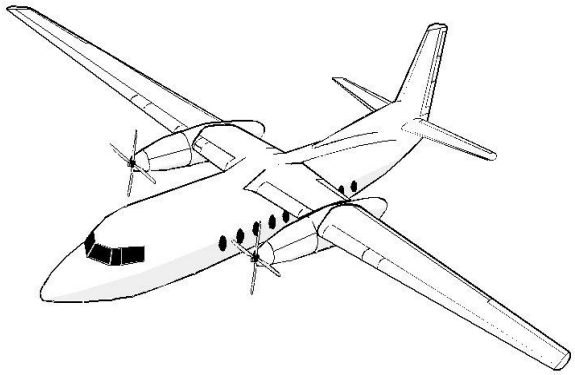
cortical tissue slice



Cells lined up in the cortical surface

Language Tasks

Picture Naming

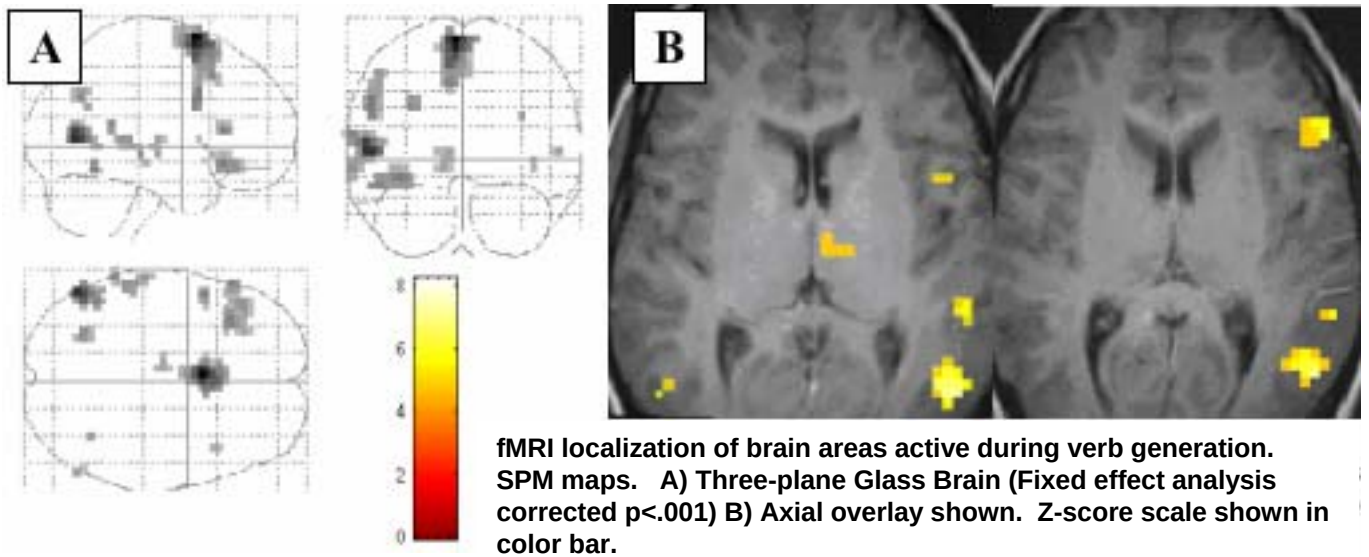


Verb Generation

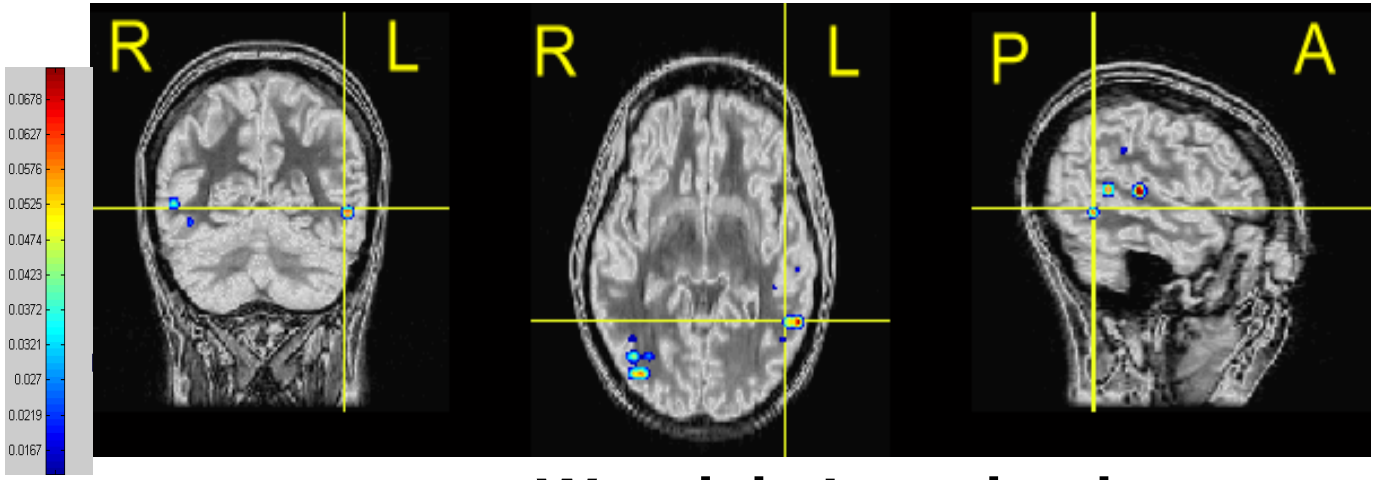
Book

Identical tasks used during intracranial mapping ECoG.

Verb Generation



fMRI localization of brain areas active during verb generation. SPM maps. A) Three-plane Glass Brain (Fixed effect analysis corrected p<.001) B) Axial overlay shown. Z-score scale shown in color bar.



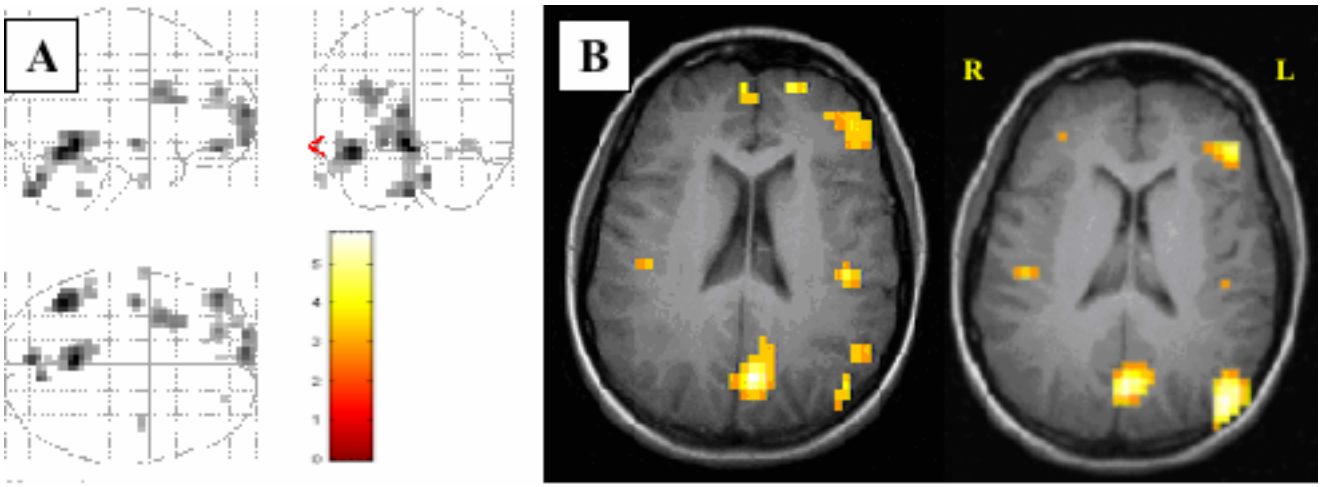
nanoAmp-meters

MEG localization at 255 ms after onset of Visual word. This is the point at which the brain is generating the verb. MR-FOCUSS results scale in nanoAmp-Meters

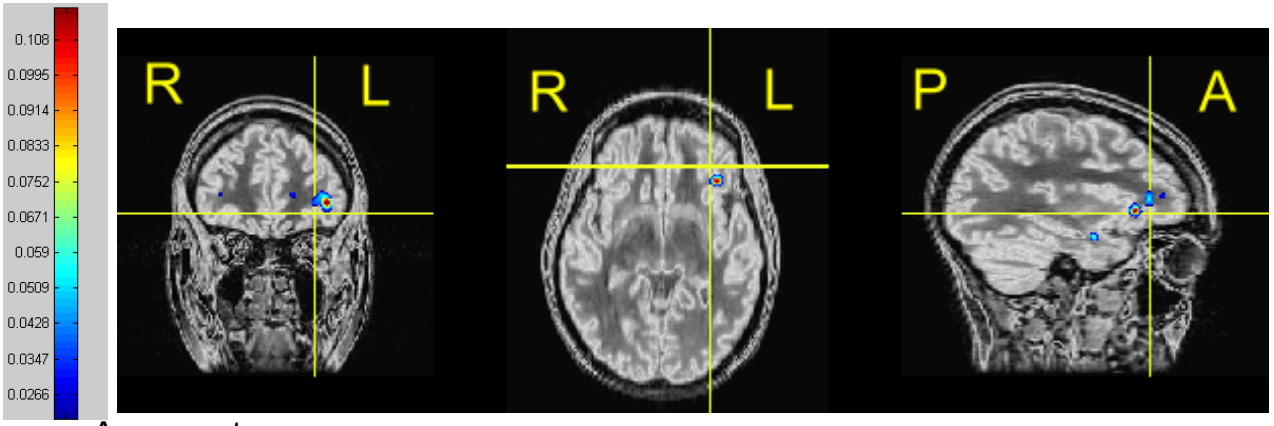
Bowyer et al 2004

Wernicke's activation

Picture Naming



fMRI localization of brain areas active during Picture Naming. SPM maps. A) Three-plane Glass Brain (Fixed effect analysis corrected p<.001) B) Axial overlay shown. Z-score scale shown.



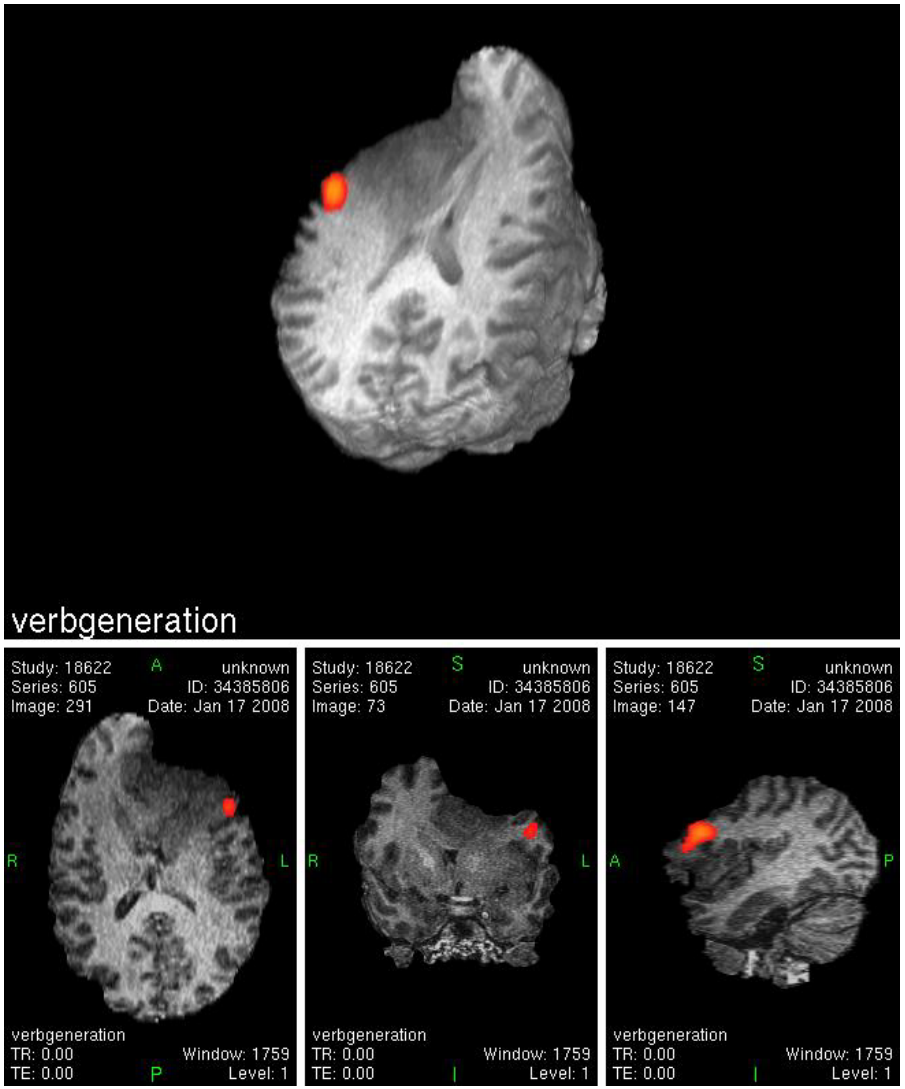
nanoAmp-meters

MEG localization at 320 ms after onset of Visual picture. This is the point at which the brain is telling the mouth to say the word. MR-FOCUSS results scale in nanoAmp-Meters

Bowyer et al 2004

Broca's activation

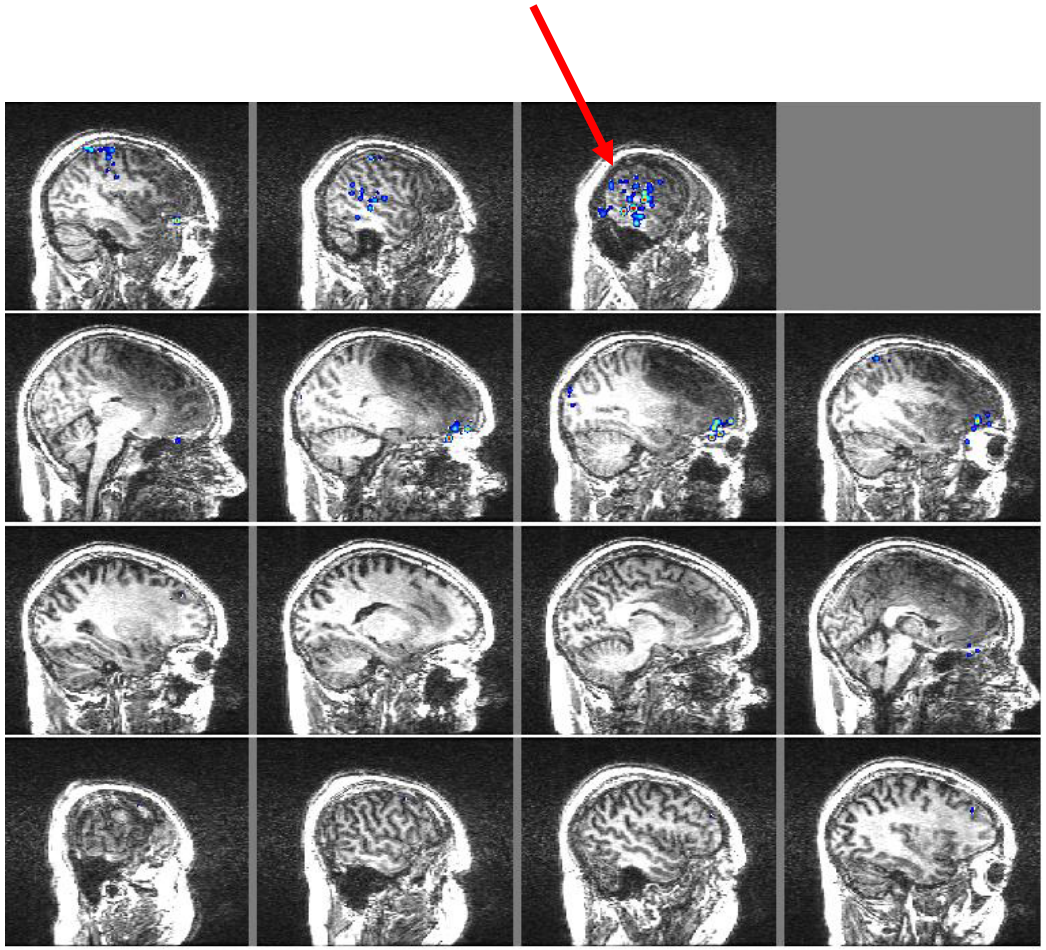
Tumor patient fMRI language localization

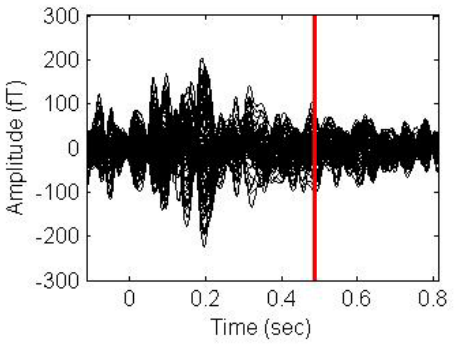


fMRI localization of Broca's area

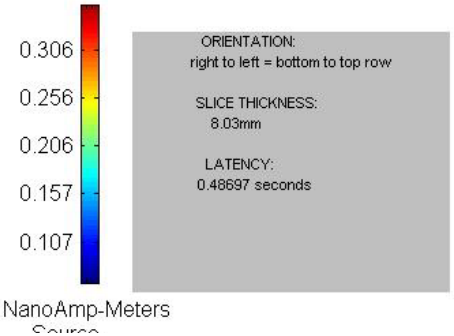
Verb Generation

Broca’s area Picture naming

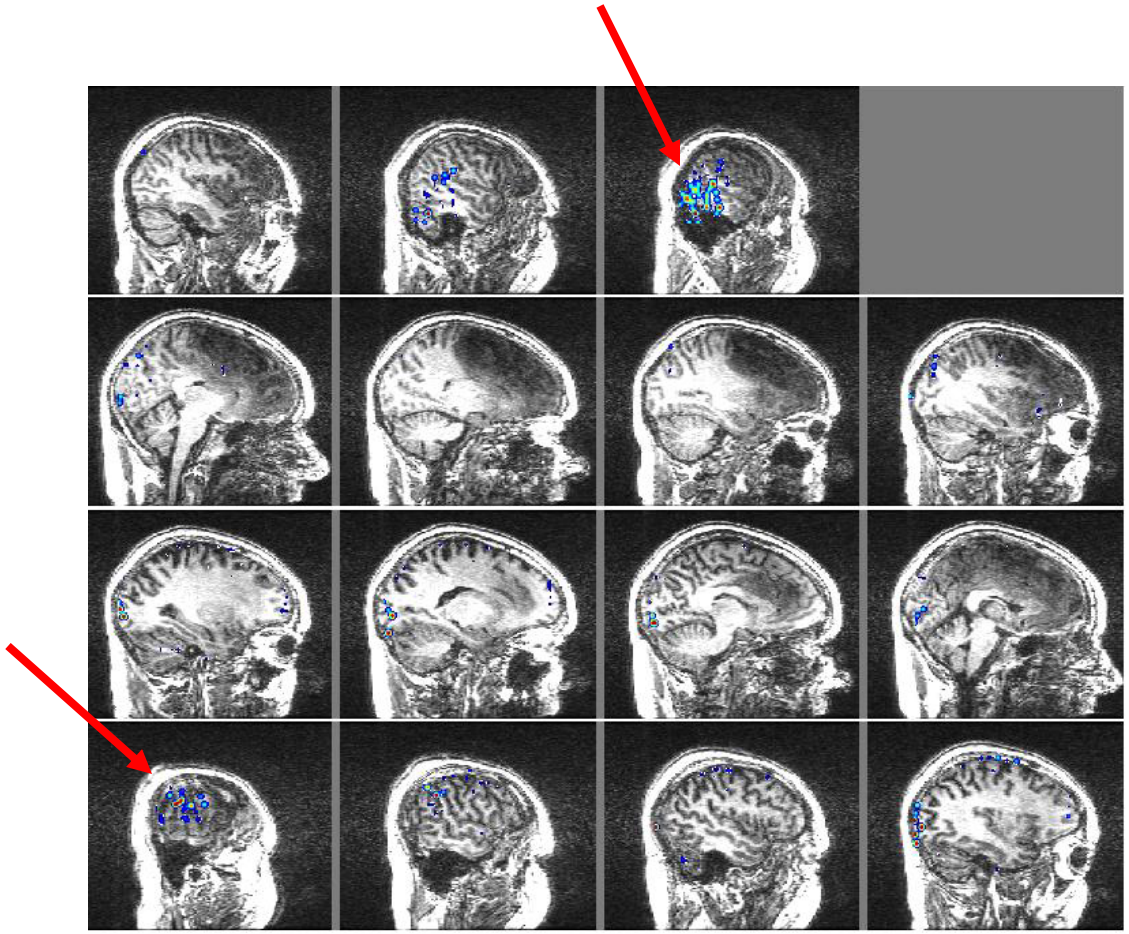


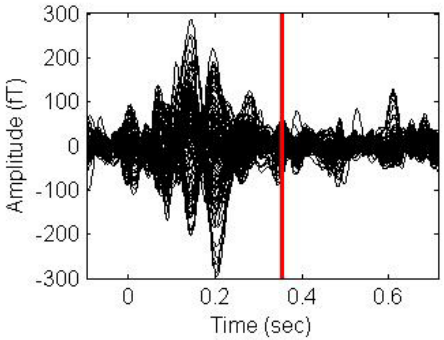


15-80+% of Max Amplitude
(Time Dependent Scaling)

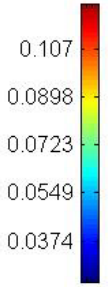


Wernicke’s area Verb generation





15-80+% of Max Amplitude
(Time Dependent Scaling)



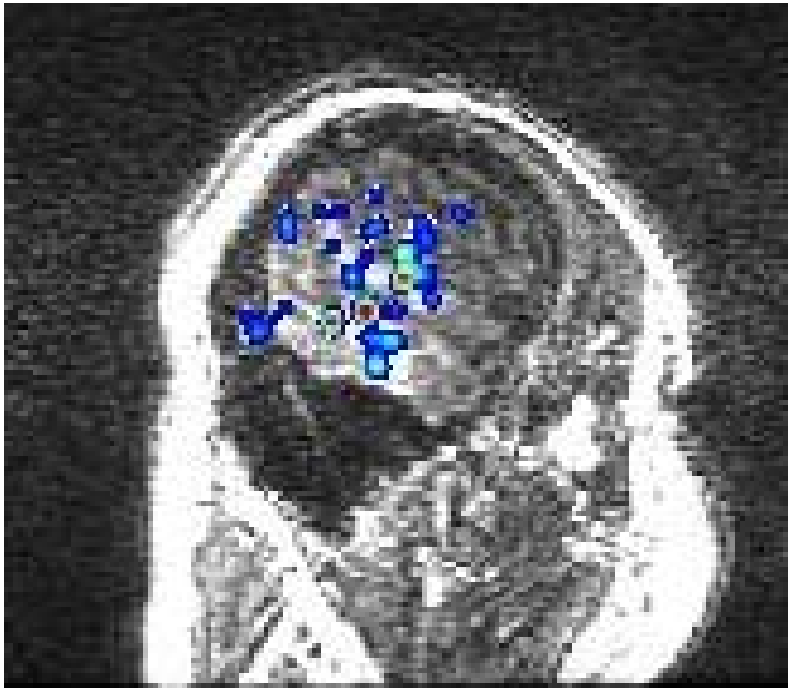
NanoAmp-Meters

ORIENTATION:
right to left = bottom to top row

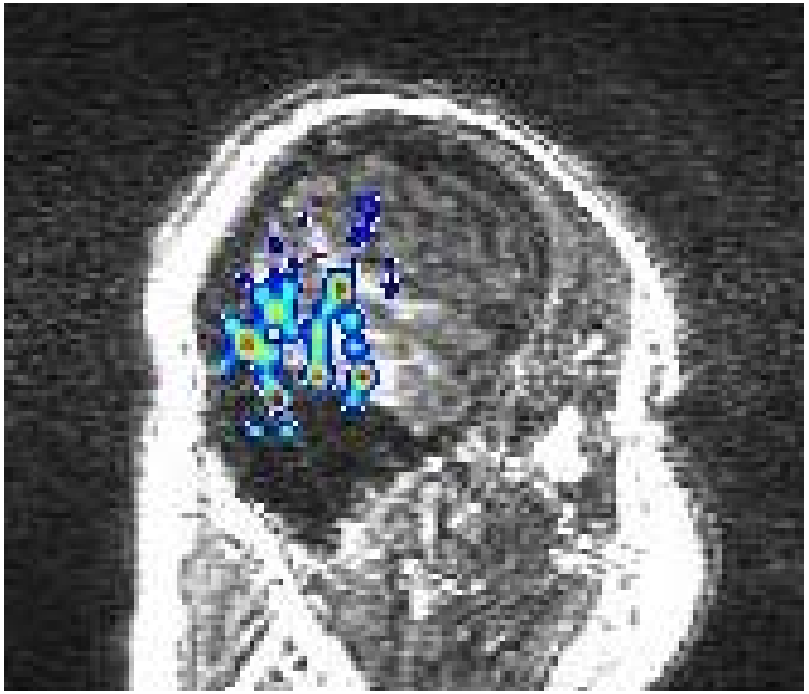
SLICE THICKNESS:
8.03mm

LATENCY:
0.35327 seconds

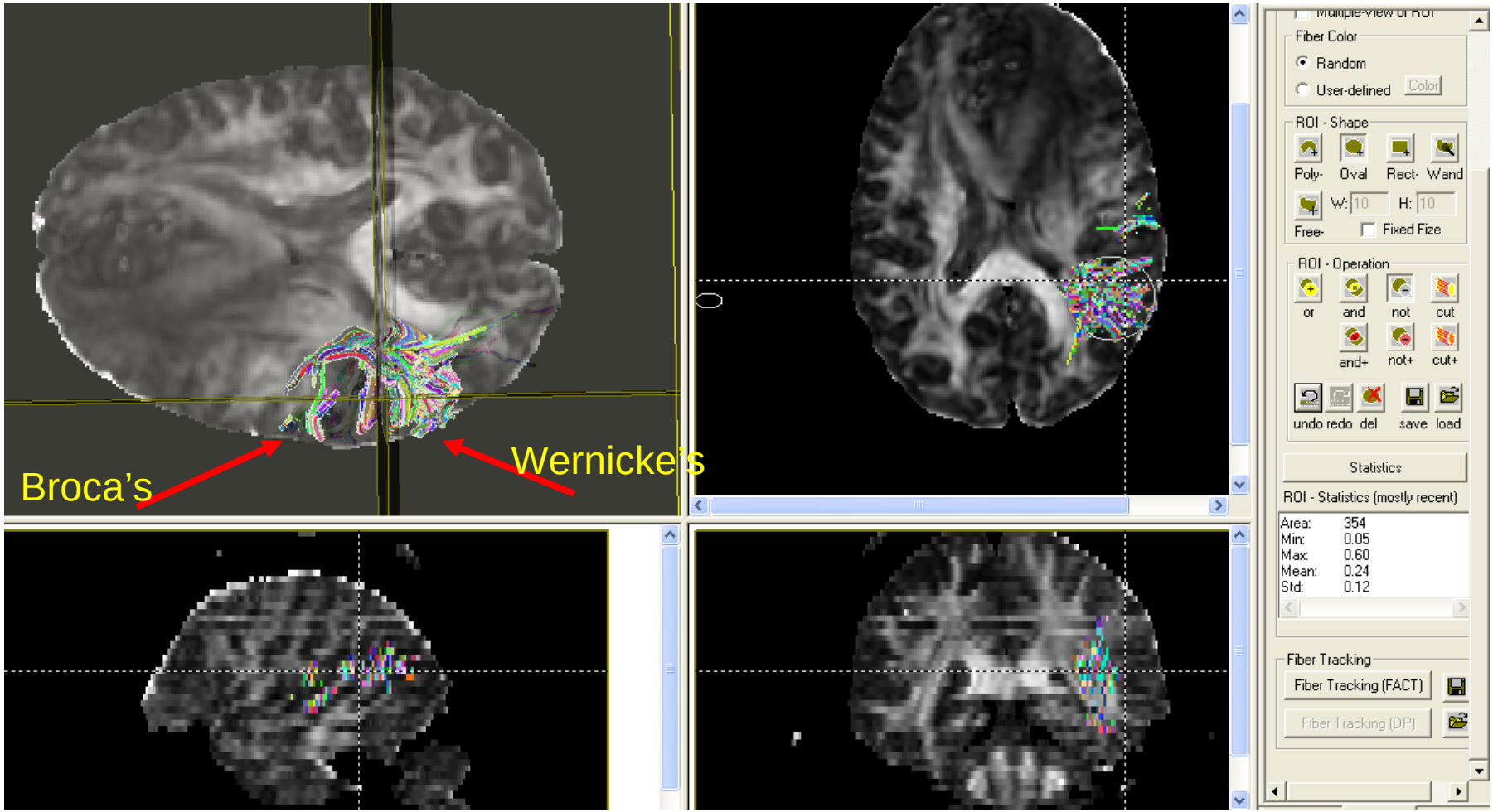
Broca’s areas



Wernicke’s area



DTI Imaging


Broca's
Wernicke's
Fiber Color
Random
User-defined
Color
ROI - Shape
Poly-
Oval
Rect-
Wand
W: 10
H: 10
Free-
Fixed Fize
ROI - Operation
or
and
not
cut
and+
not+
cut+
undo
redo
del
save
load
Statistics
ROI - Statistics (mostly recent)
Area: 354
Min: 0.05
Max: 0.60
Mean: 0.24
Std: 0.12
Fiber Tracking
Fiber Tracking (FACT)
Fiber Tracking (DP)

Coherence

- Measures consistency of phase between cortical sites participating in a neuronal network within a narrow frequency band.
- A measure of connectivity between sources with stationary signal characteristics (the distribution of source amplitudes is identical for any time segment of data.)
- Neural networks have multiple harmonic activation modes (10 Hz mode, 20 Hz mode, 35 Hz mode)
- Cortical sites participate in multiple modes and networks
- Activity at each site is a mixture of independent signals
- Basis for advanced network evaluation techniques (Granger causality, narrow band filtering or Essential Mode Decomposition with Hilbert transforms, wavelets) these are applied to non-stationary data.
  - Determine the direction of network interactions
  - Quantify significance of network structures

Extracting real-time neural networks from MEG data

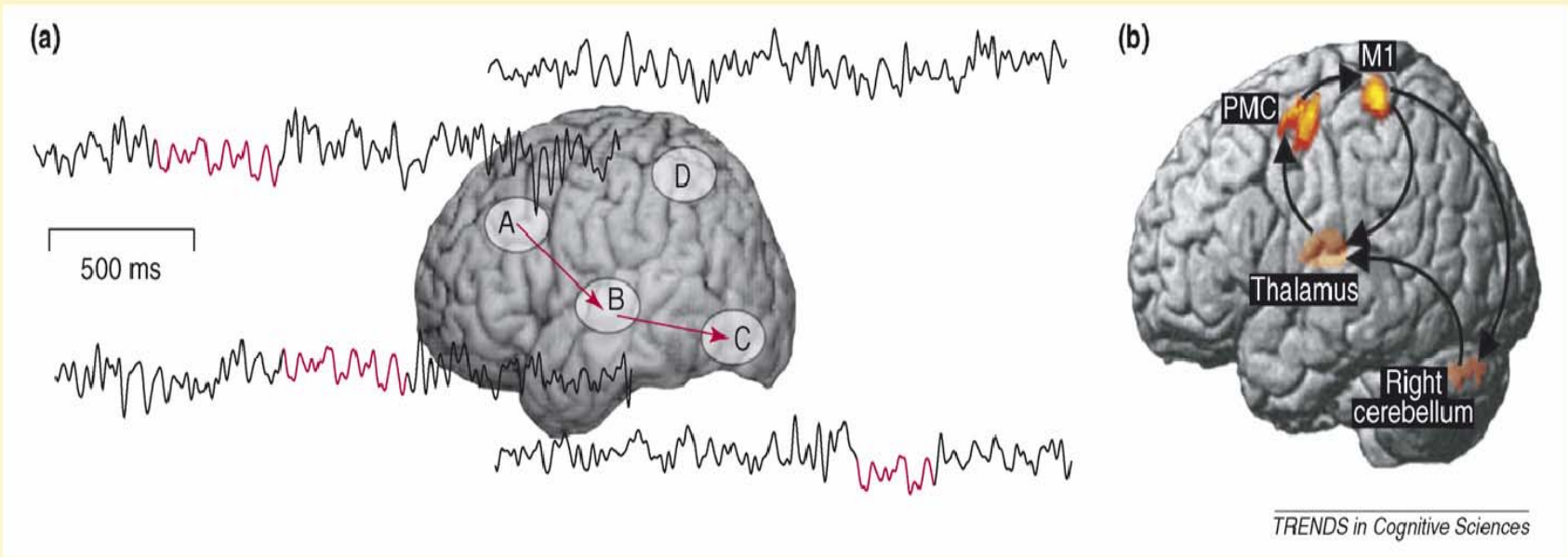
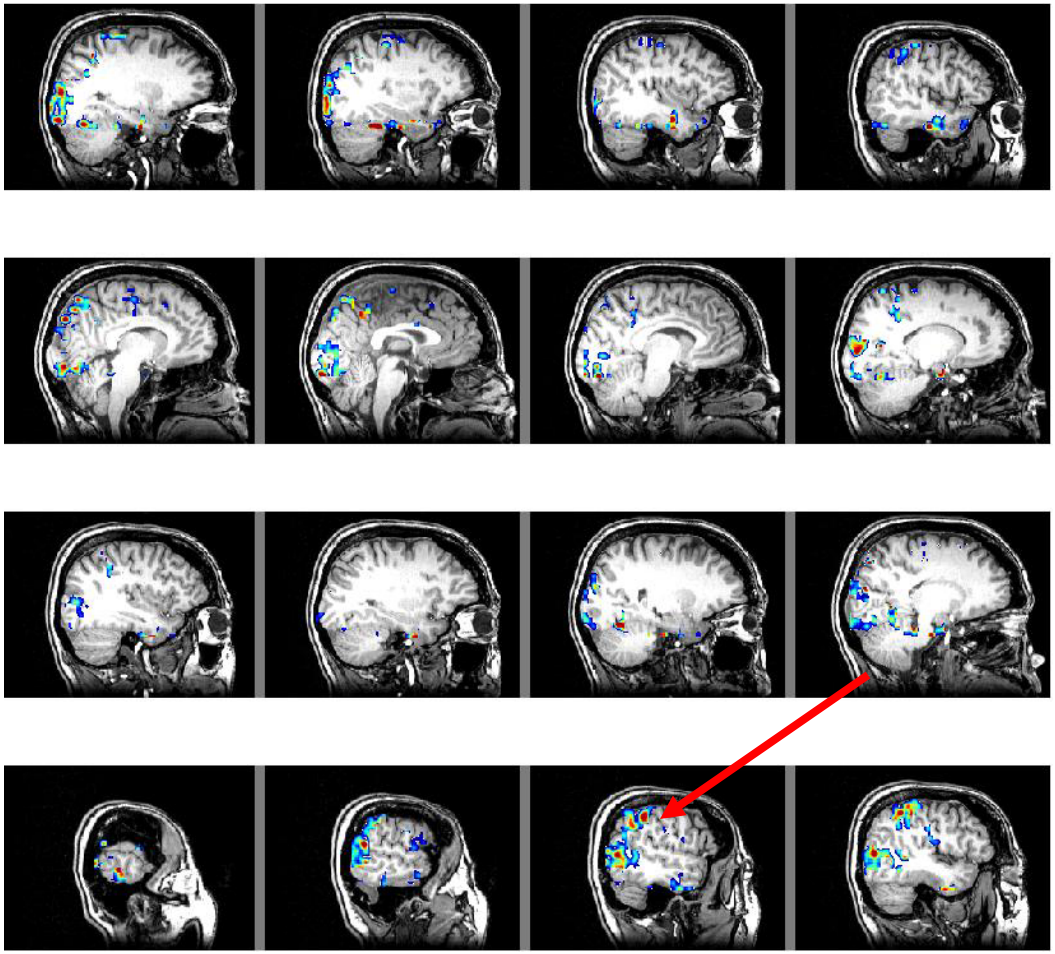
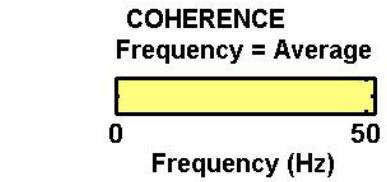


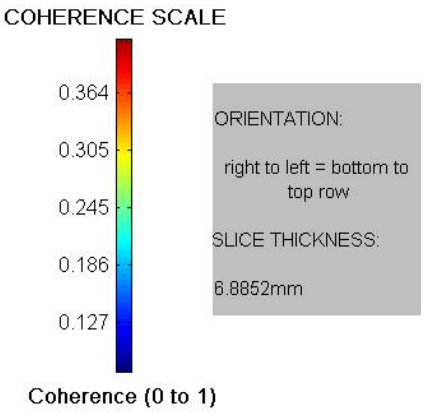
Figure I. Extracting long-range neural connectivity from MEG data. **(a)** Simplified presentation of the basic idea. Curves depict time courses of activity in four brain areas (gray ellipses). If neuronal populations in these areas are functionally connected, one would expect to detect similar time courses of activation in the different areas (red segments), at least occasionally. Time shifts between similar stretches of activity could be interpreted as flow of information. In this example, one could argue that there is a drive from area A to B and a weaker drive further to area C. Delays between the repeated segments are exaggerated. **(b)** Neural network during slow movements of the right index finger. Here, EMG from the moving finger provided a meaningful, nonbrain reference signal. EMG–MEG coherence led to the contralateral motor cortex, which served as a reference area for identification of the network within the brain. Abbreviations: M1, primary motor cortex; PMC, premotor cortex. Reproduced, with permission, from Ref. [48].

Gross J, et al Proc Natl, Acad Sci. 2002

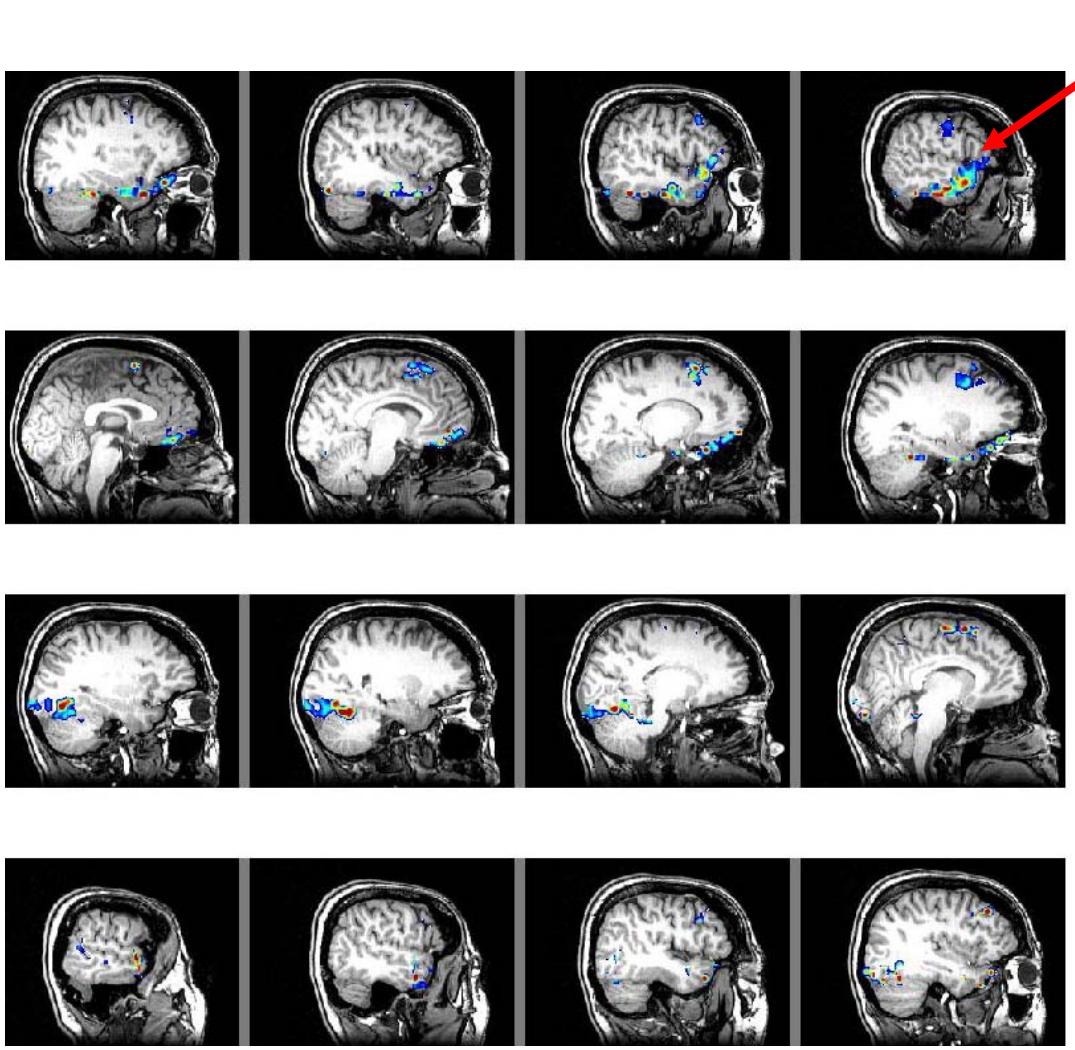
Wernicke's in Epilepsy patient Coherence imaging

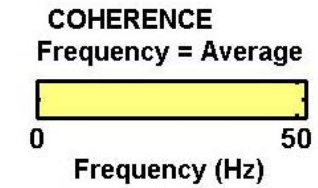


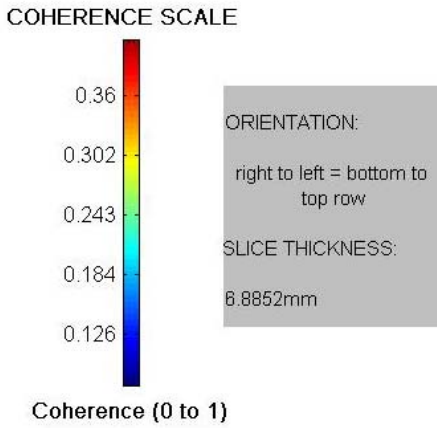




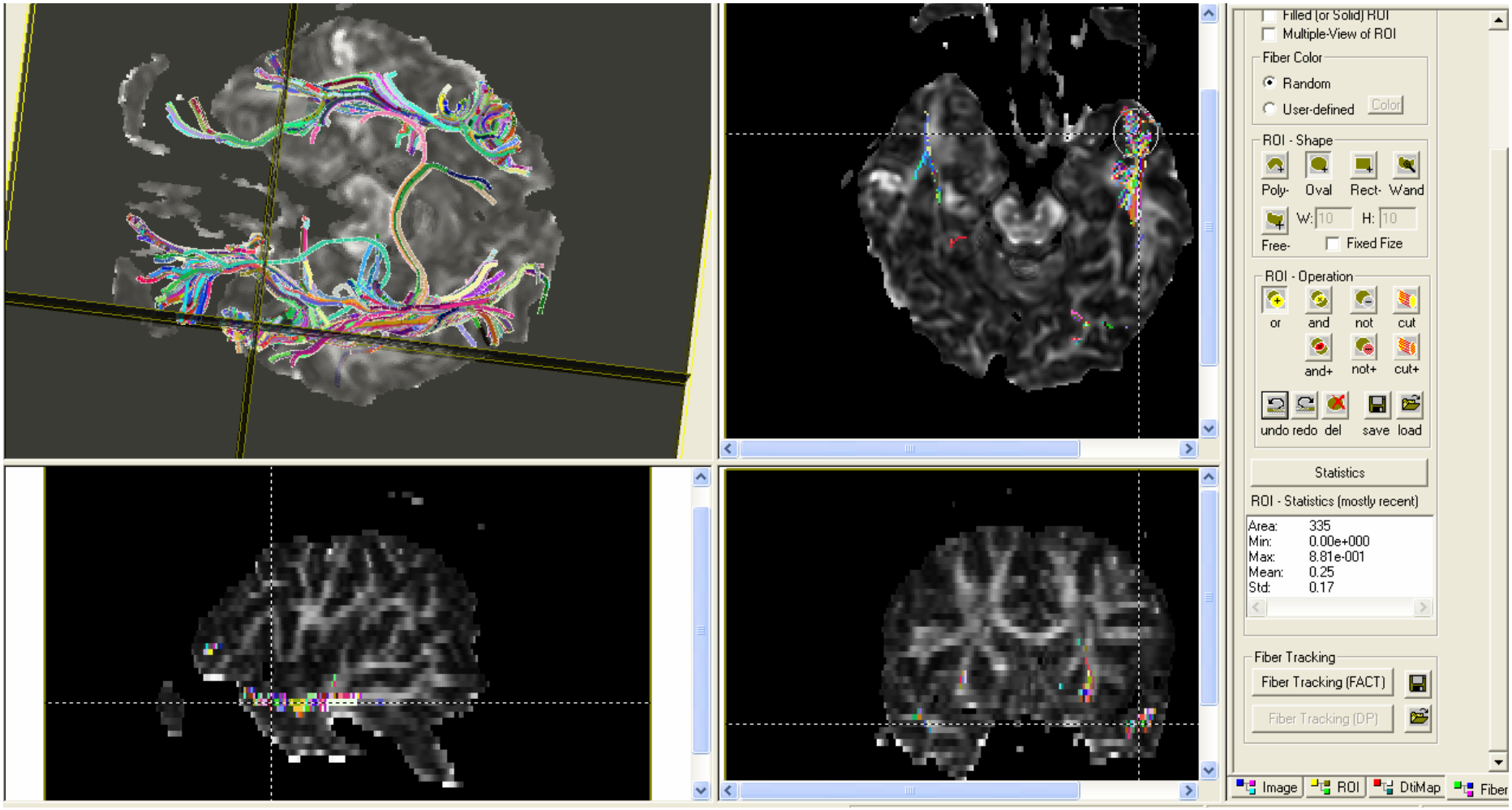
Broca's in Epilepsy patient Coherence imaging



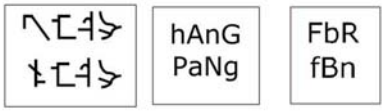


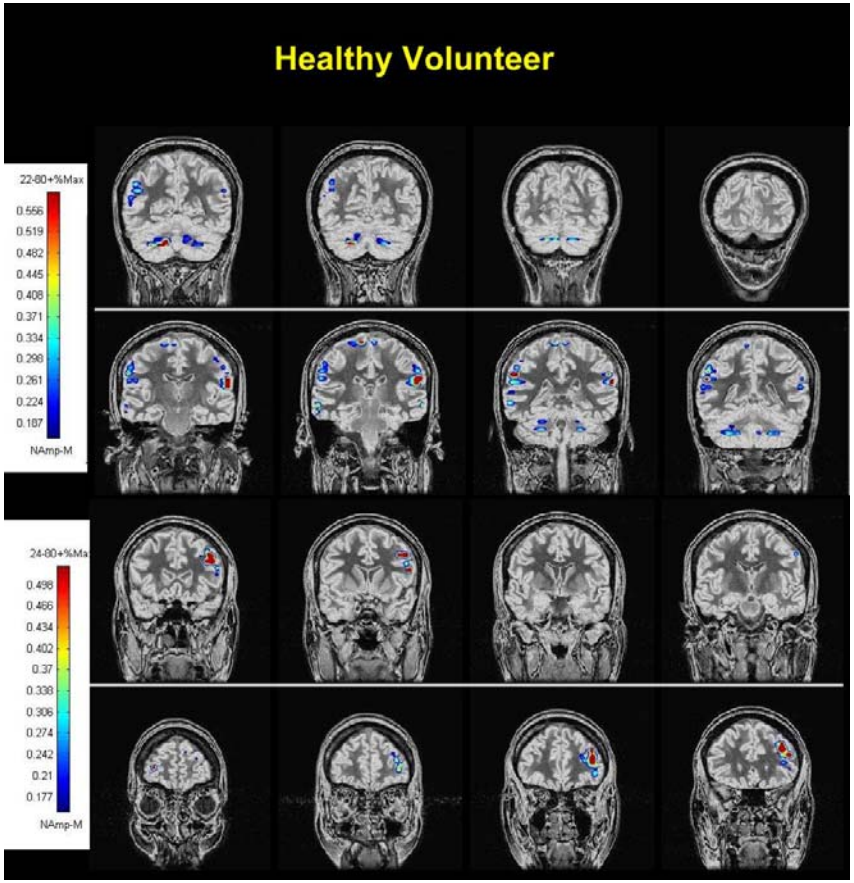


DTI Imaging


Filled (or Solid) ROI
Multiple-View of ROI
Fiber Color
Random
User-defined
Color
ROI - Shape
Poly-
Oval
Rect-
Wand
Free-
W: 10
H: 10
Fixed Fize
ROI - Operation
or
and
not
cut
and+
not+
cut+
undo
redo
del
save
load
Statistics
ROI - Statistics (mostly recent)
Area: 335
Min: 0.00e+000
Max: 8.81e-001
Mean: 0.25
Std: 0.17
Fiber Tracking
Fiber Tracking (FACT)
Fiber Tracking (DP)
Image
ROI
DtiMap
Fiber

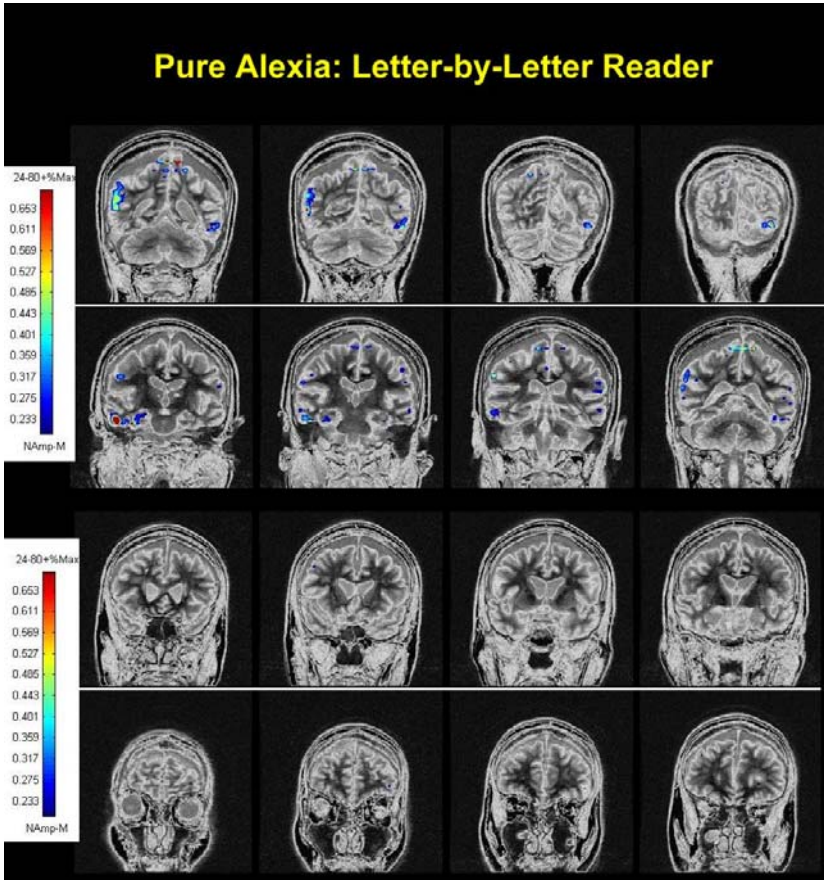
Aphasia Patients





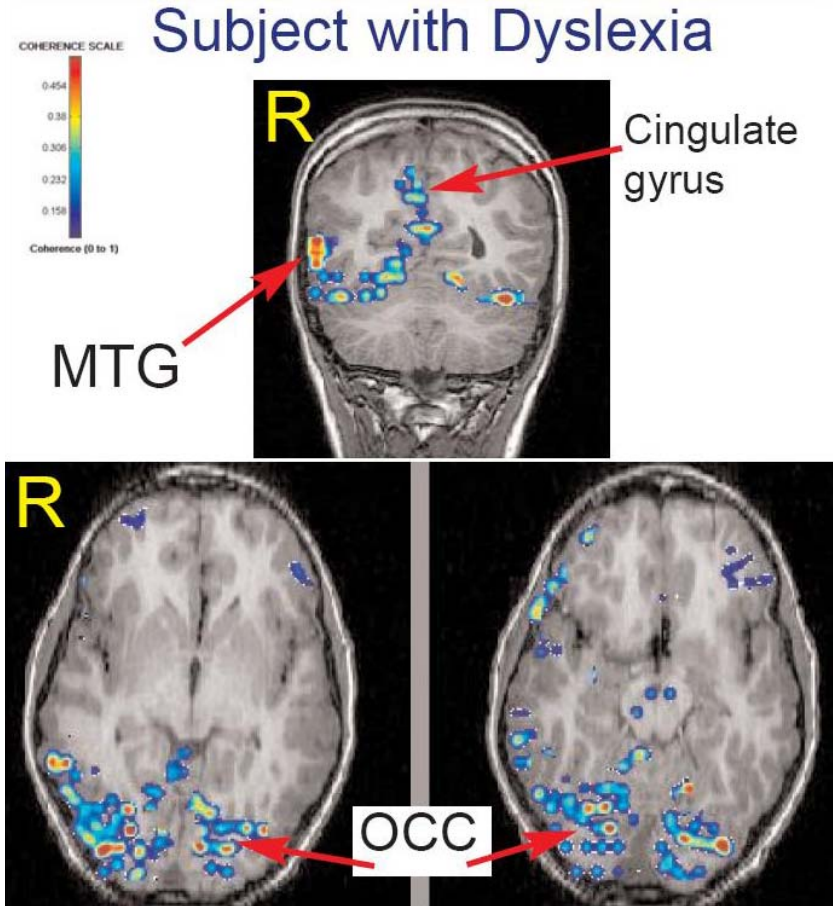
Analysis of the MEG recordings during the word matching task.

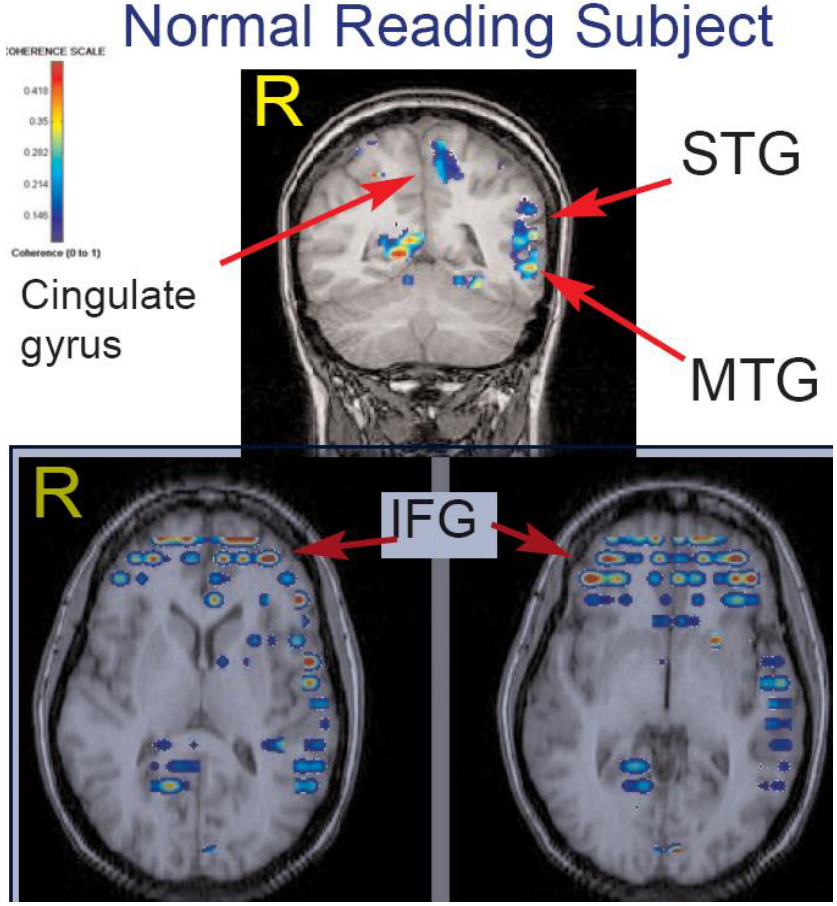
A) Early in reading process, bilateral parietal activation is evident (74 ms).
B) By 247 ms latency, left frontal cortex is activated.



A) During early stage of reading (78 ms), activation of right parietal and temporal regions is noted, but left parietal activation is restricted to superior parietal region.
B) By 333 ms latency, left frontal activation is absent.

Dyslexia





Dyslexic Subject displayed more highly coherent regions (red) in the occipital lobe than normal readers. Also the middle temporal gyrus (MTG) in the RIGHT hemisphere has more coherence than LEFT hemisphere.

Normal Reading Subject displayed more highly coherent regions in the inferior frontal gyrus than subjects with dyslexia. Also the MTG in the LEFT hemisphere had more coherent activity than the RIGHT hemisphere.

Summary

- Functional imaging techniques are a safe and non-invasive technique to image neural function of language processes.
- fMRI provides millimeter spatial resolution for language localization.
- MEG provides millimeter spatial resolution PLUS millisecond temporal resolution needed to understand language processing steps.

Thanks to My Colleagues

- Renee Lajiness-O'Neill, Psychologist
  Easter Michigan University
- Margaret Greenwald, Cognitive Neuropsychologist
  Wayne State University
- Karen Mason MEG/EEG Technologist
- Gregory L Barkley and Brien Smith Neurologists
- Kost Elisevich and Mark Rosenblum Neurosurgeons
- John Moran, Physicist
- Norman Tepley Physicist and Lab Director
  Henry Ford Hospital

www.megimaging.com
drsusan@umich.edu