MEG Coherence Imaging Applications for Language Mapping

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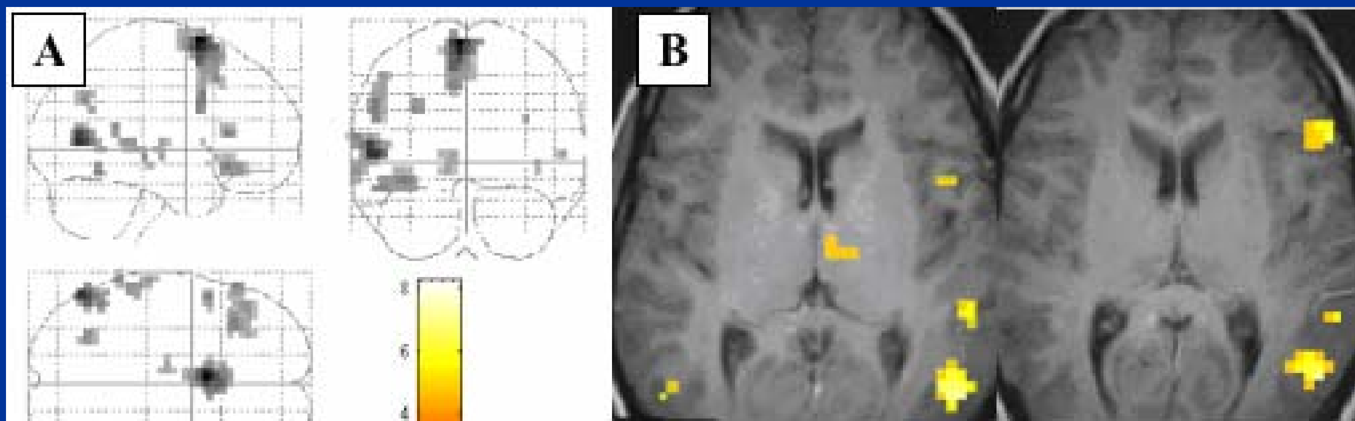
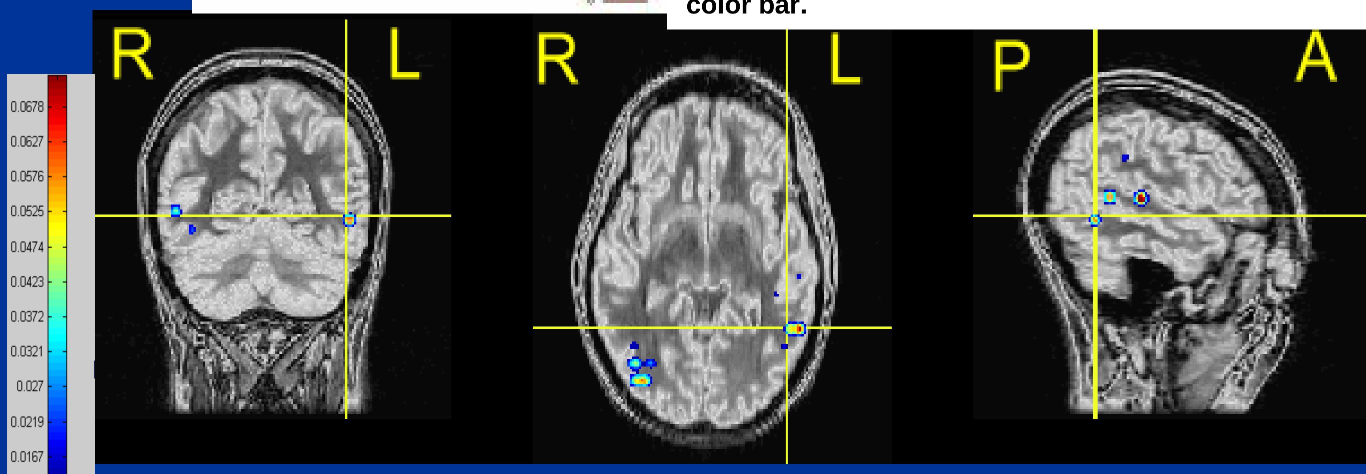
Language Mapping

- Localization: Currently Neuroimaging_displays the "where" and "when" brain areas are active. Great for Neurosurgeons!
- Laterality: Which hemisphere is dominant for language? Numerous MEG and fMRI studies on Laterality have fail to find 100% correlation to WADA, specifically when the WADA has not failed.
- We now turn our attention to How the brain processes language in an attempt to find the dominant hemisphere.

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.



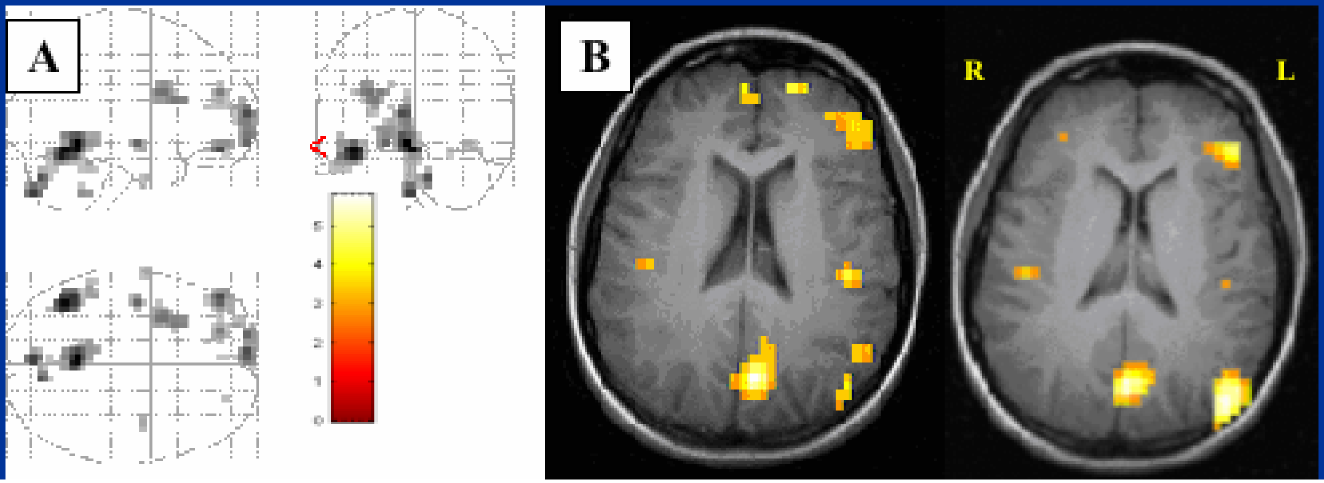
nanoAmp-meters

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

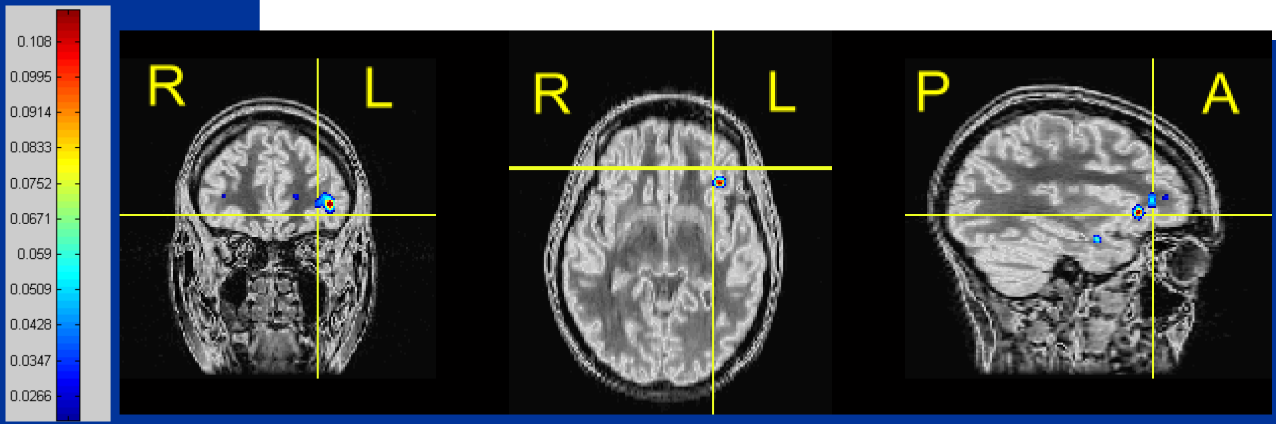
Bowyer et al 2004

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 in color bar.



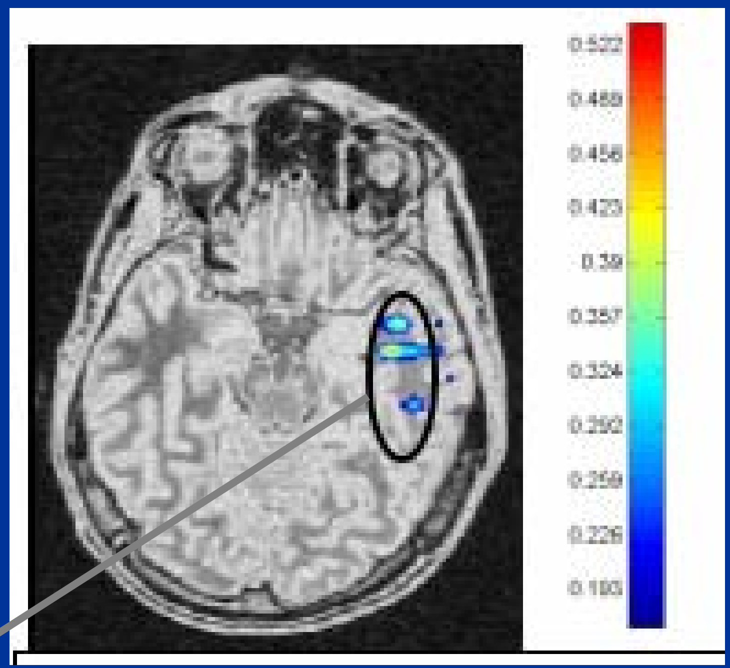
nanoAmp-meters

Broca's activation

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

Basal Temporal Language Area



fusiform gyrus

nanoAmp-meters

BTLA's activation seen at 180 ms after onset of visual stimuli during Verb Generation.

Bowyer et al 2005

Advanced MEG Data Analysis Protocols for Looking at How the Brain Processes Language

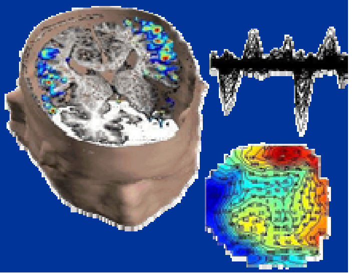
Current density- allows extended patterns of currents to be mapped

– MR-FOCUSS - Multi Resolution FOCal Underdetermined System Solver

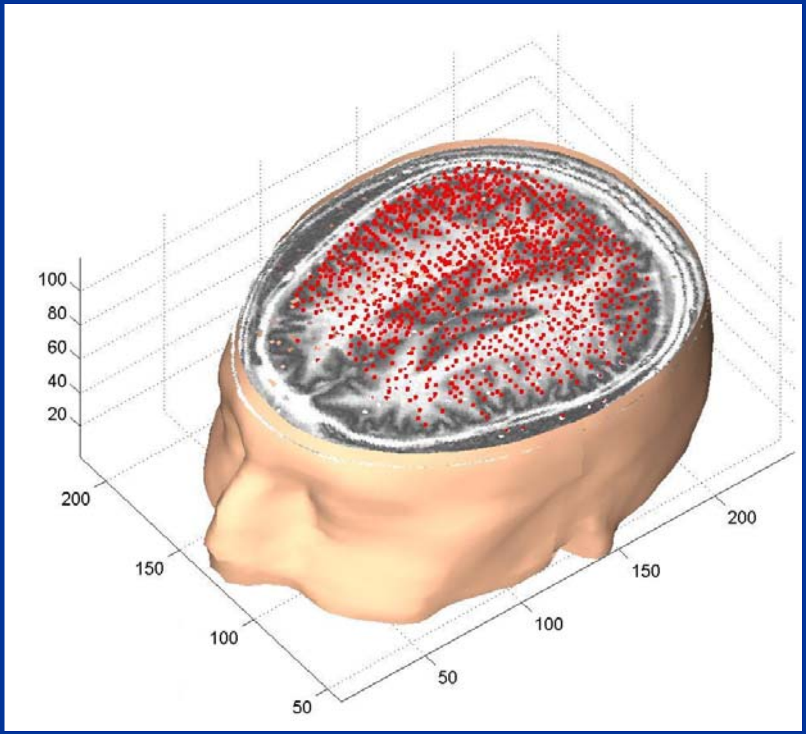
<u>Supplementary imaging enhancers</u>

<u>to yield useful information prior to localization</u>

- Independent component analysis (ICA)- source separation of multiple complex spatial signals
- Coherence- a measure of synchronization between brain regions. Synchronized activity within a neuronal network is determined by the strength of network connections. Focal regions that sporadically drive the network will exhibit high coherence with all other regions.



Cortical Model



- Created from Volumetric MRI Data
- 4,000 cortical locations
- 3 dipoles at each location that represent x, y, z
- Distribution matches cortical gray matter

Coherence Imaging: Calculation

1. Calculate time sequence of brain activity
   a. ICA extraction of burst activity brain source signals
   b. MR-FOCUSS (current density) imaging of ICA components
2. Calculate FFT sequence
3. Calculate cross-spectral density between sources by multiplying the Fourier-transformed signals (frequency space) of the time series.
4. Calculate coherence matrix by normalizing the cross spectral density with the power spectral density of both time series. Its values ranges from 0 (no similarity) to 1 (identical time series).
5. Calculate average coherence for each source (1-50Hz).

Extracting real-time neural networks from MEG data

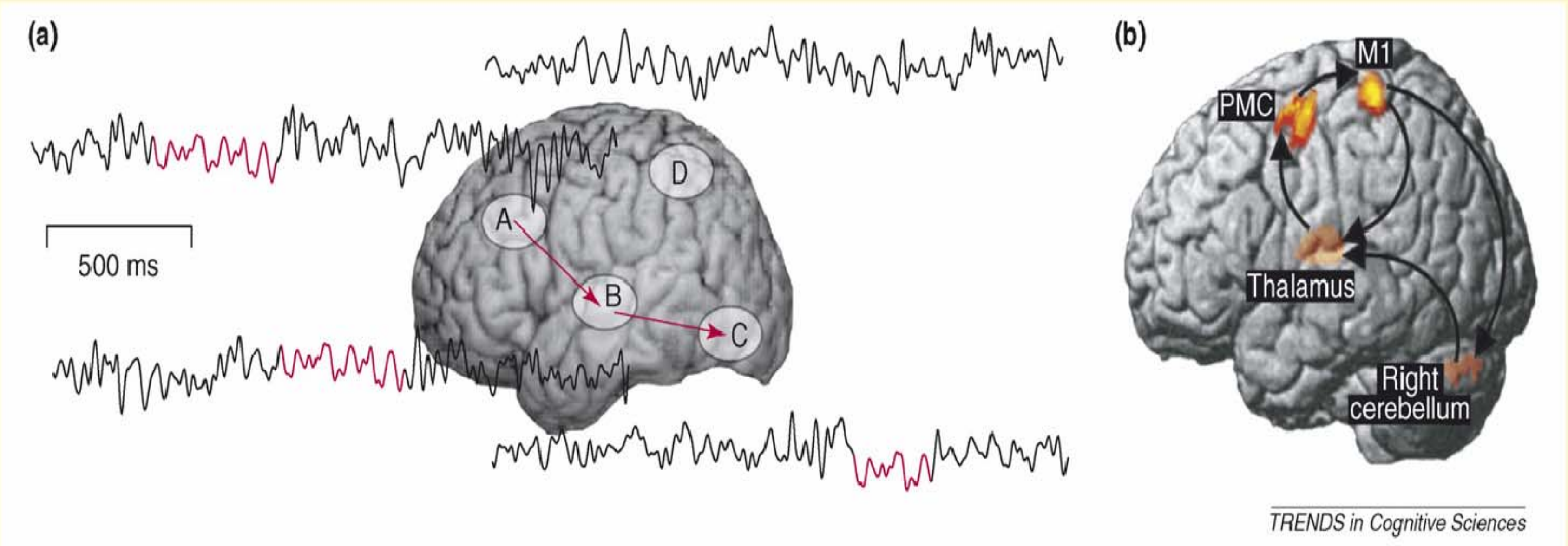
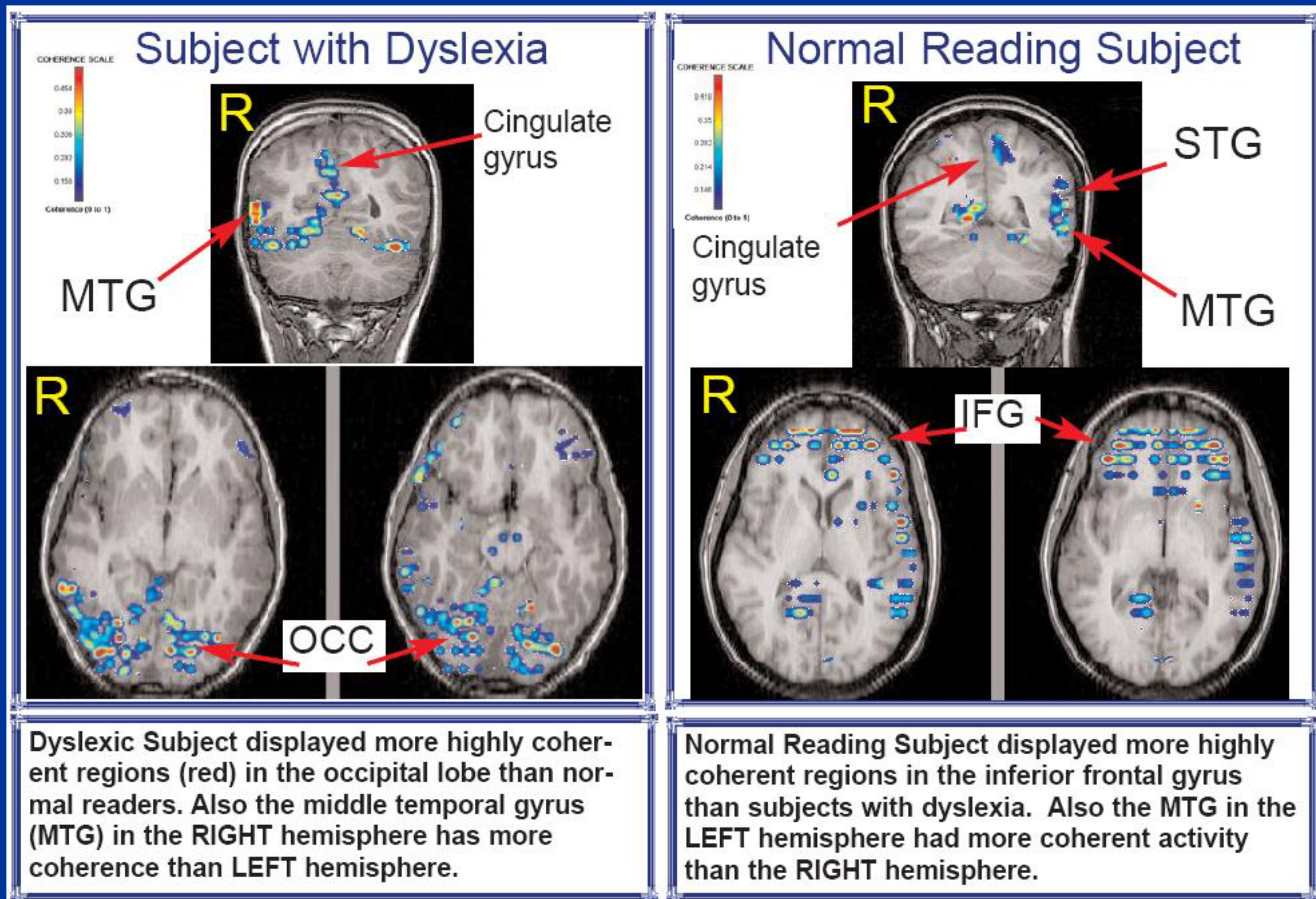


Figure I. Extracting long-range neural connectivity from MEG data. **(a)** Simplified presentation of the basic idea. Curves depict time courses of activity in four brain areas (gray ellipses). If neuronal populations in these areas are functionally connected, one would expect to detect similar time 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

Dyslexia vs Normal reader
Verb generation task



Bowyer, HBM 2007

Language Tasks

Expressive

- Broca’s and Wernicke's areas.
- Some memory involved.

Receptive

- Memory and Wernicke's areas.
- Some Broca’s

WADA Test

Language

- Paralysis of motor speech (Broca’s area)

Memory

- Which Hemisphere supports memory

The Test data

- Eight sets of language data from the Huston MEG center.

- These data sets were a mixture of brain activity, artifact and noise.

- A Receptive Language task
  - Involved presenting the subject with target words (to memorize), then recording brain activity while subjects listened to a series of words. If a word matched one of the memorized words the subject raised his or her finger.
  - Responses were not recorded

- Two channels of Electrophysiologic signals were recorded.

Table of Results

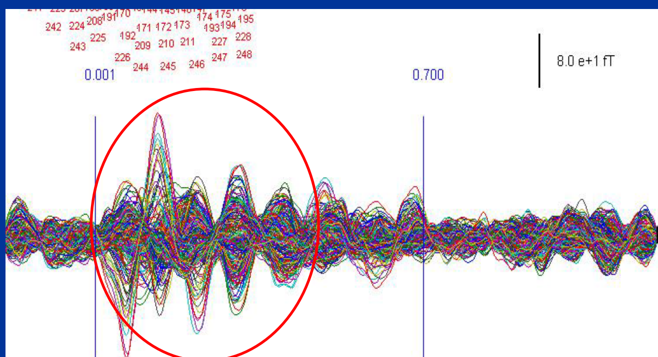
Patient ID		WADA Laterality Language	WADA Laterality Memory	Quality of MEG Recordings	Original Laterality Estimates Based on Single Dipole	Coherence Detroit Mapping Estimates of Laterality Language	MNE Madrid Estimates of Language Laterality	MNE Houston Estimates of Language Laterality		Coherence Occipito-Temporal Area
								No Normalized	Normalized	
1526	Run1	L	Bi	Good	L	L	L	L	L	L
	Run2			Very good		L				
1611	Run1	B(R>L)	R	Very good	L	R	L	L	L	R
	Run2			Good		R				
1631	Run1	B(L>R)	Bi	Good	B(L>R)	R	L	R	L	L
	Run2			Good		R				
1692	Run1	L	L	Noisy	L	R	L	L	L	L
	Run2			Noisy		R				
1693	Run1	L	Bi	Good	L	R	R	R	L	L
	Run2			Good		R				
1894	Run1	L	L	Noisy	B(L>R)	R	L	R	L	Bi L>R
	Run2			Noisy		R				
1900	Run1	L	L	Good	B(L>R)	L	R	L	L	Bi L>R
	Run2			Good		L				
1933	Run1	R	R	Noisy	B(L>R)	R	L	R	R	R
	Run2			Noisy		R				

Subject # 1631

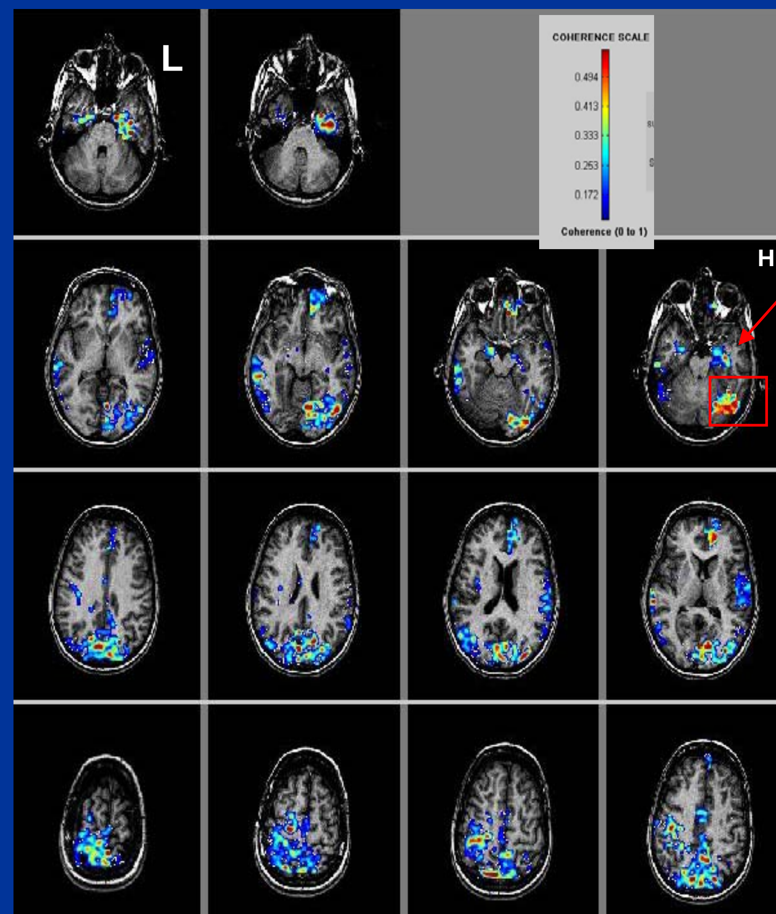
WADA Language
Bi Lateral, LEFT

Coherence: -39, 41 Bi Lateral

MEG waveform



Evoked responses can be seen



Hippocampus

Match

High coherence (red>blue)

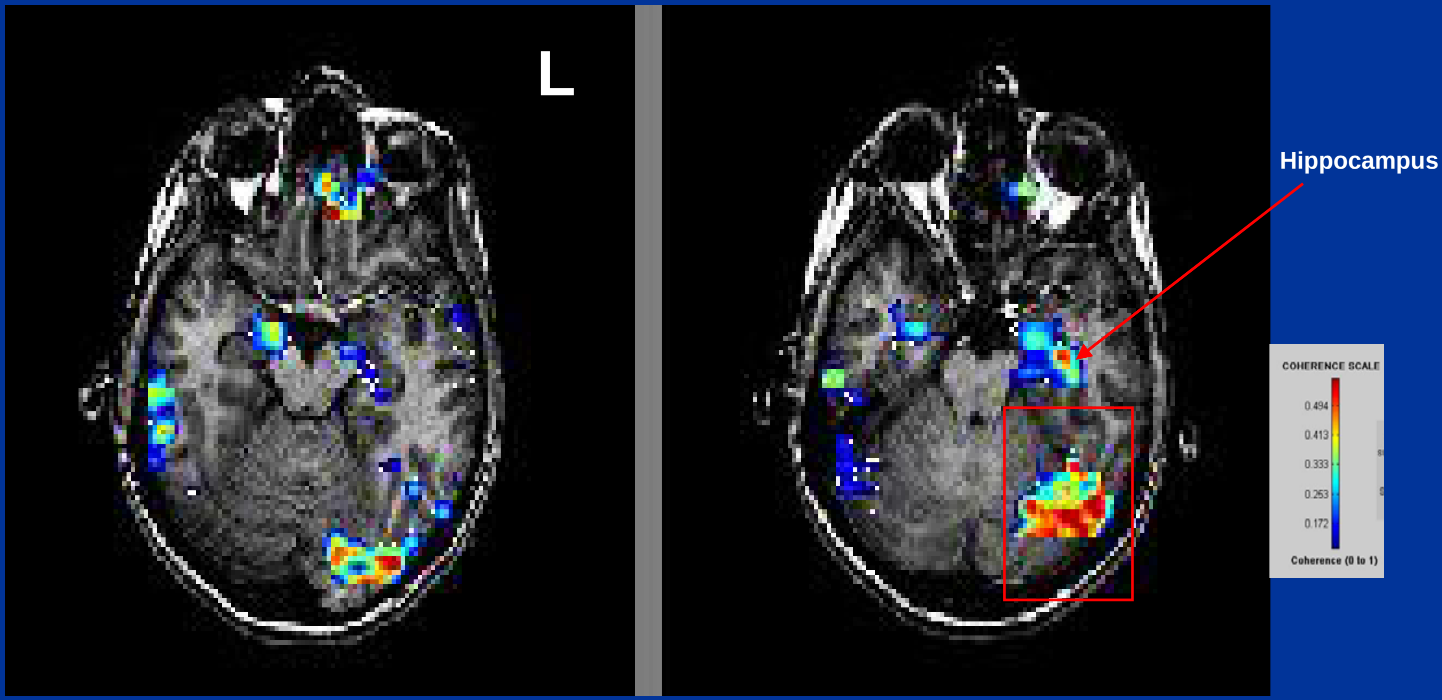
MR-FOCUSS
Laterality Time Index

100-1000: 47, 55 Right
239-290: 50, 100 Right
390-460: 50, 100 Right

Subject # 1631

WADA Language
Bi Lateral, LEFT

Coherence: LEFT Match



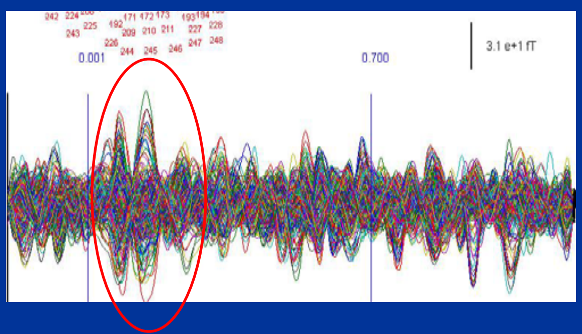
High coherence (red>blue)

Subject # 1692

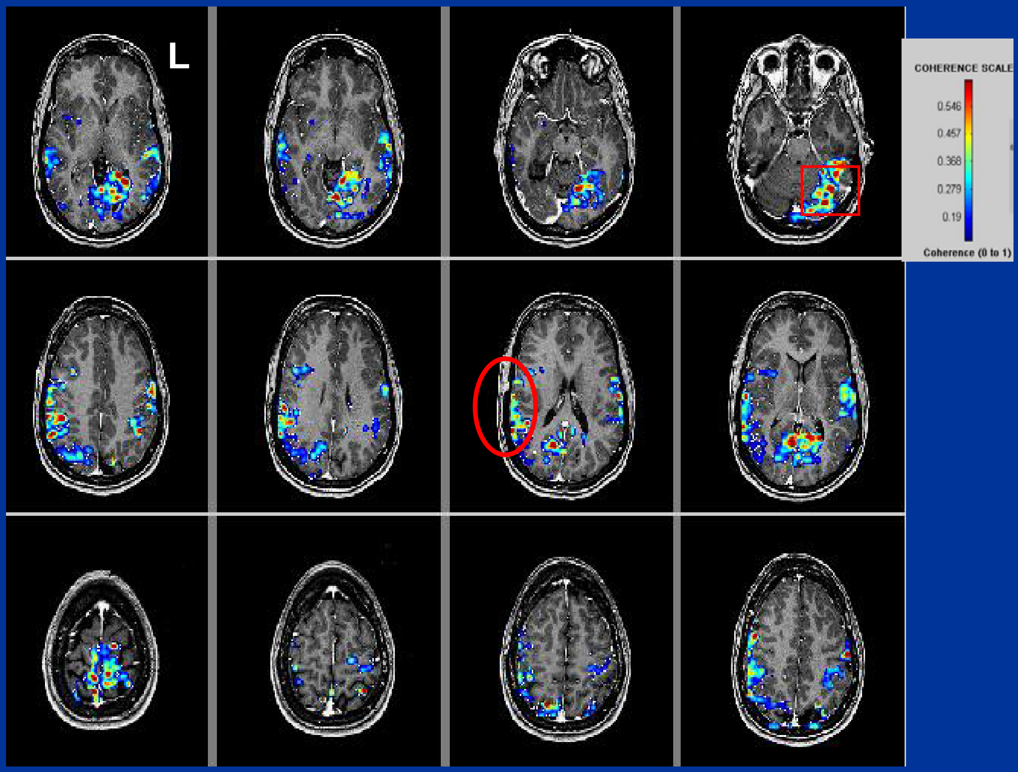
WADA Language
Left

Coherence: 76, 80 Right

MEG waveform



Poor evoked response can be seen



High coherence (red>blue)

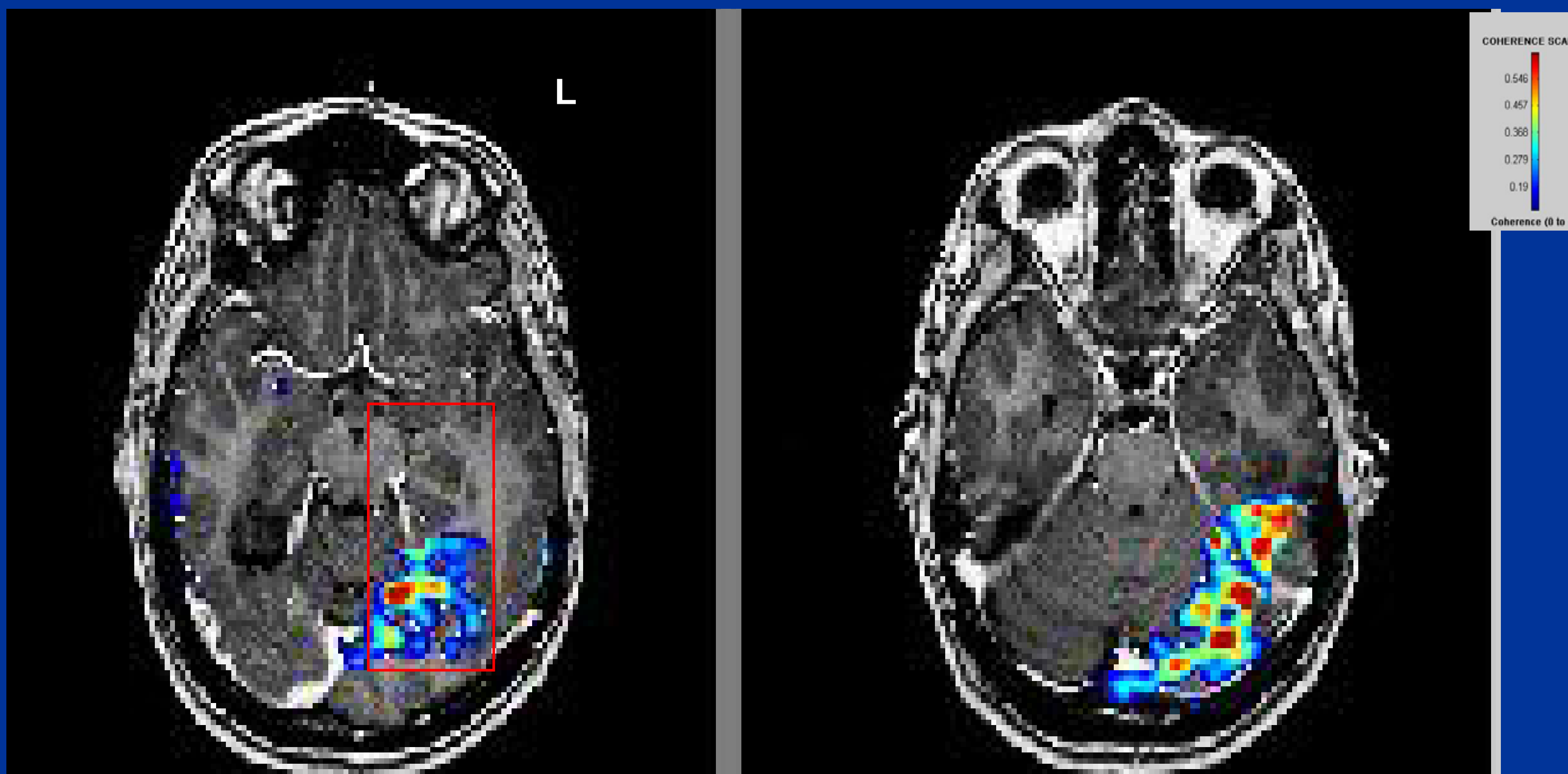
MR-FOCUSS
Laterality Time Index

100-1000: 23, 14 Right
239-290: 60, 100 Right
390-460: -41, 18 Bi lateral

Subject # 1692

WADA Language
Left

Coherence: Left **Match**

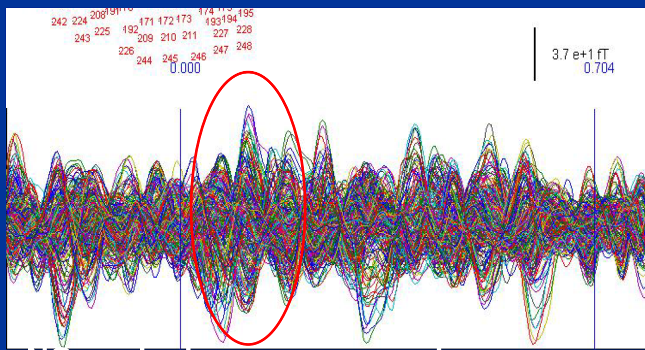


High coherence (red>blue)

Subject # 1933

WADA Language
Right

MEG waveform



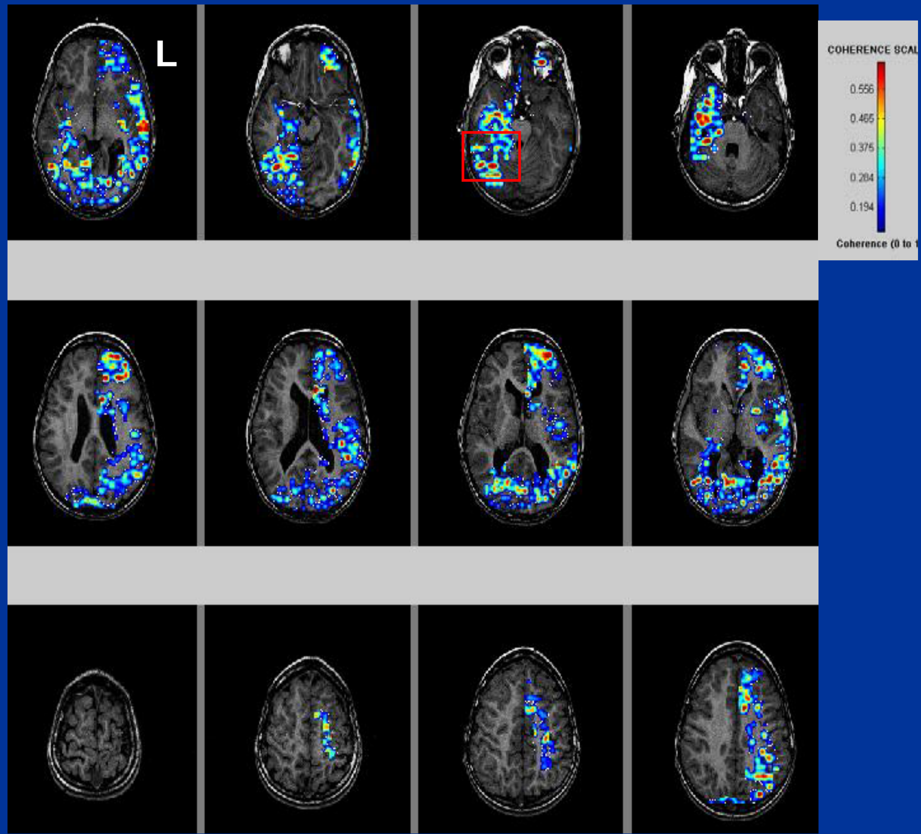
NO evoked responses can be seen

MR-FOCUSS
Laterality Time Index

100-1000: 25, 26 Right Match
239-290: 60, 73 Right Match
390-460: 17, 41 Right Match

Match

Coherence: -7, 12 Bi lateral/Right

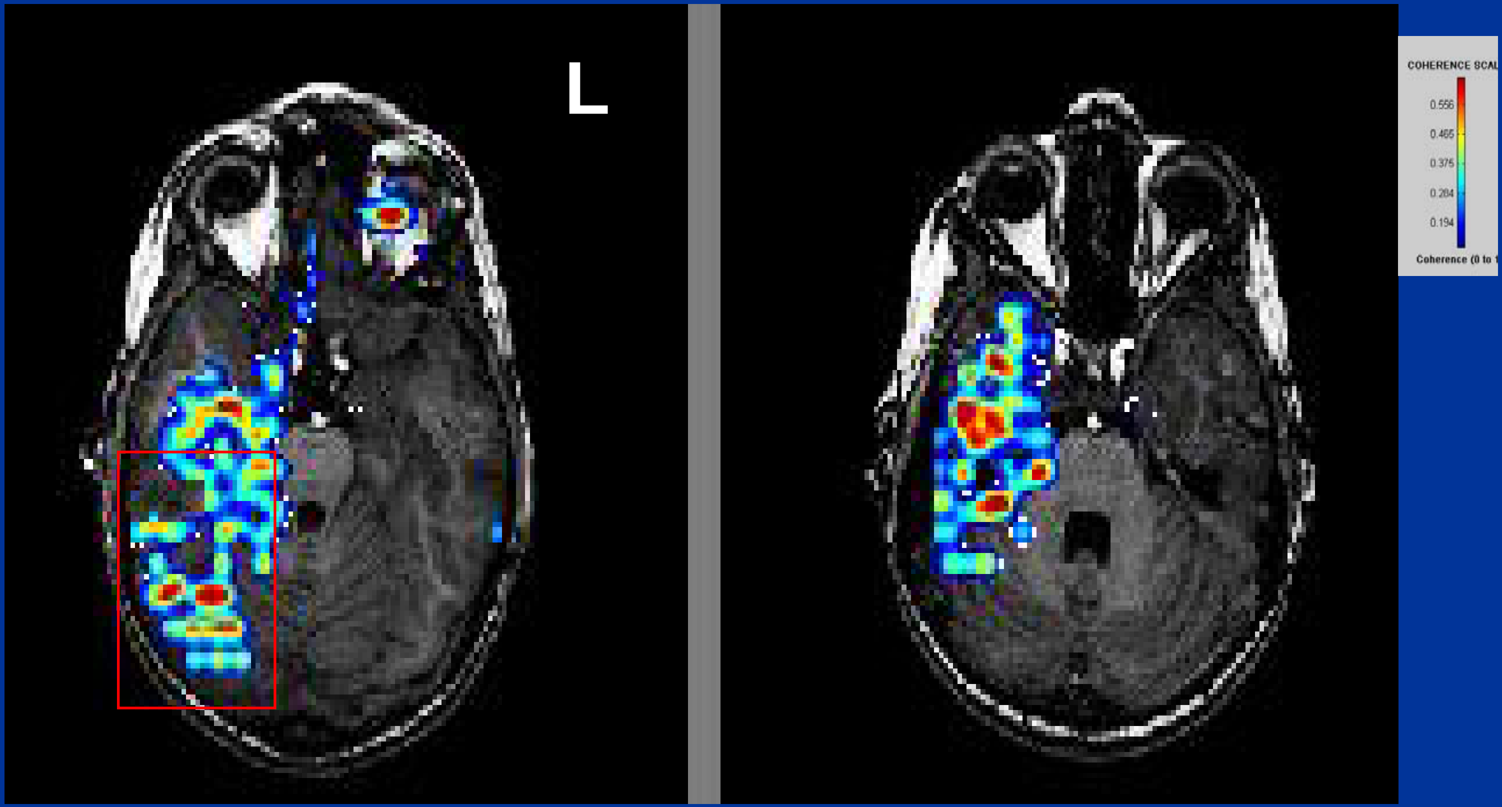


High coherence (red>blue)

Subject # 1933

WADA Language
Right

Coherence: Right **Match**



High coherence (red>blue)

Results

- Coherence matched in 4 of 8 patients
- MR-FOCUSS

  -Over all latency matched in 3 of 8 patients

  -230-290 latency matched in 4 of 8 patients

  -390-460 latency matched in 4 of 8 patients

- Coherence in the Ventral Occipitotemporal region matched in all 8 of 8 patients

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	Run2			Noisy		R				
Success Ratio					75%	50%	50%	50%	88%	100%

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1631	Run1	B(L>R)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	R	L	L
	Run2			[illegible]		[illegible]				
1692	Run1	L	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	L	L	L
	Run2			[illegible]		[illegible]				
1693	Run1	L	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	R	L	L
	Run2			Good		R				
1894	Run1	L	L	Noisy	B(L>R)	R	L	R	L	Bi L>R
	Run2			Noisy		R				
1900	Run1	L	L	Good	B(L>R)	L	R	L	L	Bi L>R
	Run2			Good		L				
1933	Run1	R	R	Noisy	B(L>R)	R	L	R	R	R
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100 % !!!!

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	Run2			Noisy		R				
Success Ratio					75%	50%	50%	50%	88%	100%

Conclusions

- Start with a good data set, free of artifact.
  -EEG and ECG helps to clean MEG data
- Knowing the state of the subject during recording. Record responses so you know they are participating in the task.
- Understanding the data set prior to analyzing.
  -What areas do you expect to be active.
- It is likely that a battery of language tasks recorded by MEG will be needed to characterize hemispheric language dominance, just as a battery of psychometric tests are used to characterize language in the Psychology Departments.
- MEG and EEG are sensitive to small changes in synchrony (coherence) within neuronal populations, but these changes do not necessarily require increased metabolism, and may be invisible in fMRI and PET recordings.

Thank you for your attention.

MEG_TOOLS

a complete MEG analysis software package **(requires Matlab)**

available at www.megimaging.com

Research supported by
NIH/NINDS Grant R01-NS30914