Coherence and MR-FOCUSS imaging for determining laterality

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MEG data analysis protocols

Types of analytical techniques

- **Current density-** allows extended patterns of currents to be mapped
  - MR-FOCUSS - Multi Resolution FOCal Underdetermined System Solver

Supplementary imaging enhancers to yield useful information prior to localization

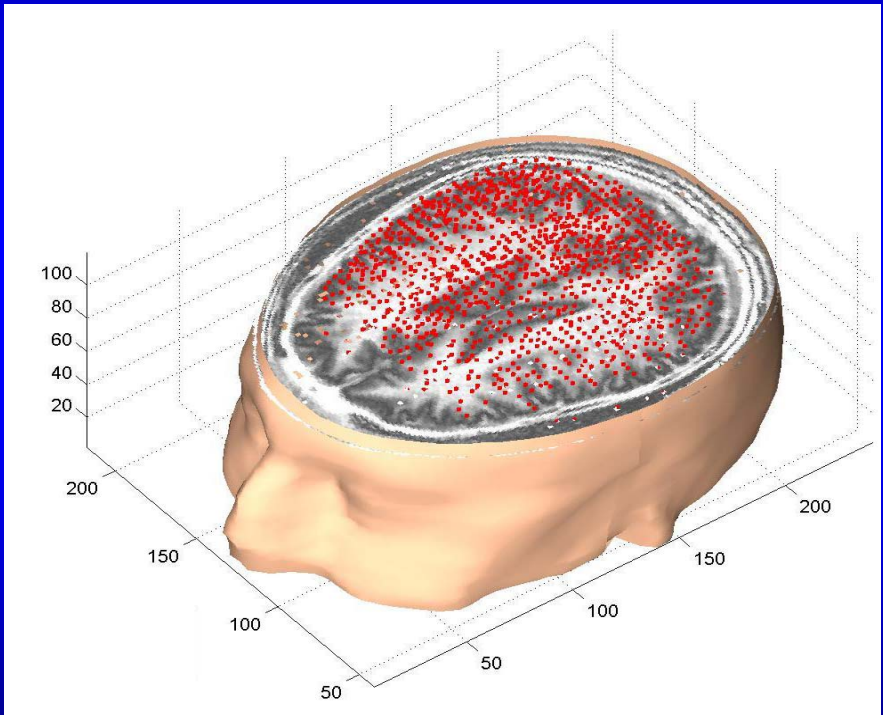
- **Independent component analysis (ICA)-** source separation of multiple complex spatial signals
- **Coherence-** a measure of synchronization between brain regions. Synchronized activity within a neuronal network is determined by the strength of network connections.

Advanced MEG Imaging

- Use of ICA and coherence mapping to identify the underlying neural connectivity in patients with epilepsy, migraine, Sleep disorders and learning disorders. (poster)

- Coherence is a measure of synchronization between brain regions. Focal regions that sporadically drive the network will exhibit high coherence with all other regions. Coherence mapping of spontaneous MEG data is easy to automate. (poster)

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 matrix 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, each source

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

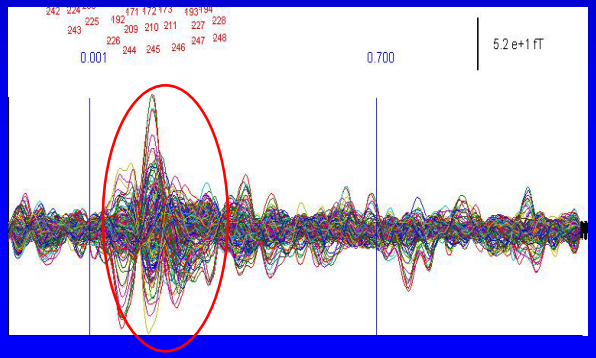
The Test data

- 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.

Subject # 1526

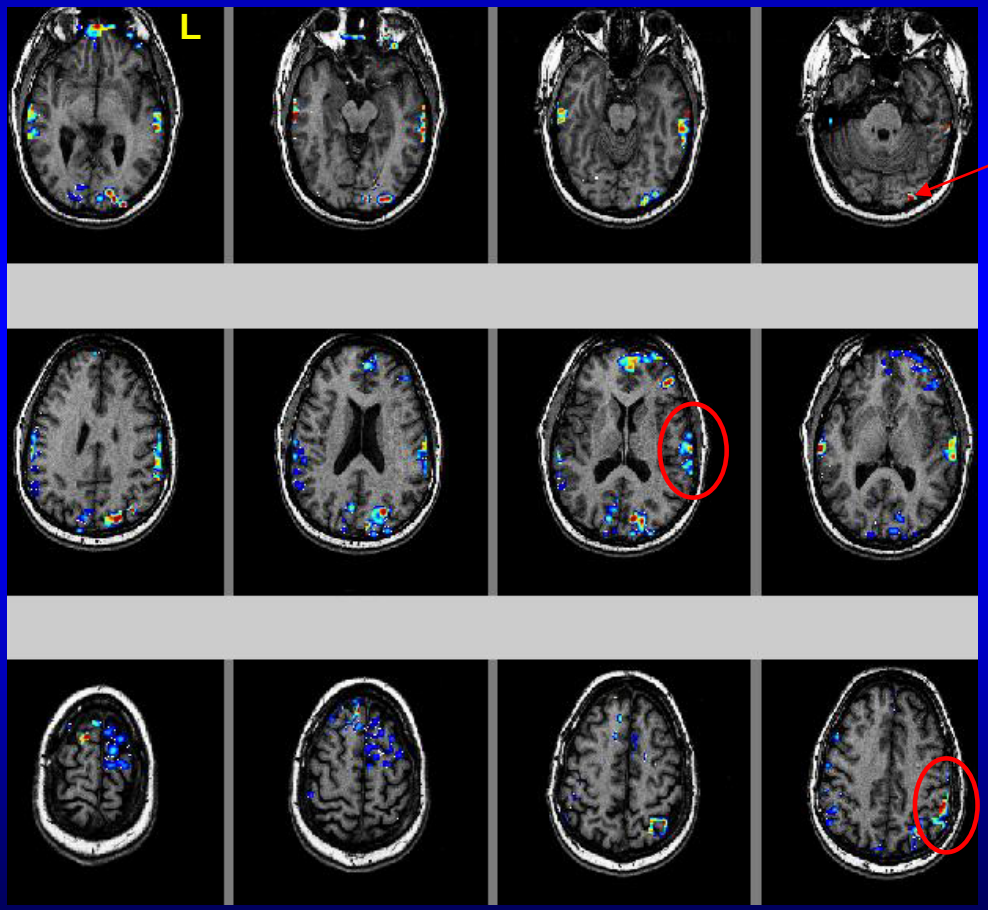
WADA Language
LEFT

MEG waveform



Evoked responses can be seen

Coherence: -43, -57 (LEFT) Match



High coherence (red>blue) Frequency 3-30 Hz

MR-FOCUSS
Laterality Time Index

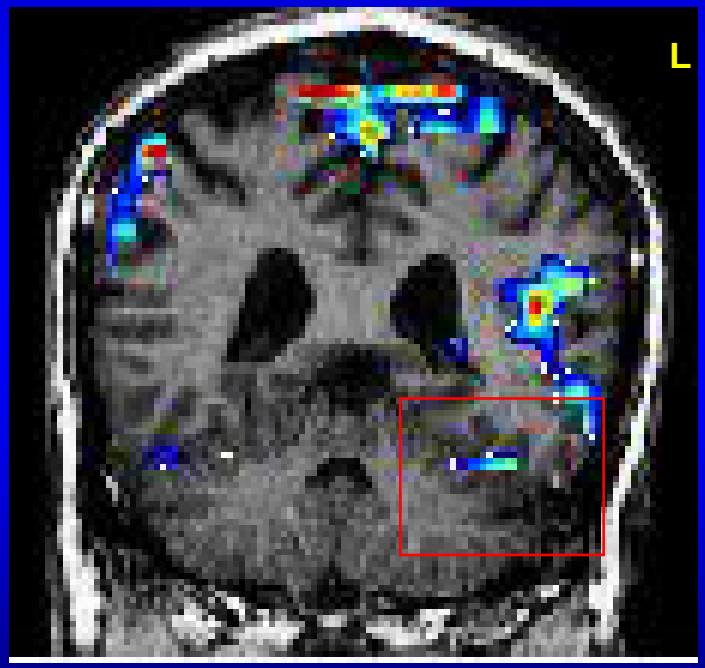
100-1000: 35, 47 Right
239-290: -20, 0 Left Match
390-460: 76, 50 Right

Subject # 1526

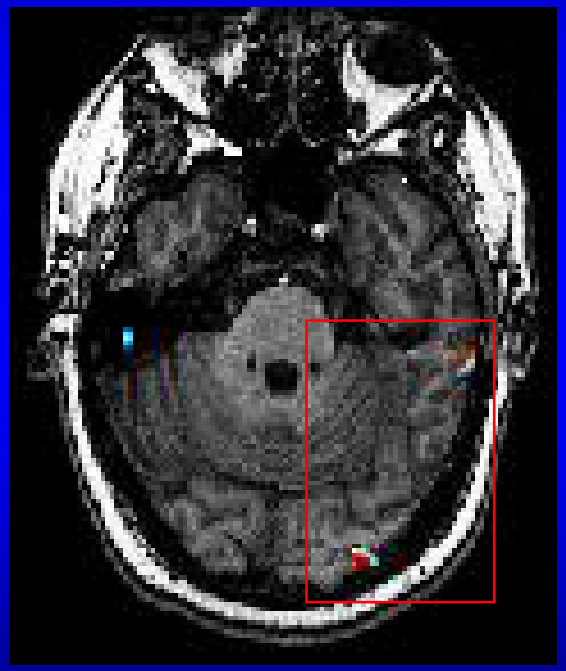
WADA Language
LEFT

Coherence: LEFT

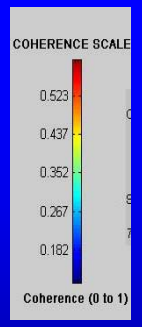
Match



Run 2



Run 1

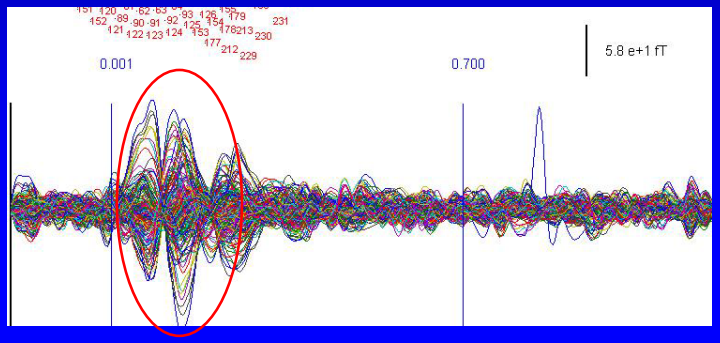


High coherence (red>blue)

Subject # 1611

WADA Language
Right

MEG waveform

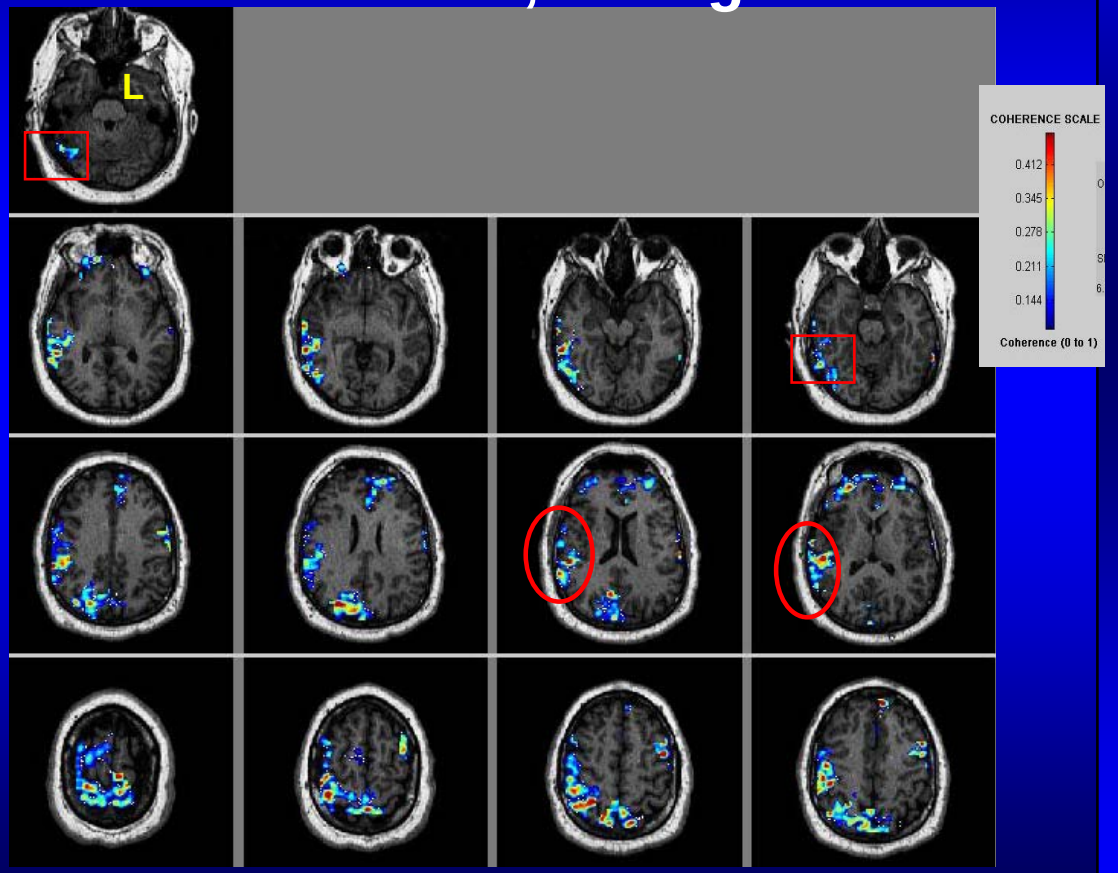


Evoked responses can be seen

MR-FOCUSS
Laterality Time Index

100-1000:	58, 17	Right	Match
239-290:	33, 7	Right	Match
390-460:	76, 41	Right	Match

Coherence: 80, 56 Right Match

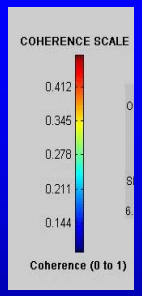


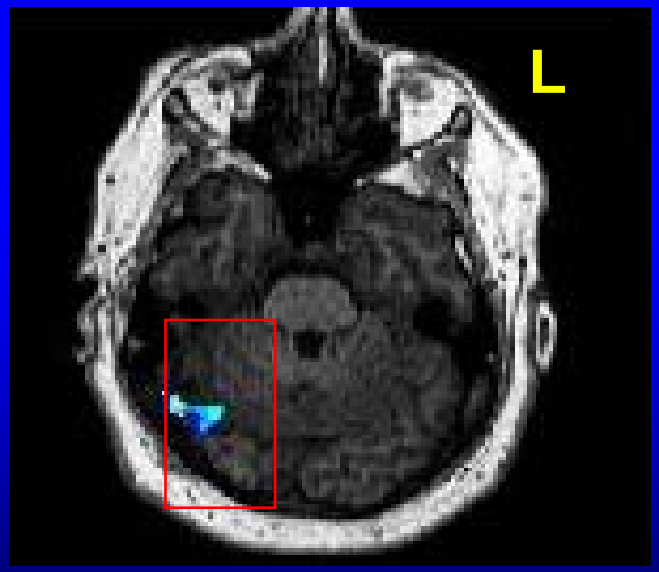
High coherence (red>blue)

Subject # 1611

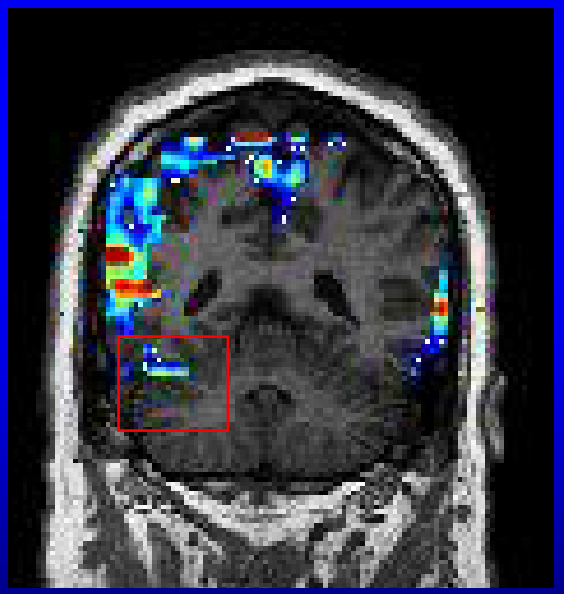
WADA Language
Right

Coherence: Right **Match**





Run 1

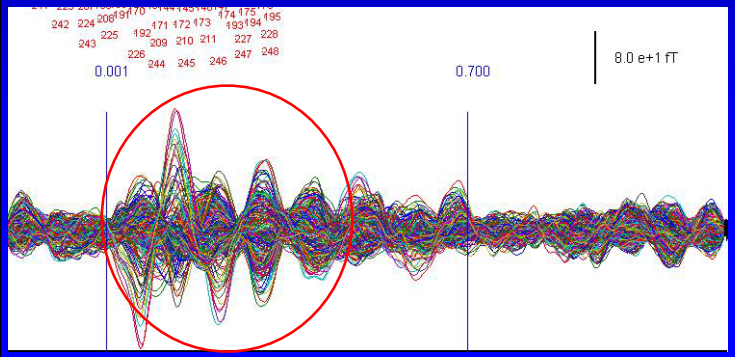


Run 2

High coherence (red>blue)

Subject # 1631

MEG waveform



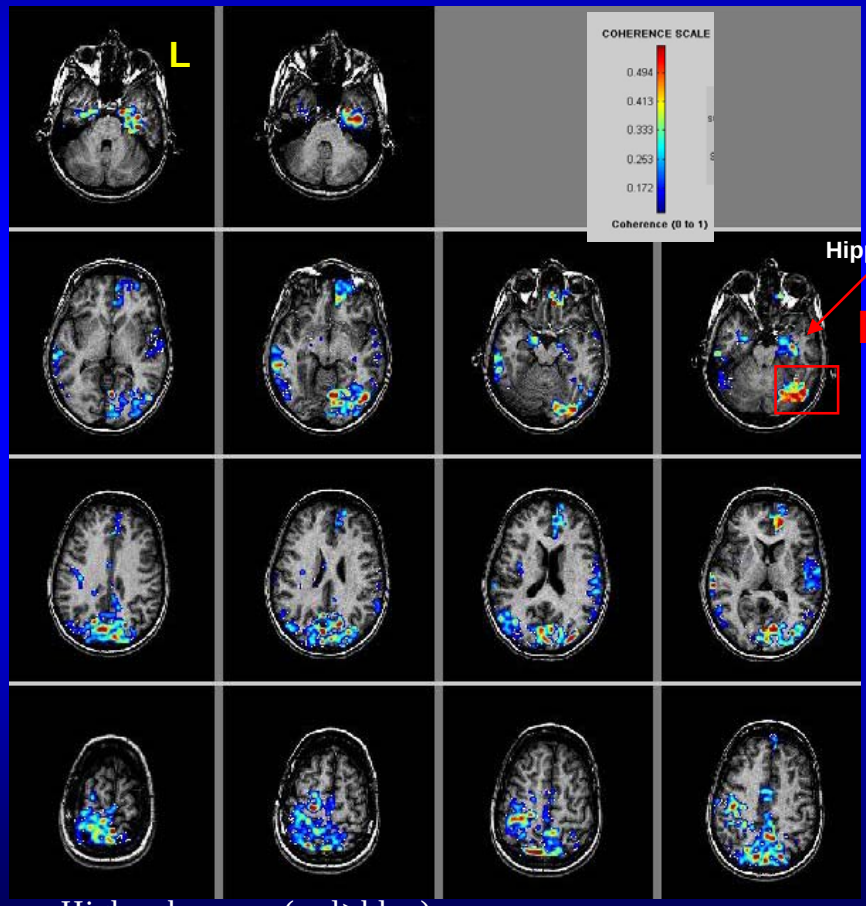
Evoked responses can be seen

MR-FOCUSS
Laterality Time Index

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

WADA Language
Bi Lateral, LEFT

Coherence: -39, 41 Bi Lateral

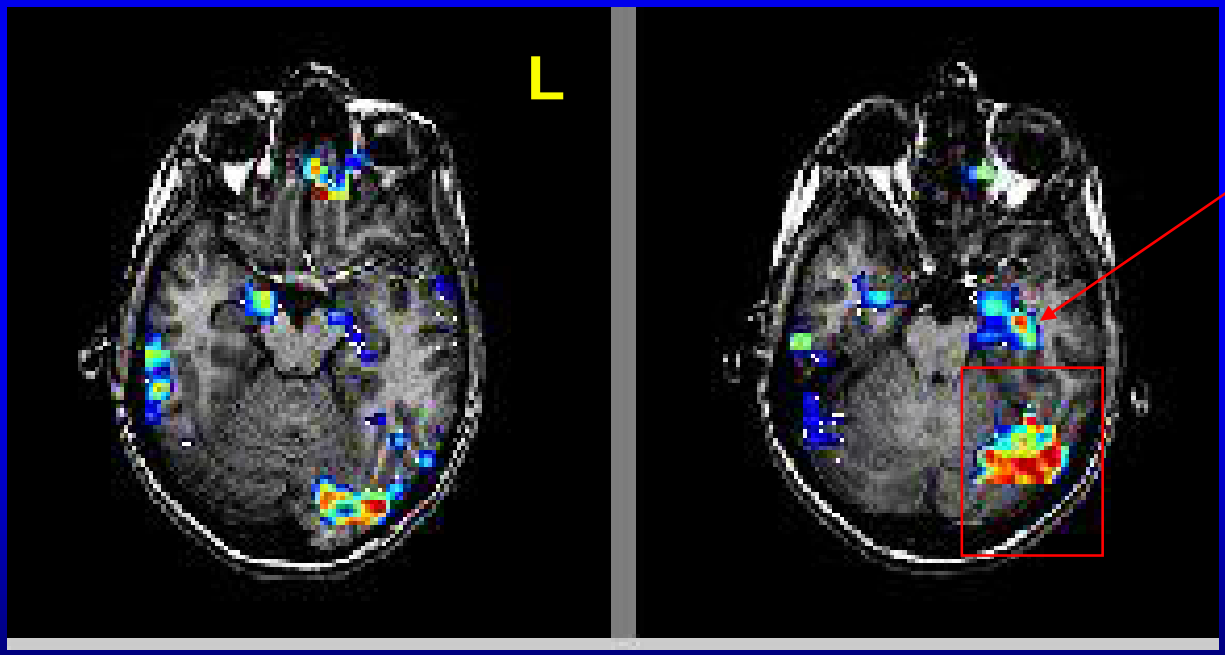


High coherence (red>blue)

Subject # 1631

WADA Language
Bi Lateral, LEFT

Coherence: LEFT Match

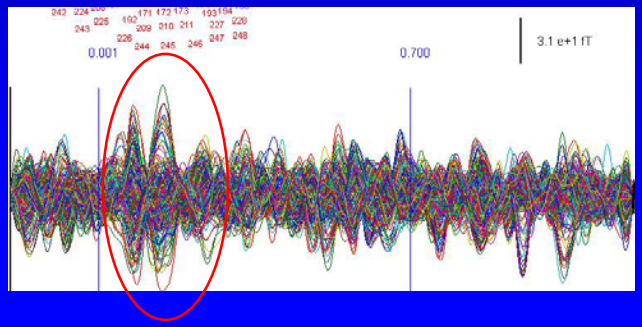


High coherence (red>blue)

Subject # 1692

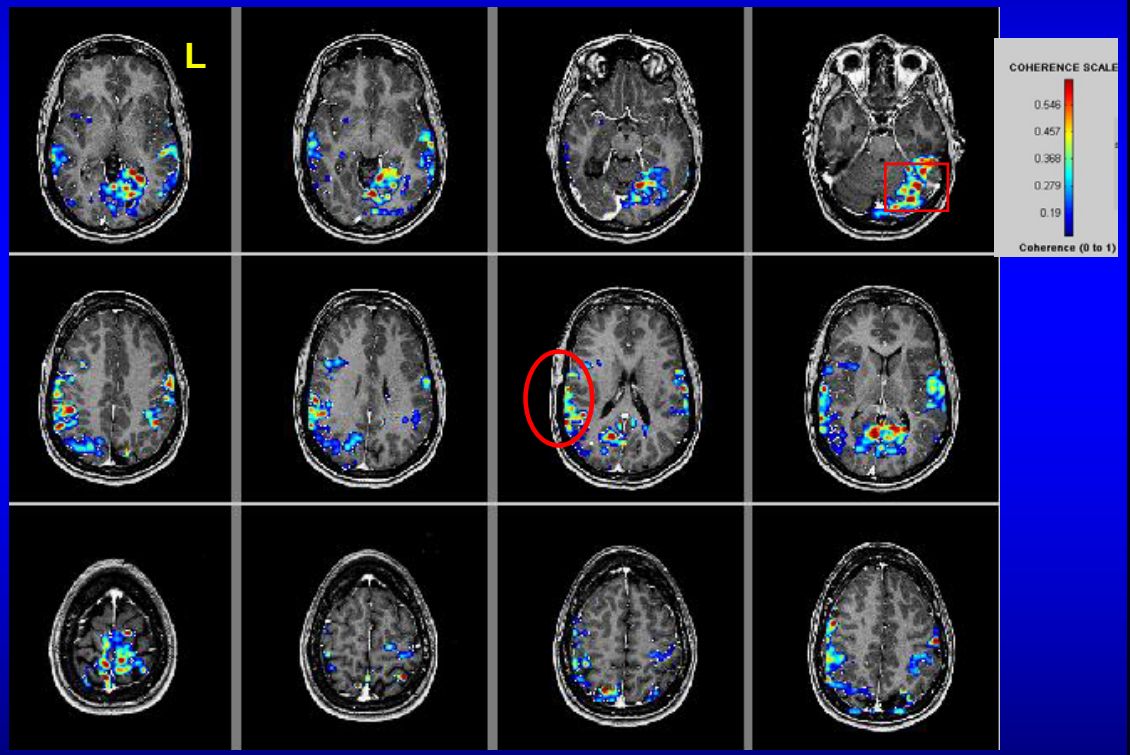
WADA Language
Left

MEG waveform



Poor evoked response can be seen

Coherence: 76, 80 Right



High coherence (red>blue)

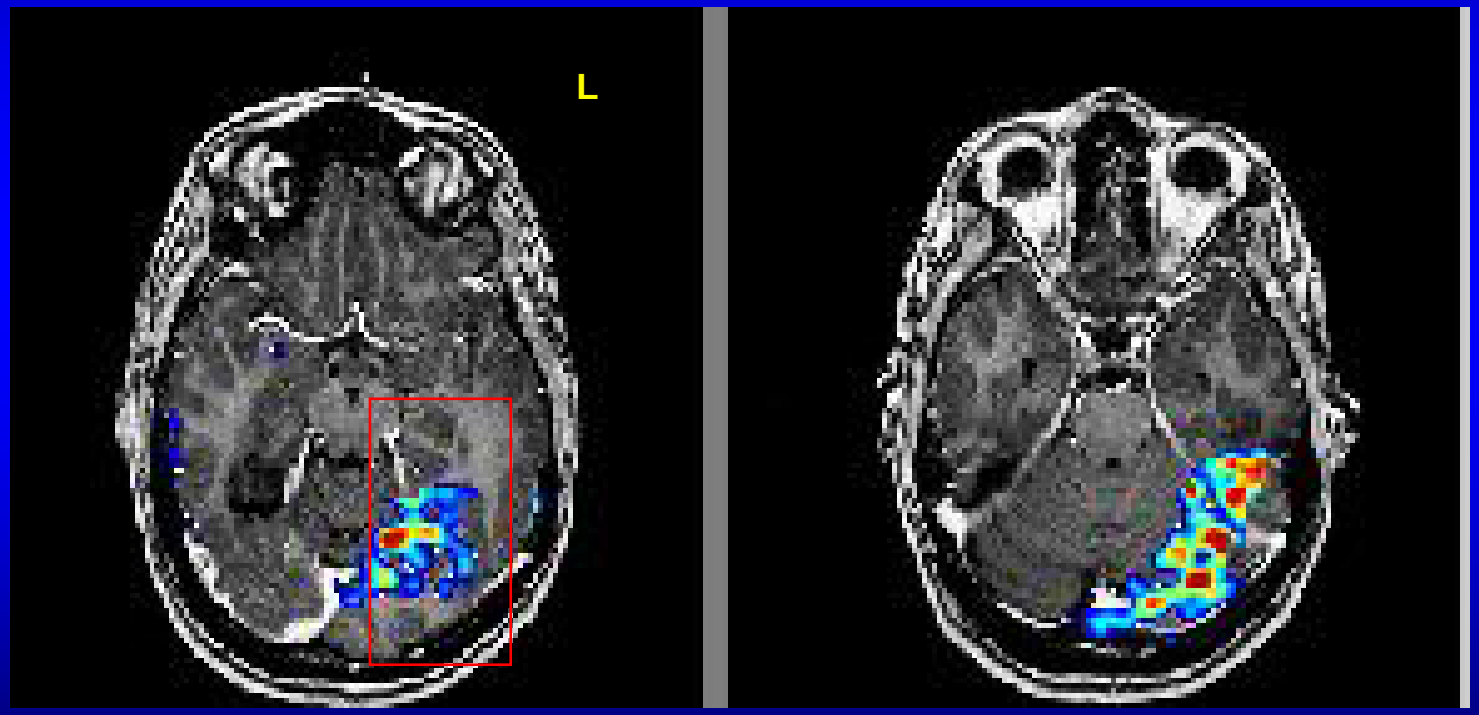
MR-FOCUSS
Laterality Time Index

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

Subject # 1692

WADA Language
Left

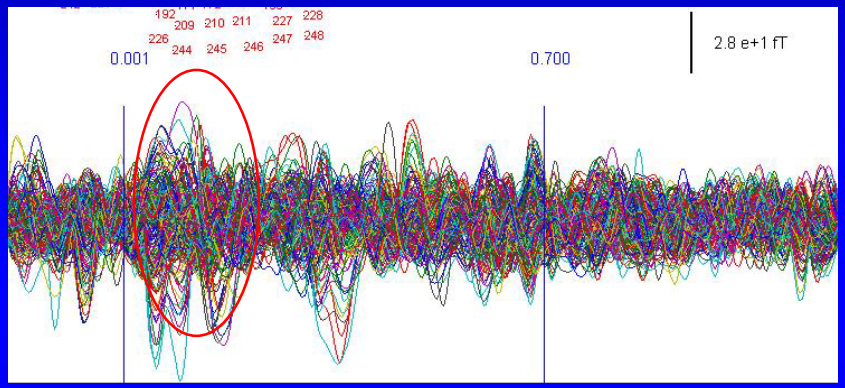
Coherence: Left **Match**



High coherence (red>blue)

Subject # 1693

MEG waveform



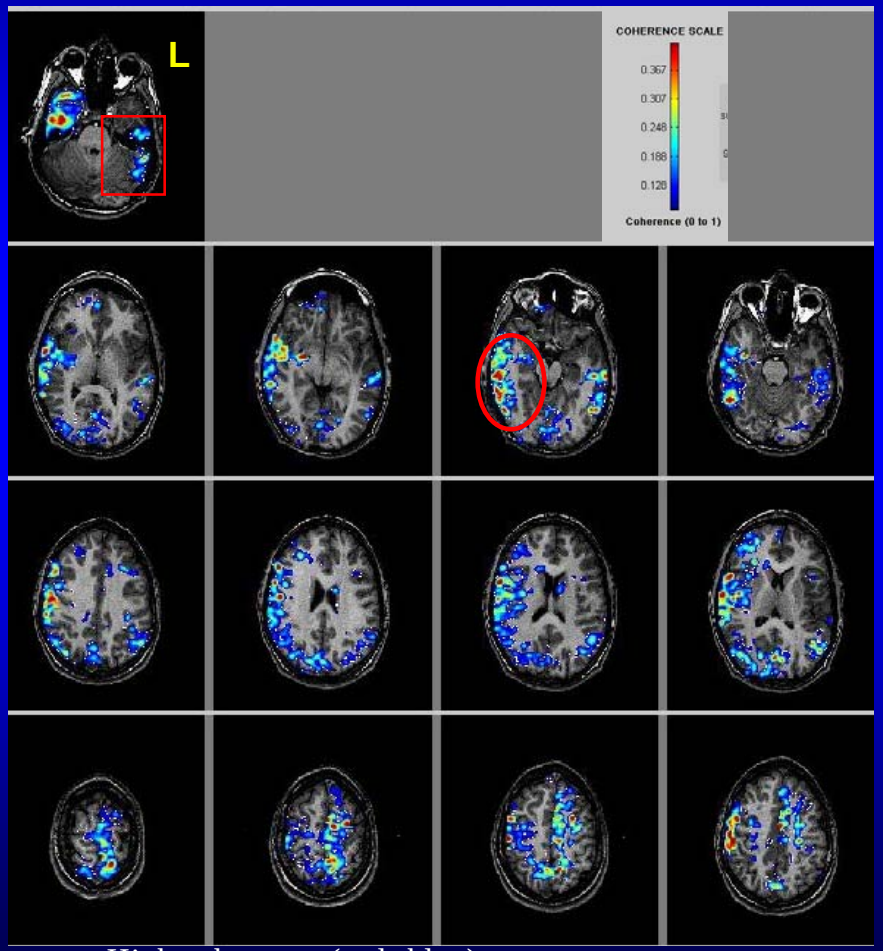
Evoked responses can barely be seen

MR-FOCUSS
Laterality Time Index

100-1000: 78, 42 Right
239-290: 100, 73 Right
390-460: 41, 41 Right

WADA Language
Left

Coherence: 20, 40 Right



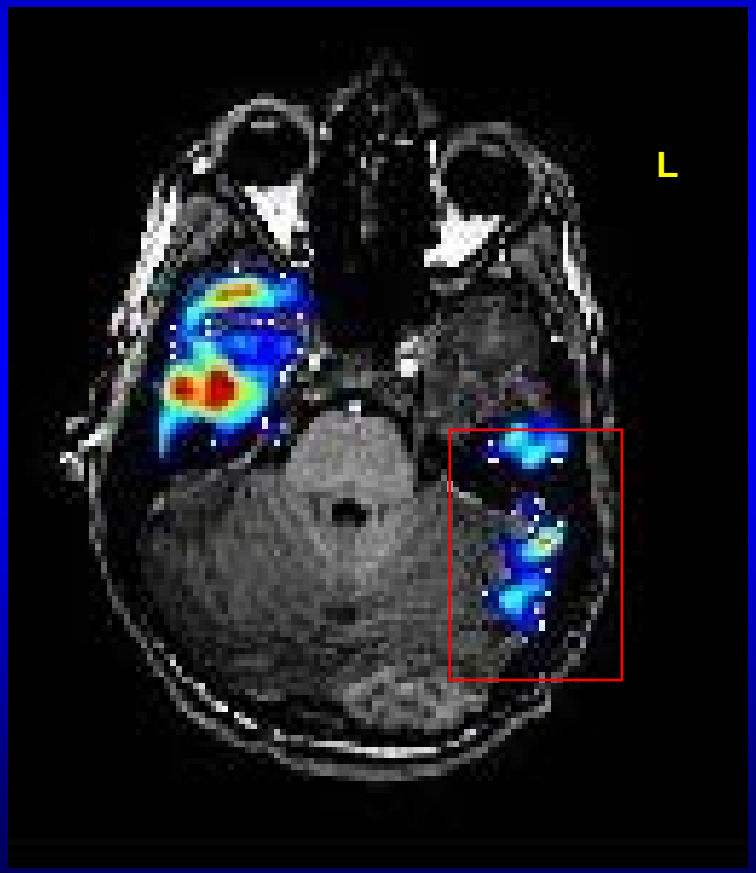
High coherence (red>blue)

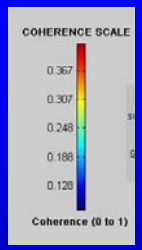
Subject # 1693

WADA Language
Left

Coherence: Left

Match

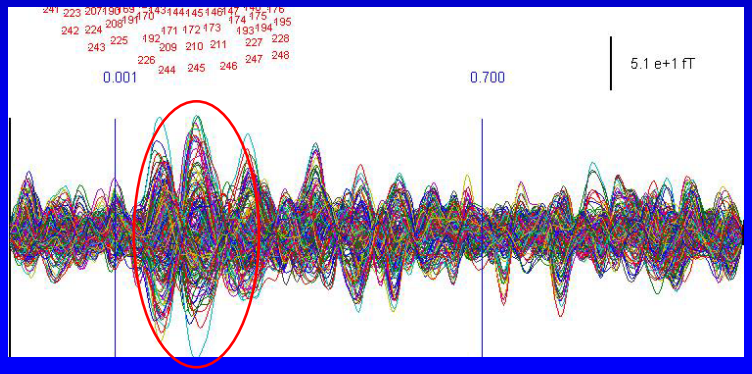




High coherence (red>blue)

Subject # 1894

MEG waveform



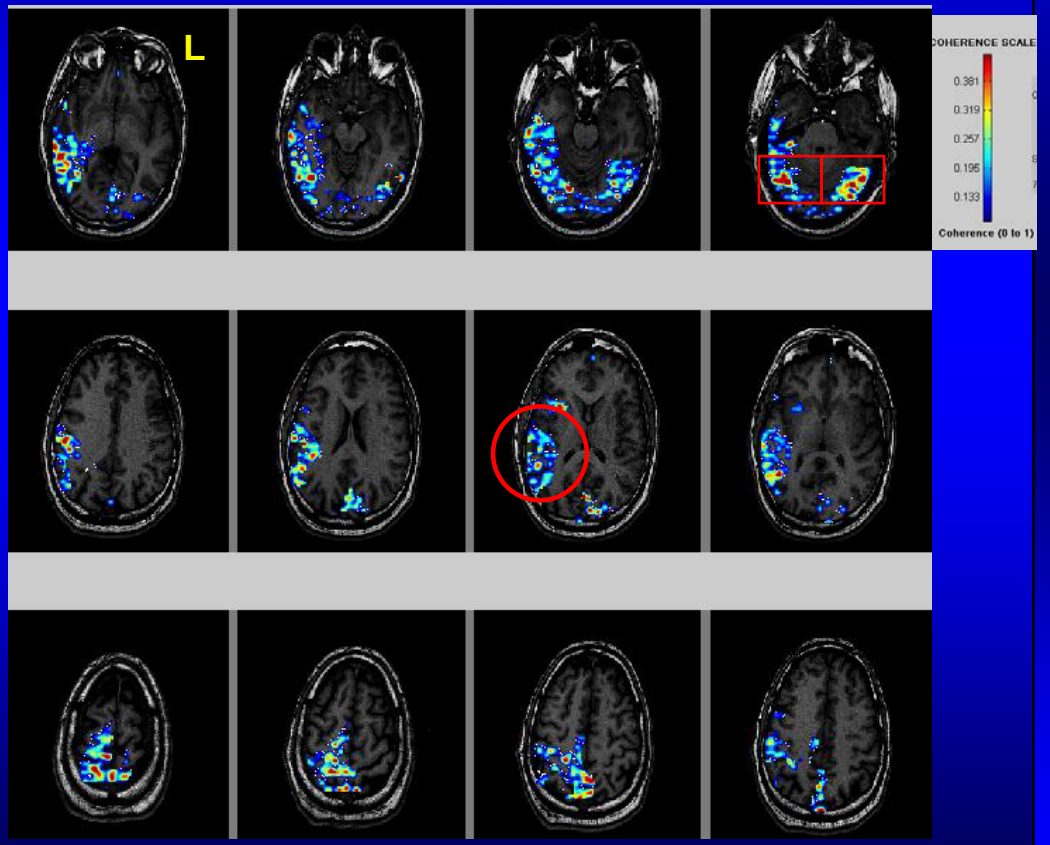
Evoked responses can be seen

MR-FOCUSS
Laterality Time Index

100-1000: -35, -20 Left Match
239-290: -100, -47 Left Match
390-460: 41, 29 Right

WADA Language
Left

Coherence: 71, 45 Right

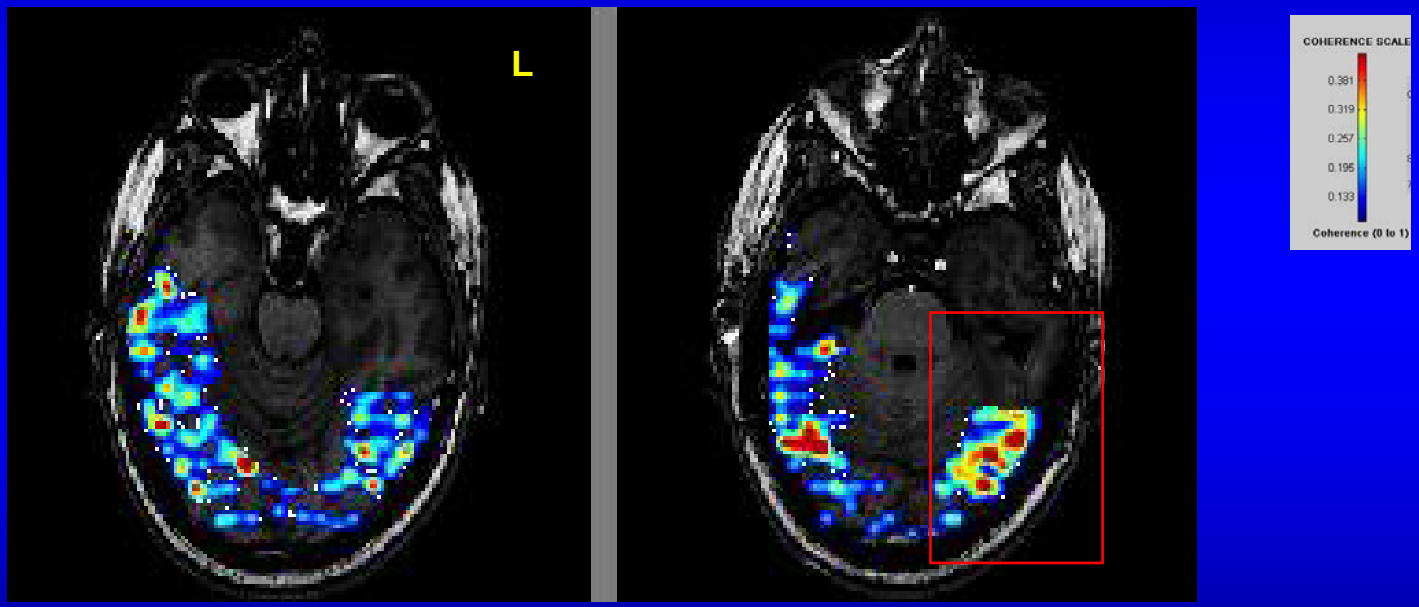


High coherence (red>blue)

Subject # 1894

WADA Language
Left

Coherence: Bi Lateral L>R **Match**

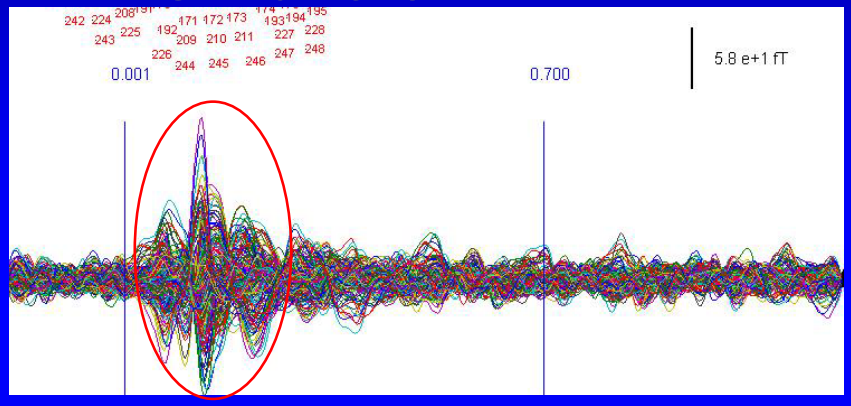


High coherence (red>blue)

Subject # 1900

WADA Language
Left

MEG waveform

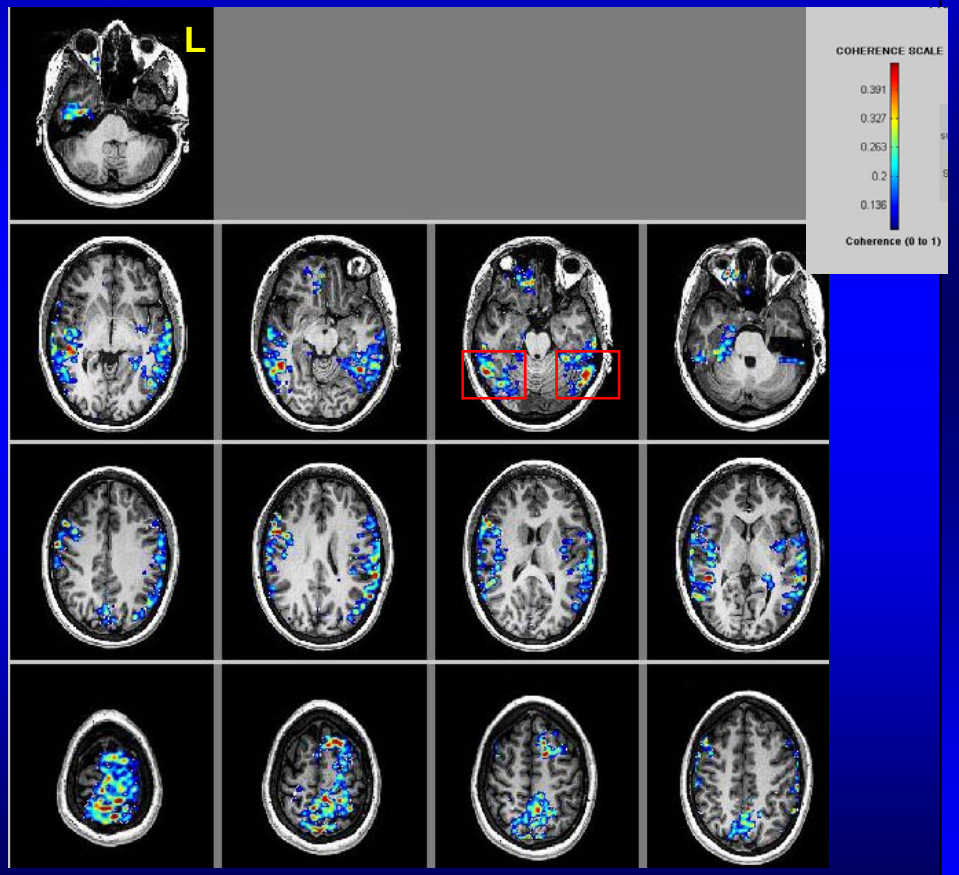


Evoked responses can be seen

MR-FOCUSS
Laterality Time Index

100-1000: 13, 28 Right
239-290: 20, 20 Right
390-460: 6, -18 Bi lateral

Coherence: -5, -61 Left Match



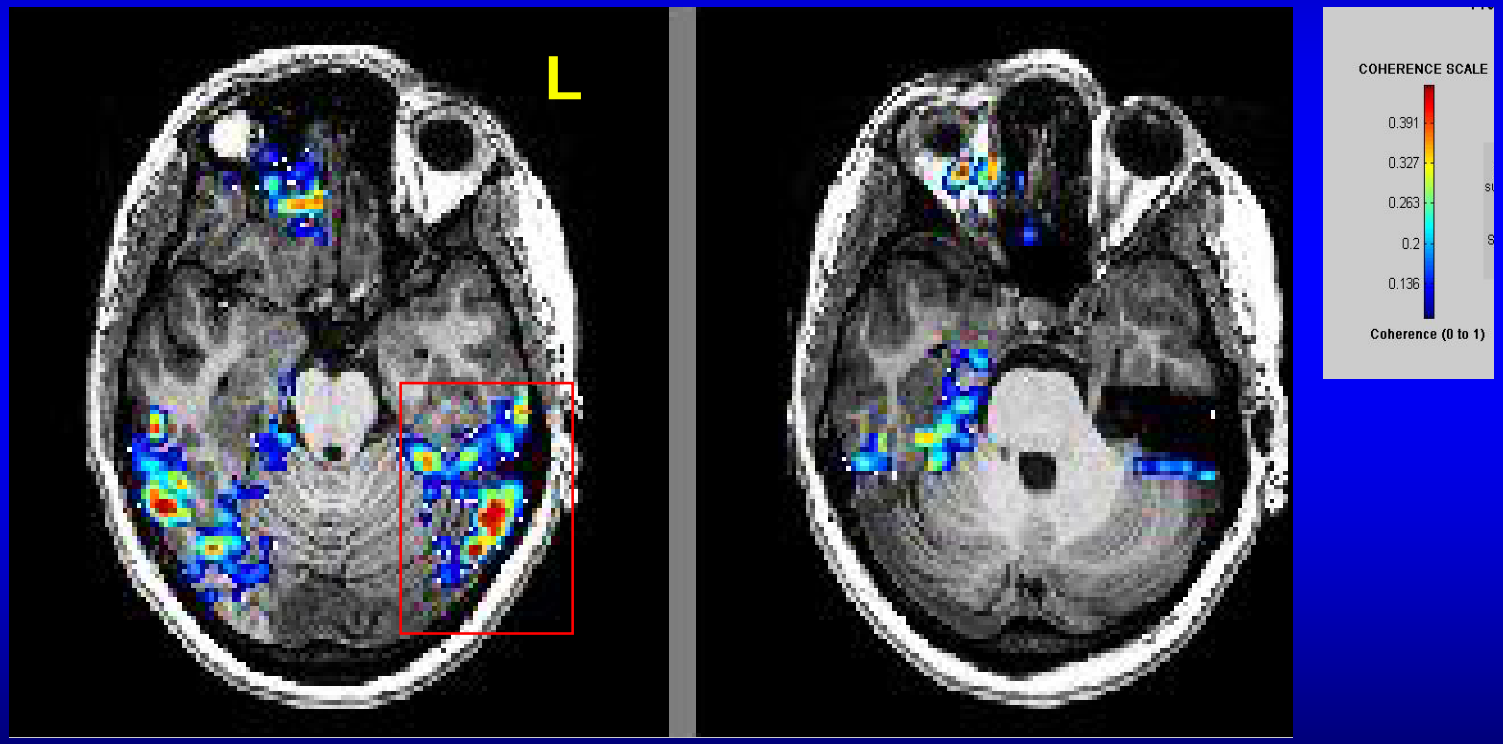
High coherence (red>blue)

Subject # 1900

WADA Language
Left

Coherence: Bi lateral L>R

Match

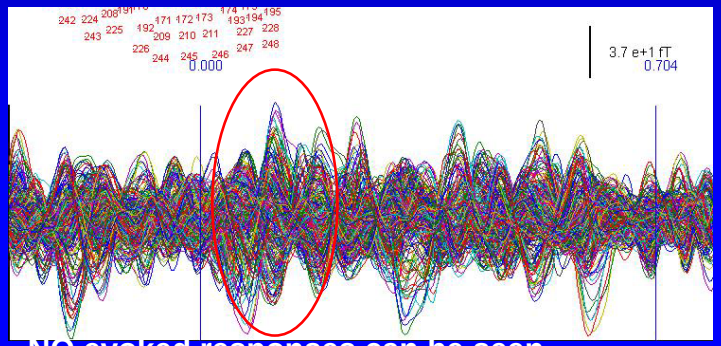


High coherence (red>blue)

Subject # 1933

WADA Language
Right

MEG waveform

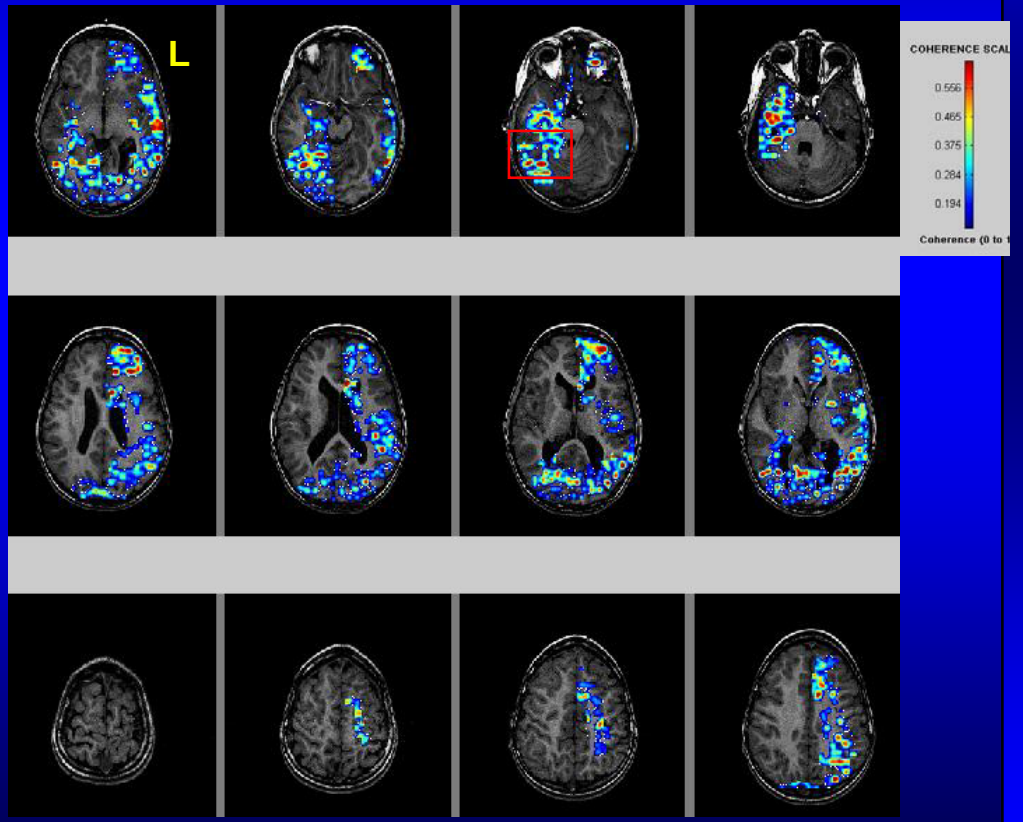


NO evoked responses can be seen

MR-FOCUSS
Laterality Time Index

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

Coherence: -7, 12 Bi lateral/Right Match

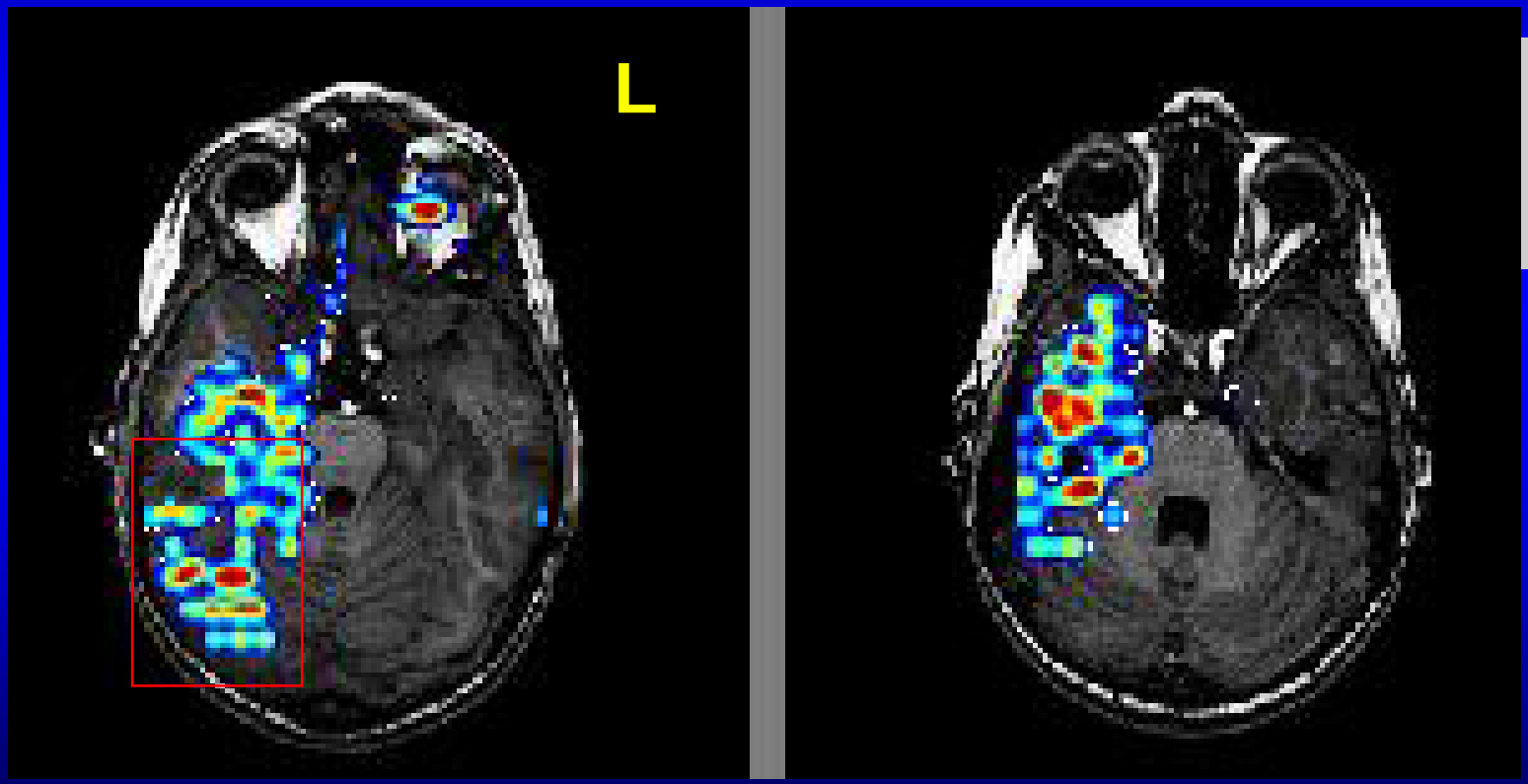


High coherence (red>blue)

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 Occipitotemporal region matched in all 8 of 8 patients

Table of results

Patient ID		WADA Laterality Language	WADA Laterality Memory	Quality of MEG Recordings	Original Laterality Estimates Based on Single Dipole	Coherence Mapping Estimates of Laterality Language	MNE Madrid Estimates of Language Laterality	MNE Houston Estimates of Language Laterality		Occipito-Temporal
								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				
Success Ratio					75%	50%	50%	50%	88%	100%

Conclusions

- NEED to 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 by MEG, just as a battery of psychometric tests are used to characterize language in the Psychology Departments.

Future

- Perform a retrospective analysis of Patients that have clean MEG data sets.
- Advanced network evaluation techniques (Granger causality, narrow band filtering or Essential Mode Decomposition with Hilbert transforms, wavelets) can be applied to non-stationary data.
  - Determine the direction of network interactions
  - Quantify significance of network structures

MEG_TOOLS

a complete MEG analysis software package (requires Matlab)

available at www.megimaging.com