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AMERICAN CLINICAL MEG SOCIETY

On behalf of the Program and Course Committees and the ACMEGS Board of Directors, let me welcome you to Orlando! This is a perfect opportunity to update your MEG knowledge, gain some insights to help launch new scientific endeavors, and – for those of us in the northern climes – enjoy a pleasant spot of sun.

Our sixth joint meeting with the American Clinical Neurophysiology Society is a testament to our relationship with ACNS which has grown even closer, with good interdigitation of meeting sessions and representation on the ACNS council. I know that those who have made the trip to Orlando have excellent opportunities to learn and interact with colleagues – in all areas of clinical neurophysiology, including MEG.

ACMEGS's first decade has recently passed, and this milestone will be celebrated not only at the ACMEGS meeting, but during a companion session on Saturday February 12 at the ACNS meeting ("The Wisdom and Vision from the ACMEGS Inaugural Decade"). This MEG SIG will review the history of our organization and take a look at what ACMEGS can look forward to in the future.

The MEG community continues to thrive, with several MEG centers added this year or already in the construction phase. The need for training of the personnel who staff these centers, access to the latest clinical techniques and research findings, and opportunities to interact with colleagues has never been greater. In the epilepsy realm, I am especially pleased to see MEG results presented often and as part of the standard of care – along with MRI, PET, etc – during case presentations at other meetings (e.g. AES). Just three or four years ago, the presentation of MEG findings from patient workups was rare. Progress on standardization of insurance coverage policies has also continued to move forward.

As for ACMEGS, we are expanding: we welcomed our very first European member this year, and our meeting program features speakers from Korea, France, Germany, and Canada! We hope that you will also join us at our annual business meeting, where we will update you on some progress on the reimbursement front as well as opportunities for members to participate in the activities of ACMEGS, including the election of new board members.

The meeting day concludes with our traditional ACMEGS dinner (included as always in your meeting registration) at a restaurant chosen for its delicious Florida Keys specialties!

Sincerely,

Richard C. Burgess, MD, PhD, FACNS
President, American Clinical Magnetoencephalography Society (ACMEGS)

Organizing Committee:
Anto Bagić, University of Pittsburgh, Pittsburgh, PA
Susan Bowyer, Henry Ford Hospital, Detroit, MI
Richard Burgess, Cleveland Clinic, Cleveland, OH
Michael Funke, University of Texas, Houston, TX
Paul Ferrari, University of Texas at Austin, Austin, TX
Heidi Kirsch, University of California San Francisco, CA
Gretchen Von Allmen, University of Texas, Houston, TX

2016 ACMEGS Annual Conference
Thursday, February 11, 2016
Hilton Orlando Lake Buena Vista • Orlando, Florida

8:30am	Arrival / Breakfast Reception	
9:30 am	ACMEGS Presidential Address 2016 *Welcome and Introduction (Richard Burgess, Cleveland)*	
9:50am	MEG Analysis Across Different Types of Neurological Disorders	Chair: Heidi Kirsch, San Francisco

- *Mesial Temporal Lobe Epilepsy with Hippocampal Sclerosis is a Network Disorder with Altered Cortical Hubs* Seung-Hyun Jin, Seoul
- *Global and Regional Functional Connectivity Maps of Neural Oscillations in Focal Epilepsy* - Heidi Kirsch, San Francisco
- *MEG-Based Detection and Localization of Peri-Lesional Dysfunction in Chronic Stroke* - Ron Chu, Toronto

11:30am Annual ACMEGS Photo Shoot / Lunch

12:15pm Clinical MEG Quality Assurance — Chair: Richard Burgess, Cleveland

- *Basic Assurance of Recording Quality* - John Mosher, Cleveland
- *Systematic Review of Normal Variants* - Stefan Rampp, Erlangen
- *Recognizing and Correcting MEG Artifacts* - Richard Burgess, Cleveland

1:55pm Coffee Break

2:15pm Current Issues and Enduring Questions in Clinical MEG — Chair: Gretchen Von Allmen, Houston

- *Beyond the Spike: Alternative Markers for the Epileptic Network* - Stefan Rampp, Erlangen
- *Integration of MEG with Other Brain Imaging Modalities and Intracranial EEG* - Irene Wang, Cleveland
- *Localizing Language Function with MEG* - Catherine Liegeois-Chauvel, Cleveland

4:00pm Update on Educational Initiatives — Chair: Richard Burgess, Cleveland

- *The State of MEG Fellowships*
- *Update and Announcements on MEG/EEG-Technologist Activities*

4:30pm What's on the Horizon: Vendor Innovations and Plans — Chair: Richard Burgess, Cleveland

- *ANT Neuro North America* - Frank Zanow
- *Compumedics, USA* – Curtis Ponton, Vice President, Chief Science Officer
- *Elekta Neuroscience* – Miikka Putaala, Director, Business Line MEG
- *York Instruments* - Gary Green, Director

5:00pm Meeting Adjourn
The ACMEGS Business Meeting follows at 5:10pm (see next page). All are welcome to attend, but only ACMEGS members may vote. All registered attendees at the ACMEGS meeting are invited to our annual dinner at 6:30pm.

5:10pm Business Meeting Chair: Richard Burgess, Cleveland

- *President's Report – Richard Burgess, Cleveland*
- *Financial Report* - Susan Bowyer, Detroit
- *Membership Report* - Susan Bowyer, Detroit
- *Public Relations Committee* - Susan Bowyer, Detroit
- *Website Committee* - Paul Ferrari, Austin
- *New Business*
    - ACMEGS Committee Involvement - Richard Burgess, Cleveland
    - Joint Meeting with ACNS—hosting 31st ICCN in May 2018 - Richard Burgess, Cleveland
    - Tales from the Reimbursement Front – Angel Hernandez, Dallas, and Michael Funke, Houston
- *Board Elections* - Richard Burgess, Cleveland

6:30pm **ACMEGS Dinner at HEMINGWAY'S**
One Grand Cypress Blvd., Hyatt Regency Grand Cypress Hotel (1.6 Miles from Hilton Orlando Buena Vista Hotel)

Presidential Address
Richard C. Burgess, Cleveland

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Mesial Temporal Lobe Epilepsy with Hippocampal Sclerosis is a Network Disorder with Altered Cortical Hubs

Seung-Hyun Jin, Seoul

In this study, we investigated resting-state network hubs in patients with mesial temporal epilepsy (MTLE) associated with hippocampal sclerosis (HS).

Resting-state functional networks, by using MEG signals in the theta, alpha, beta, and gamma frequency bands, were evaluated. Networks in 44 mTLE patients with HS (left MTLE = 22; right MTLE = 22) were compared with those in 46 age-matched healthy controls (HC). We investigated betweenness centrality (BC) at the source–level MEG network.

The main network hubs were at the pole of the left superior temporal gyrus in the beta band, the pole of the left middle temporal gyrus in the beta and gamma bands, left hippocampus in the theta and alpha bands, and right posterior cingulate gyrus in all 4–frequency bands in MTLE patients; all of which were different from the main network hubs in HC. Only left MTLE patients showed profound differences from HC at the left hippocampus in the alpha band. Our analysis of resting-state MEG signals shows that altered electrophysiological functional hubs in MTLE patients reflect pathophysiological brain network reorganization. Since we detected network hubs in both hippocampal and extra-hippocampal areas, it is probable that MTLE is a large-scale network disorder rather than a focal disorder. The hippocampus was a network hub in left MTLE but not in right MTLE patients, which may be due to intrinsic functional and structural asymmetries between left and right MTLE patients. The evaluation of cortical hubs, even in the spike-free resting-state, could be a clinical diagnostic marker of MTLE with HS. Our results suggest the feasibility of using functional brain network analysis of resting-state MEG to elucidate the intrinsic brain network differences in MTLE patients.

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Medial Temporal Lobe Epilepsy with Hippocampal Sclerosis is a Network Disorder with Altered Cortical Hubs

Seung-Hyun Jin, Ph.D.
Neuroscience Research Institute,
Seoul National University College of Medicine;
Human Brain Function Lab., Seoul National University;

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Contents

1. Introduction
2. Motivation and hypothesis
3. Subjects and methods
4. Results
5. Discussion
6. Conclusion

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Introduction

- Temporal lobe epilepsy (TLE) is the most common drug-resistant epilepsy in adults.
- Accumulating evidences has shown that TLE is a disorder of abnormal epileptogenic network, rather than focal sources (Bernhardt et al., 2013; review).
- <u>**Altered structural and functional networks**</u> were reported in TLE (Bernhardt et al., 2013; review).

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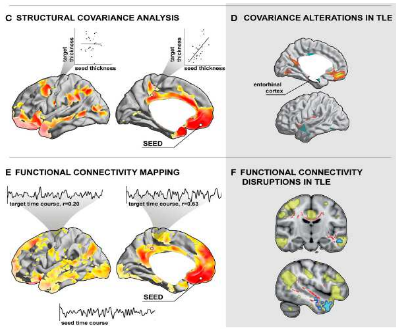
Introduction



Bernhardt et al., (2013) Front Hum Neurosci

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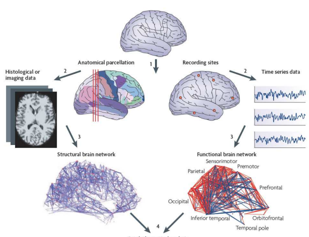
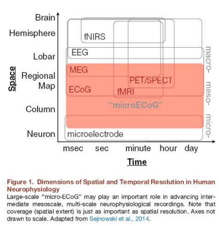
Introduction

- Graph-theoretic analysis of brain networks





Bullmore and Sporns, 2009, Nat Rev Neurosci

Chang, 2015, Neuron

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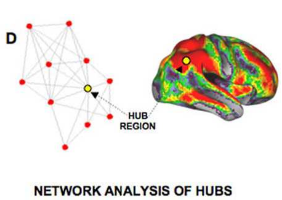
Introduction

- **Network hubs**

  → a privileged role in organizing network dynamics (Bullmore and Sporns, 2012).



Buckner et al., (2009) J Neurosci

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Motivation and hypotheses

- **Electrophysiological network analysis** → high temporal resolution
- The electrophysiological hubs of the large-scale (whole-brain) functional networks in mTLE with HS have not been investigated.

Hypotheses

I. Altered functional cortical hubs in mTLE with HS
II. The hippocampus would comprise functional hubs in the resting-state large-scale brain networks of mTLE patients with HS.

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Subjects

Subjects: 44 mTLE patients who had histopathologically proven HS and post-surgical seizure freedom (f.u. > 2 yrs) and 46 age-matched healthy controls

	HC (n=46)	mTLE Patients		
		Left mTLE (n=22)	Right mTLE (n=22)	Total (n=44)
Sex, M:F	19:27	10:12	7:15	17:27
Mean age (range), year	29 (21-60)	31 (20-51)†	32 (17-56)† n.s.	32 (17-56)
Mean age at seizure onset (range), year	n.a.	10 (1-34)	14 (1-39)n.s.	12 (1-39)
Duration of epilepsy (range), year	n.a.	21 (1-36)	18 (1-39)n.s.	19 (1-39)

Abbreviations: HC = healthy controls; mTLE = mesial temporal lobe epilepsy with hippocampal sclerosis; n.a. = not applicable; n.s. = not significant between left mTLE and right mTLE. Note: † indicates mean age at surgery.

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Methods

A. **Recording**

MEG recording during eyes-closed resting state

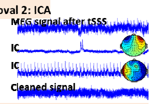
B. **Artifact removal 1: tSSS**
temporal signal space separation

⇩

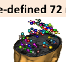
Epoching (5 epochs of 10 sec (pt: spike-free))

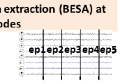
⇩

Artifact removal 2: ICA

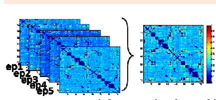


C. **Source waveform extraction (BESA) at pre-defined 72 nodes**

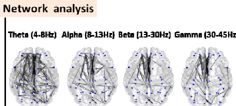




D. **MI estimation:** To define functional connectivity among MEG source signals



E. **Network analysis**



Betweenness Centrality (BC)
To define a network hub

Functional connectivity measure

Mutual Information (MI)

1. As a functional connectivity measure
2. MI has been used to evaluate functional coupling between brain regions.

$$\mathrm{MI} = \mathrm{MI}_{XY} = \mathrm{MI}_{YX} = \mathrm{MI}(X(t), Y(t))$$
$$= -\sum_{X(t),Y(t)} p(X(t),Y(t)) \log \frac{p(X(t),Y(t))}{p(X(t))\,p(Y(t))}$$

P(•): Probability density function (PDF)
MI=0, when the time series X and Y are independent.
MI=maximum, when the time series X and Y are identical.

Rationale: MI is a relatively sensitive way to reveal frequency-specific functional connectivity compared to cross-correlation, generalized synchronization, and phase synchronization [David et al., 2004]

Network hub measure

Betweenness centrality

1. **Betweenness centrality (BC)** is defined as the fraction of all shortest paths in the network that pass through a given node.
2. BC measures **how often a network node occurs on the shortest paths between other nodes.**

$$BC = \sum_{\substack{h,\, j \in N \\ h \neq j,\, h \neq i,\, j \neq i}} \frac{g_{hj}(i)}{g_{hj}}$$

$g_{hj}(i)$: the number of shortest paths between node *h* and *j* passing through *i*.

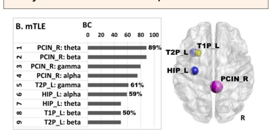
g_{hj}: the number of shortest paths between node *h* and *j*

Statistical analysis

1st test: Single subject level.
The nodes with a z-score of > 2 SD were defined functional cortical hubs with high BC.

→ Aggregated ranking percent irrespective of the frequency bands ⇒ main hubs (when > 50% of subjects have this hub)

$$z_i = \frac{\mathrm{BC}(i) - \mathrm{mean}(\mathrm{BC})}{\mathrm{SD}(\mathrm{BC})}$$



2nd test: Group level.
A Kruskal-Wallis test (group-wise comparison between the mTLE and HC groups) and a post-hoc Mann-Whitney test (group wise comparisons, corrected).

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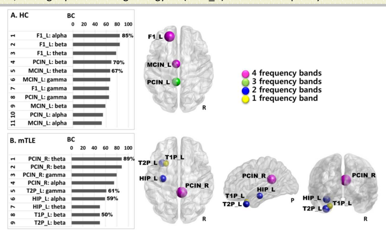
Results

Ranked distribution of all the hubs irrespective of the frequency bands showing the main network hubs

- The HC group: the left dorsolateral superior frontal gyrus (F1_L) in all four frequency bands, left middle cingulate gyrus (MCIN_L) in all four frequency bands, and left posterior cingulate gyrus (PCIN_L) in the alpha, beta and gamma bands.
- The mTLE group: the left temporal pole of the superior temporal gyrus (T1P_L) in the beta band, left temporal pole of the middle temporal gyrus (T2P_L) in the beta and gamma bands, left hippocampus (HIP_L) in the theta and alpha bands, and right posterior cingulate gyrus (PCIN_R) in all four frequency bands.



Note: hub color = the number of frequency bands identified at the hubs at the same location; hub size = the largest aggregated ranking percentage of the hub location.

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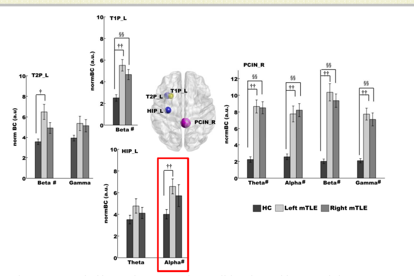
Results

Group differences in BC at the mTLE patients' hubs

- Of the 9 identified hubs of the mTLE patients, 7 hubs were significantly different between HC and mTLE groups.
- Interestingly, only left mTLE patients had significantly greater BC values than those of HC at left temporal pole of the middle temporal gyrus (T2P_L) in the beta band and left hippocampus (HIP_L) in the alpha band.



Abbreviations: HIP = hippocampus; HC = healthy controls; mTLE = mesial temporal lobe epilepsy with hippocampal sclerosis; T1P = superior temporal gyrus (temporal pole); T2P = middle temporal gyrus (temporal pole); PCIN = posterior cingulate gyrus; _L or _R = left or right.

Note: # $p < 0.05$ (corrected, between HC and mTLE); † $p < 0.05$ (corrected, between HC and left mTLE); †† $p < 0.01$ (corrected, between HC and left mTLE); §§ $p < 0.01$ (corrected, between HC and right mTLE);

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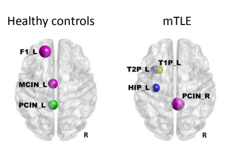
Discussion

1. Altered electrophysiological functional hubs in mTLE patients

➡ It is reflective of the pathophysiologic brain network reorganization of mTLE patients' brains.



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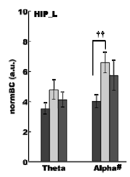
Discussion

2. Our hippocampal hypothesis turned out to be only valid in left mTLE patients.

- It may be due to intrinsic functional and structural asymmetries between left and right mTLE patients.
- It suggested that the HIP_L in the alpha band might be an electrophysiological functional network biomarker of an epileptogenic network in left mTLE patients.



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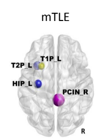
Discussion

3. Network hubs in the extrahippocampal regions

- It suggests that mTLE is a disorder of neuronal networks that is not limited to the hippocampal lesion, but a disorder that involves the large-scale functional network.
- The appearance of T1P_L, T2P_L and PCIN_R as hubs could indicate the presence of different intrinsic resting state functional hubs in mTLE patients compared to HC.



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Conclusion

- Altered electrophysiological functional hubs in mTLE patients
- The mTLE is a large-scale network disorder rather than a focal disorder.
- The evaluation of cortical hubs, even in the spike-free resting-state, could be a clinical diagnostic marker of mTLE with HS.

Acknowledgments

Grant: the Korean Health Technology R&D Project, Ministry of Health & Welfare (Grant no. HI11C1360) and the National Research Foundation of Korea (NRF) funded by the Ministry of Science, ICT & Future Planning (MSIP) (Grant no. 2010-0028631).

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Thank you for your attention !

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Global and Regional Functional Connectivity Maps of Neural Oscillations in Focal Epilepsy

Heidi Kirsch, San Francisco

Intractable focal epilepsy is a devastating disorder with profound effects on cognition and quality of life. Epilepsy surgery can lead to seizure freedom in patients with focal epilepsy; however, sometimes it fails due to an incomplete delineation of the epileptogenic zone. Brain networks in epilepsy can be studied with resting-state functional connectivity analysis, yet previous investigations using functional magnetic resonance imaging or electrocorticography have produced inconsistent results. Magnetoencephalography allows non-invasive whole-brain recordings, and can be used to study both long-range network disturbances in focal epilepsy and regional connectivity at the epileptogenic zone. In magnetoencephalography recordings from presurgical epilepsy patients, we examined: (i) global functional connectivity maps in patients versus controls; and (ii) regional functional connectivity maps at the region of resection, compared to the homotopic non-epileptogenic region in the contralateral hemisphere. Sixty-one patients were studied, including 30 with mesial temporal lobe epilepsy and 31 with focal neocortical epilepsy. Compared with a group of 31controls, patients with epilepsy had decreased resting-state functional connectivity in widespread regions, including perisylvian, posterior temporo-parietal, and orbitofrontal cortices ($P<0.01$, t-test). Decreased mean global connectivity was related to longer duration of epilepsy and higher frequency of consciousness-impairing seizures ($P<0.01$, linear regression). Furthermore, patients with increased regional connectivity within the resection site ($n = 24$) were more likely to achieve seizure postoperative seizure freedom (87.5% with Engel I outcome) than those with neutral ($n = 15$, 64.3% seizure free) or decreased ($n = 23$, 47.8% seizure free) regional connectivity ($P<0.02$, chi-square). Widespread global decreases in functional connectivity are observed in patients with focal epilepsy, and may reflect deleterious long-term effects of recurrent seizures. Furthermore, enhanced regional functional connectivity at the area of resection may help predict seizure outcome and aid surgical planning.

Global and regional functional connectivity maps of neural oscillations in focal epilepsy

Heidi E. Kirsch, MS, MD
UCSF Biomagnetic Imaging Center
UCSF Epilepsy Center

University of California San Francisco

Disclosures

No COI to disclose.

University of California San Francisco

RESTING-STATE FUNCTIONAL CONNECTIVITY ANALYSIS

What is functional connectivity?

Why study it in epilepsy?

- To improve surgical targeting of the epileptogenic zone (EZ)
- To understand the deleterious network effects of epilepsy

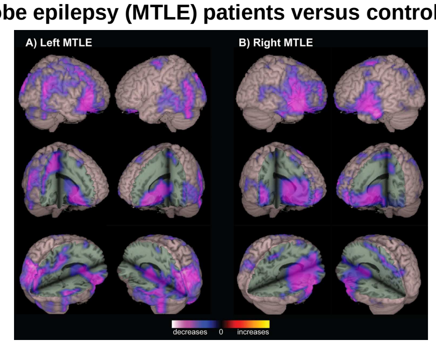
UCSF University of California San Francisco

MEG functional connectivity in epilepsy: Study methods and goals

- Methods:
  - Calculate alpha-band imaginary coherence from resting-state recordings
  - Source-space analysis, 3D grid of voxels, 8-mm spatial resolution
  - Exclude: age < 18, infiltrative lesion, prior surgery, no spike-less data
- 1) Whole-brain functional connectivity across epilepsy patients versus controls (n = 61)
- 2) Regional connectivity at the presumed EZ versus contralateral hemisphere (within patients)

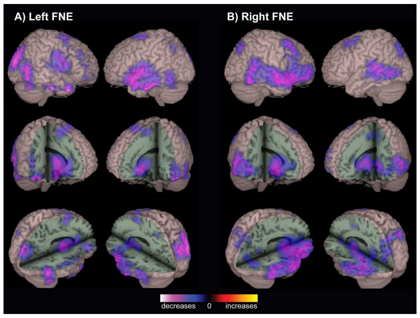
UCSF University of California San Francisco

Decreased functional connectivity in mesial temporal lobe epilepsy (MTLE) patients versus controls



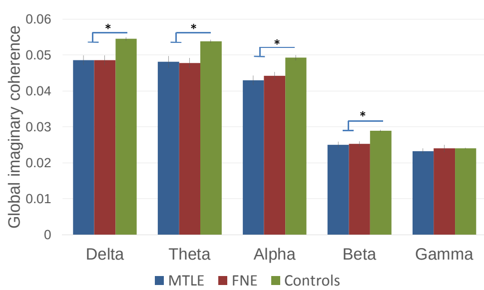
Unpaired *t*-tests, alpha-band imaginary coherence, 18 patients with left or 12 with right MTLE vs. equal number of controls, FDR-corrected, threshold $p < 0.01$.
Englot et al., Brain 2015, 138(Pt 8):2249-62.

Decreased functional connectivity in focal neocortical epilepsy (FNE) patients versus controls



Unpaired *t*-tests, alpha-band imaginary coherence, 17 patients with left or 14 with right FNE vs. equal number of controls, FDR-corrected, threshold $p < 0.01$.
Englot et al., Brain 2015, 138(Pt 8):2249-62.

Functional connectivity is decreased in most frequency bands in epilepsy



*p < 0.01, Bonferroni-corrected t-test. MTLE (N = 30), FNE (N = 31), controls (N = 31).
Englot et al., Brain 2015, 138(Pt 8):2249-62.

Multivariate analysis of factors associated with global functional connectivity

Continuous variables
Age (years)
Duration of epilepsy (years)
Seizure frequency (#/week)
No. previous AEDs
No. current AEDs

Categorical variables
Gender
Handedness
Side of surgery
MTLE vs. FNE
Lesional vs. non-lesional (based on MRI)

Linear regression

Significant predictors of global functional connectivity
Duration of epilepsy (*p* < 0.001)
Seizure frequency (*p* = 0.03)

Consciousness-impairing seizures (CPS, GTCS): *p* < 0.001

Consciousness-sparing seizures (SPS): *p* = 0.77

Stepwise generalized linear regression for multivariate analysis of factors associated with mean imaginary coherence in 61 patients with MTLE (30) and FNE (31). CPS: complex-partial seizures, GTCS: generalized tonic-clonic seizures, SPS: simple partial seizures.

Seizure types in focal epilepsy
(old ILAE terminology)

Increasing severity ↓

Simple partial seizure (SPS)
consciousness-sparing, no convulsion (includes aura)

Complex partial seizure (CPS)
consciousness-impairing, no convulsion

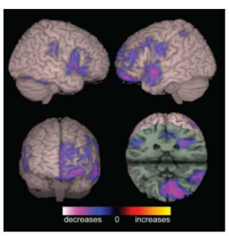
Generalized tonic clonic seizure (GTCS)
consciousness-impairing, + convulsion

Consciousness-impairing seizures associated with ↑morbidity:
↑ motor vehicle accidents, ↓work/school performance,
↓quality of life, cognitive decline, cortical atrophy

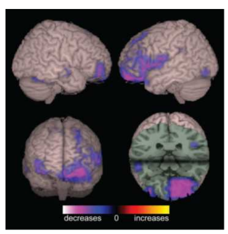
UCSF University of California San Francisco

Duration and severity of illness are related to decreased connectivity in the frontal lobes

Duration of epilepsy

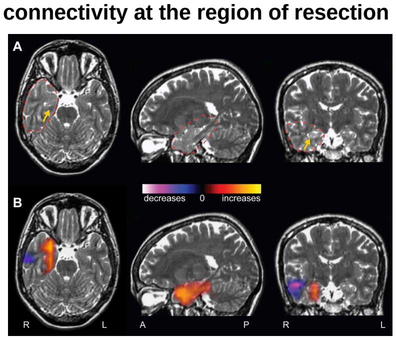


Frequency of consciousness-impairing seizures



Connectivity maps reflecting linear regression analysis. N = all 61 patients together with MTLE (N = 30) and FNE (N = 31). FDR-corrected, threshold $p < 0.01$.
Englot et al., Brain 2015, 138(Pt 8):2249-62.

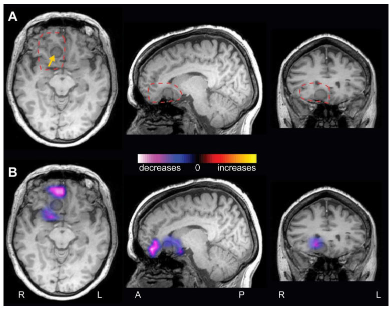
Example of a patient with increased functional connectivity at the region of resection



34-year old right-handed female with MTLE and mesial temporal sclerosis. A) ROI and lesion highlighted. B) ROI connectivity vs. contralateral hemisphere. Englot et al., Brain 2015, 138(Pt 8):2249-62.

UCSF University of California San Francisco

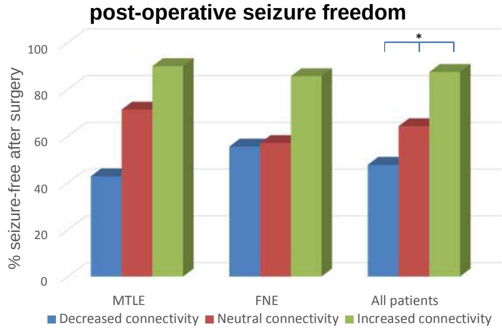
Example of a patient with decreased functional connectivity at the region of resection



55-year old right-handed female with FNE and a meningioma.
A) ROI and lesion highlighted. B) ROI connectivity vs. contralateral region.
Englot et al., Brain 2015, 138(Pt 8):2249-62.

UCSF University of California San Francisco

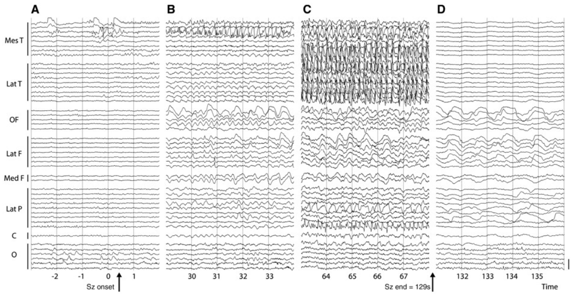
Increased connectivity at the resection region is associated with post-operative seizure freedom



*X^2 = 8.5, p = 0.015 (all patients). MTLE (N = 30) and FNE (N = 31); decreased (N = 23), neutral (N = 14), and increased (N = 24) connectivity. Englot et al., Brain 2015, 138(Pt 8):2249-62.

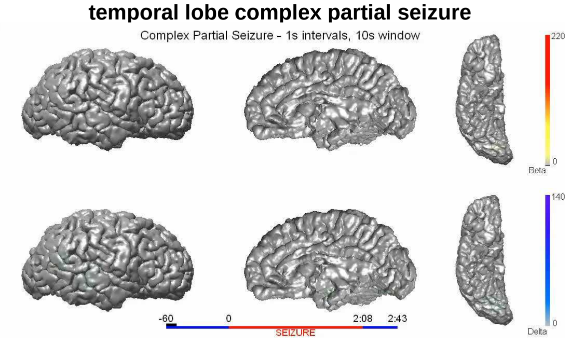
RELATING <u>ICTAL</u> EFFECTS OF SEIZURES TO LONG-TERM <u>INTERICTAL</u> NETWORK DISTURBANCES

Intracranial EEG recording during a temporal lobe complex partial seizure



Englot et al., Brain 2010;133:3764-3777.

Beta and delta activity during a temporal lobe complex partial seizure



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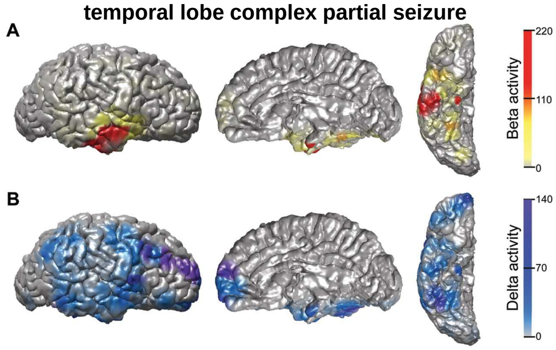

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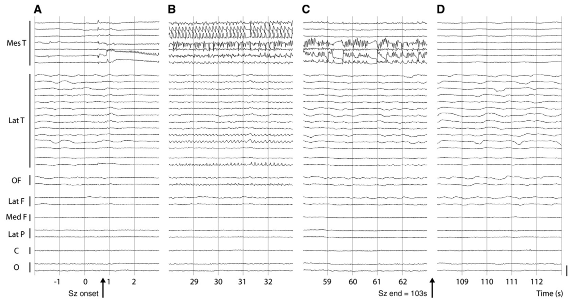
Intracranial EEG recording during a temporal lobe simple partial seizure



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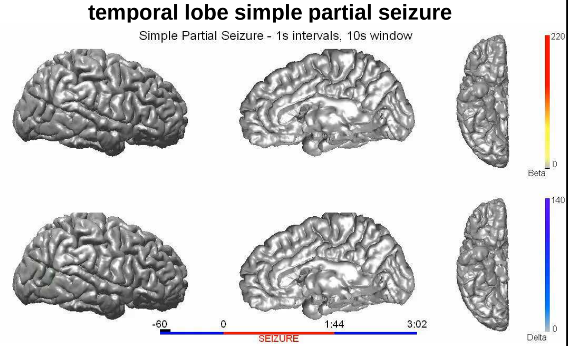

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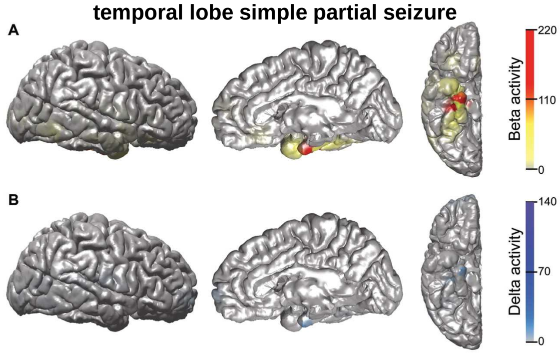
Beta and delta activity during a temporal lobe simple partial seizure



Englot et al., Brain 2010;133:3764-3777.

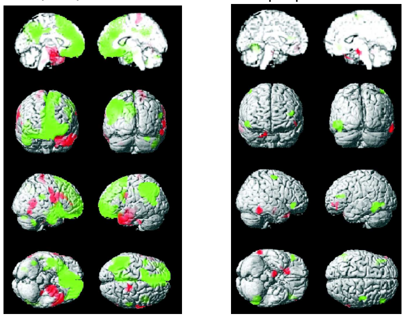
Complex partial seizures in MTLE lead to decreased cerebral blood flow (CBF) in the neocortex

Ictal SPECT

RED = increased CBF

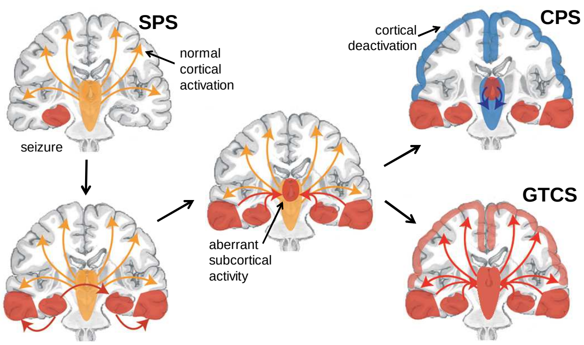
GREEN = decreased CBF

Complex partial seizure | Simple partial seizure



Blumenfeld et al., Cereb Cortex. 2004 Aug;14(8):892-902.

Network inhibition hypothesis for impaired consciousness during complex-partial seizures

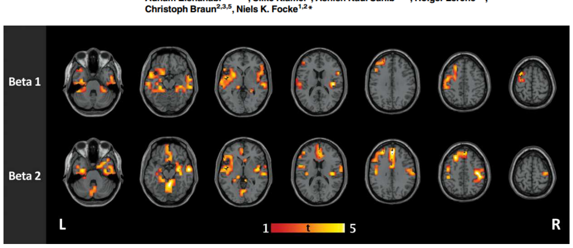


Modified from Englot and Blumenfeld, Prog Brain Res 2009;117:147-70.

PLOS ONE | PLOS ONE | DOI:10.1371/journal.pone.0138119 September 14, 2015

Magnetoencephalography Reveals a Widespread Increase in Network Connectivity in Idiopathic/Genetic Generalized Epilepsy

Adham Elshahabi[1,2,3,4]*, Silke Klamer[1], Ashish Kaul Sahib[1,2,4], Holger Lerche[1,2], Christoph Braun[2,3,5], Niels K. Focke[1,2]*



Group comparison of functional connectivity in 13 IGE patients vs. healthy controls, showing clusters of increased connectivity in the beta1 (12–20 Hz) and beta2 (21–29 Hz) bands.

Conclusions

- MEG demonstrates decreased neocortical connectivity in focal epilepsy that is quantitatively related to severity of illness
- Regional connectivity is often increased at the EZ, and may help predict seizure outcome after surgery
- Network inhibition during seizures (ictal) may lead to reduced long-range connectivity over time (interictal)

UCSF University of California San Francisco

Thanks

MEG-Based Detection and Localization of Peri-Lesional Dysfunction in Chronic Stroke

Ron Chu, Toronto

Post-stroke impairment is associated not only with structural lesions, but also with dysfunction in surviving perilesional tissue. Previous studies using equivalent current dipole source localization of MEG/EEG signals have demonstrated a preponderance of slow-wave activity localized to perilesional areas. Recent studies have also demonstrated the utility of nonlinear analyses such as multiscale entropy (MSE) for quantifying neuronal dysfunction in a wide range of pathologies. The current study utilized beamformer-based reconstruction of signals in source space to compare aspects of electrical activity in perilesional and healthy cortex, using data collected from chronic stroke patients and healthy controls, both young and elderly. We assessed relative power in the delta (1-4Hz), theta (4-7Hz), alpha (8-12Hz) and beta (15-30Hz) frequency bands, and also measured the nonlinear complexity of electrical activity using MSE. Perilesional tissue exhibited a general slowing of the power spectrum (increased delta/theta, decreased beta) as well as a reduction in MSE. Furthermore, perilesional electrophysiological abnormalities in the left hemisphere were correlated with the degree of language task-induced activation in the right hemisphere, suggesting compensatory reorganization for stroke-induced dysfunction. We also demonstrate single subject mapping techniques that can identify dysfunctional tissue within individual patients. Together, these results suggest that both spectral and nonlinear analyses of source localized MEG signals can identify dysfunctional perilesional tissue that may be an ideal target for interventions with noninvasive brain stimulation.

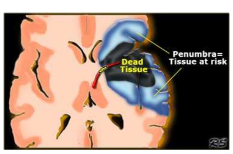
MEG-based detection of perilesional dysfunction in chronic aphasia

Outline

- Beyond structure - Perilesional tissue dysfunction
- Spectral indicators of tissue dysfunction
- Non linear approaches
- Comparing spectral and non linear analyses of source localized signals
- Implications

Lesions are bigger than they look

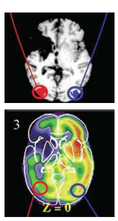
ACUTE
(< 6 months)



Language deficits in aphasia are frequently associated with structural damage to language areas

Sometimes language areas are structurally intact, but dysfunctional

CHRONIC
(>6 months)



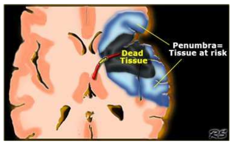
Anatomy lesion in front

Brain activity – left rear area is less active (FDG PET)

Fair et al., 2009

Lesions are bigger than they look

ACUTE
(< 6 months)



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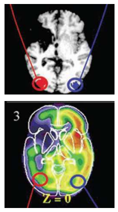


Anatomy lesion in front

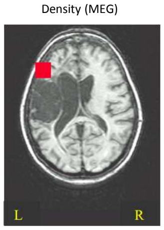
Brain activity – left rear area is less active (FDG PET)

Fair et al., 2009

Detecting perilesional dysfunction

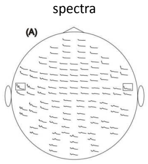
- Spectral analyses of MEG/EEG signals have uncovered several indicators or perilesional dysfunction (e.g., *Butz et al., 2004; Harmony et al., 1995; Machado et al., 2004; Meinzer et al., 2004; Zappasodi et al., 2007*)

Maximum Delta Dipole Density (MEG)

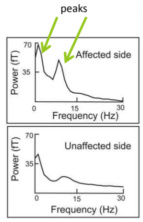


Meinzer et al., 2004

Sensor power spectra



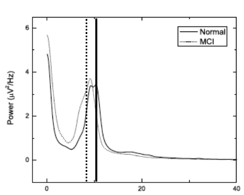
Delta and theta peaks



Butz et al., 2004

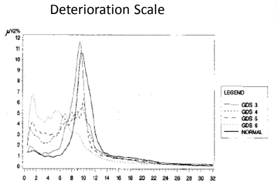
EEG slowing in neurodegenerative disease

Power spectrum, healthy older adults and Mild Cognitive Impairment



Park et al., 2007, Fractals

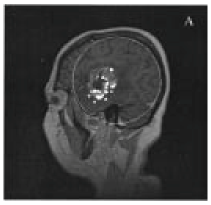
Low frequency power as the function of Global Deterioration Scale



Rodriguez et al., 1999

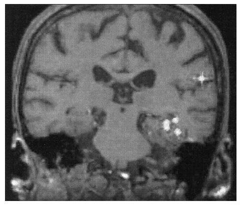
Slow wave dipole mapping

Delta dipoles around tumor



De Munck, 2001

Temporoparietal Slow Wave Activity
In Alzheimer's Disease



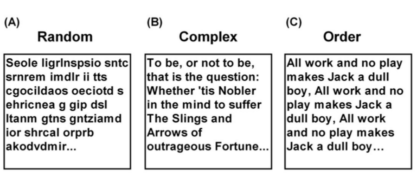
Fernandez, 2002

Spectral Analyses

- Slow wave activity is sensitive to tissue dysfunction in various diseases:
  - Alzhemier's and MCI
  - Tumors
  - Stroke
- In conditions with frank structural lesions, slow wave activity is localized to perilesional areas

Non-linear measures

- Entropy - measure of signal complexity



Low Entropy **High Entropy** Low Entropy

http://www.psynetresearch.org/complexity-analysis-of-brain-signals.html

Reduced entropy in Alzheimer's

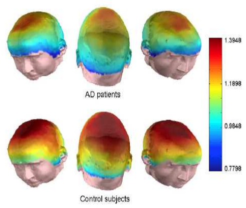
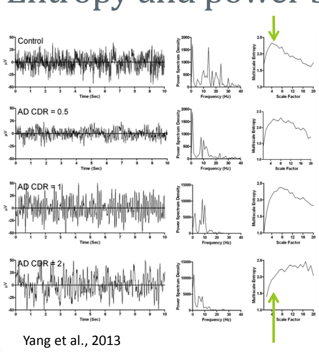


Fig. (4). Average SampEn values from MEGs in AD patients and control subjects for all channels.

Gomez et al., 2010

- Slowing and entropy extensively studied in AD as a marker of pathology
- Healthy physiological signals are characterized by **high complexity** (not completely random, not completely periodic)

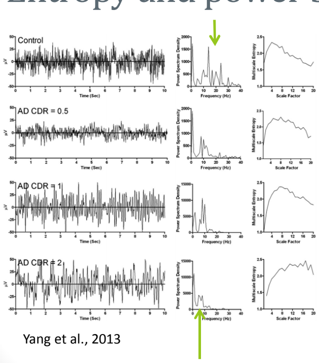
Entropy and power spectra



Yang et al., 2013

- Severity of Alzheimer's is associated with:
  - Reduced entropy at low scales

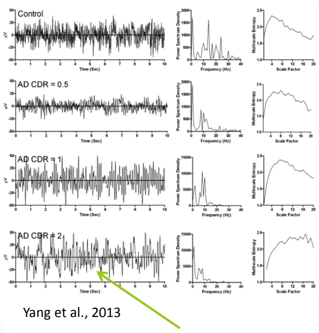
Entropy and power spectra



Yang et al., 2013

- Severity of Alzheimer's is associated with:
  - Reduced entropy at low scales
  - Spectral activity limited to low frequency bands

Entropy and power spectra



Yang et al., 2013

- Severity of Alzheimer's is associated with:
  - Reduced entropy at low scales
  - Spectral activity limited to low frequency bands
  - The signal becomes progressively more periodic with disease severity

Indicators of tissue dysfunction

- Low frequency EEG/MEG activity are associated with tissue dysfunction in various neurological conditions
- This activity is localized to perilesional tissue in conditions associated with frank structural lesions

- AD is associated with reduced entropy (complexity) of signals from sensor space
- Reduced signal complexity is correlated with increased low frequency power

- **Are entropy-based measures of source localized signals sensitive to perilesional dysfunction?**

Current Study

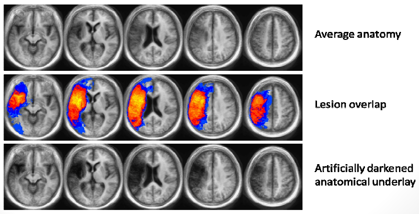
- What is the relative efficacy of spectral and non linear analyses of source localized signals for detecting perilesional dysfunction in stroke?

Methods - Participants

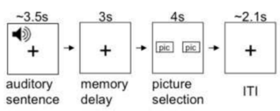
- 25 aphasic patient
  - Adequate comprehension on the lexical/semantic levels
  - At least 6 months post-stroke.

- 8 age-matched controls
- 24 young controls

Lesion maps

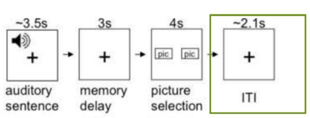


Methods – Sentence Picture Matching



Example Sentence
"The boy is biting the girl."
"The girl is biting the boy."

Methods – Sentence Picture Matching

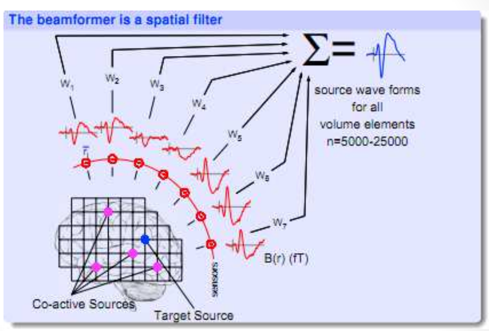


- Data from the inter-trial interval were analyzed as an estimate of spontaneous activity
- We are currently collecting true resting state data which corroborate the findings

Methods - Analyses

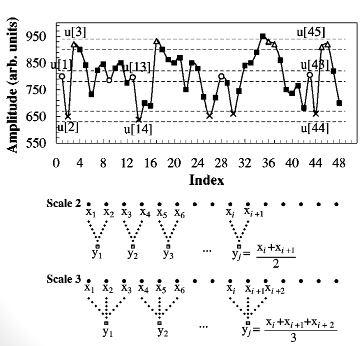
- Sensor data were localized into source space using beamformer analysis
- Source localized time series were subjected to:
  - Relative power in delta, theta, alpha, and beta bands
  - Multiscale entropy
- **Between Group Analyses**
  - Voxel-wise comparison maps
  - ROI analyses
- **Within Group Analyses (patients)**
  - Correlation of relative power and entropy with task-activation
- **Single subject maps**

Source localization



Courtesy of Dr. Bernhard Ross

Multiscale entropy



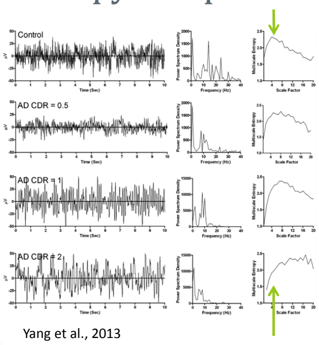
Identifies repeating patterns in the data.

Less predictability = higher entropy

Redo the calculation at increasingly course scales.

Costa et al., 2005

Entropy and power spectra

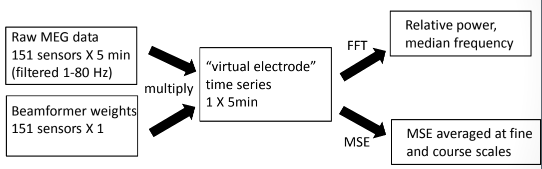


Yang et al., 2013

- We focused on MSE at the short time scales
- Sensitive to changes in AD

Whole-brain mapping

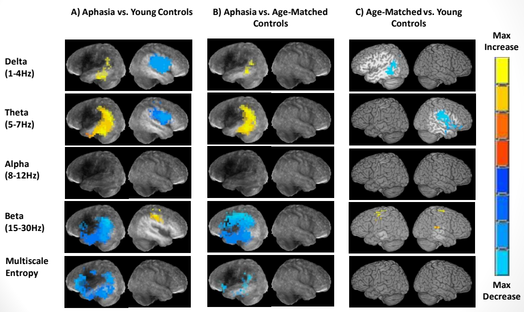
Beamforming allows us to calculate spectral and non linear analyses of the original time series in source space



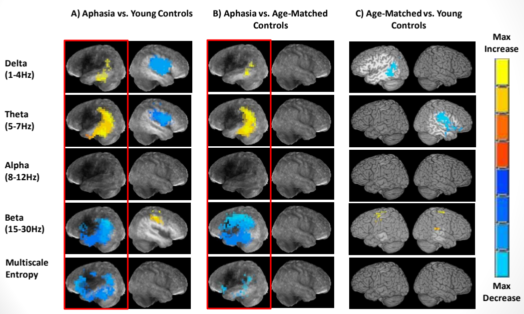
Results - Summary

- **Between Group Analyses**
  - Voxel-wise comparison maps
    - Perilesional tissue is associated with slowing and reduced complexity
    - Aging associated with faster frequencies and no changes in complexity
  - ROI analyses
- **Within Group Analyses (patients)**
  - Correlation of relative power and entropy with task-activation
- **Single subject maps**

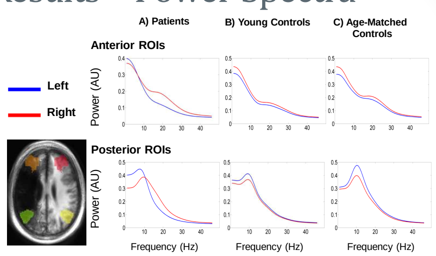
Results – Comparison maps



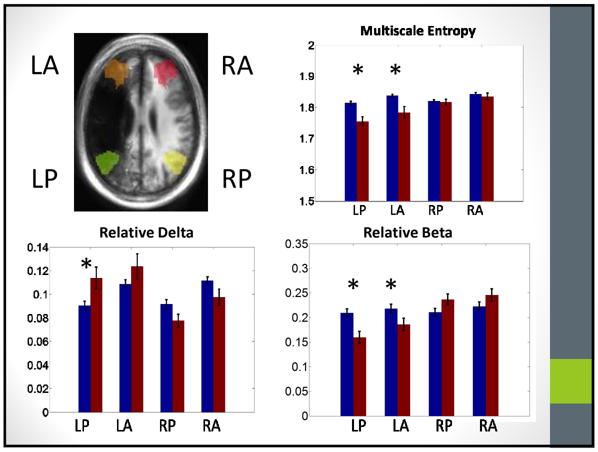
Results – Perilesional Changes



Results – Power Spectra



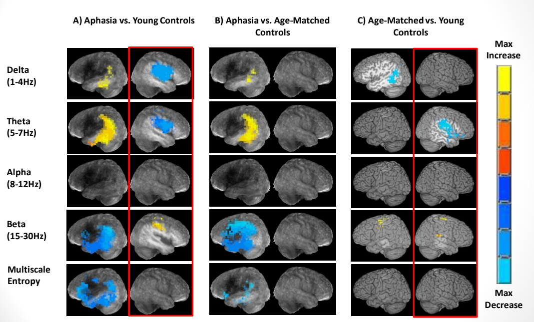
Anterior ROI associated with reduced high frequency power
Posterior ROI associated with increased low frequency power



Results - Summary

- **Between Group Analyses – Perilesional Changes**
  - Voxel-wise comparison maps
    - Perilesional tissue is associated with slowing and reduced complexity
  - ROI Analysis
    - Delta power sensitive to changes in posterior perilesional areas
    - Beta power and MSE sensitive to changes in posterior and anterior areas

Results – Aging

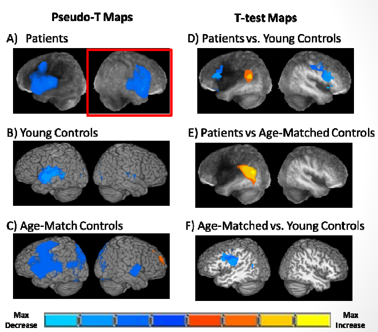


Results - Summary

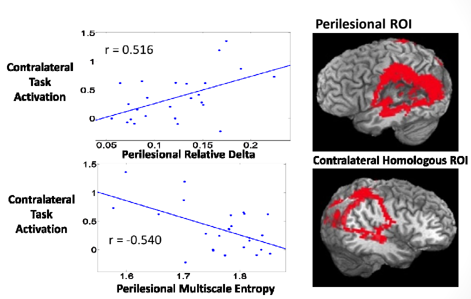
- **Between Group Analyses – Aging**
  - Voxel-wise comparison maps
    - Aging associated with reduced delta and increased beta
    - MSE not sensitive to aging effects

Correlates of RH task activation

- Patients exhibit increased right hemisphere task activation (30Hz ERD) when compared to controls
- Is this associated with perilesional dysfunction?



Correlates of RH task activation



Magnitude of perilesional delta and MSE correlates with task activation at RH homologous

Results - Summary

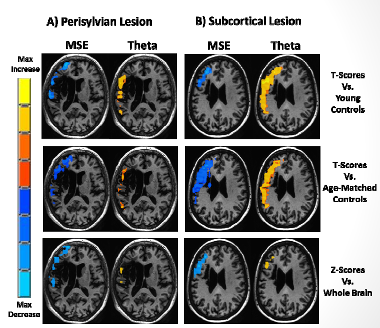
- **Within group - Correlations**
  - Perilesional delta power is positively correlated with RH task activation
  - Perilesional MSE is positively correlated with RH task activation
  - Greater dysfunction is associated with greater RH activation

Results - Single Subject Mapping

- Can we identify changes at the single subject level?
- Two approaches:
  - 1) Compute a Z-score at each voxel relative to the subject's brain
  - 2) Compute an unequal two-sample t-test at each voxel vs. a control group

Results - Single Subject Mapping

- Both patients exhibited reduced MSE and increase theta along perilesional regions
- MSE appears more sensitive when using the whole-brain method



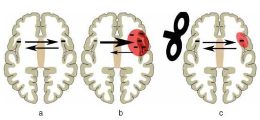
$p<0.05$ (uncorrected)

Results - Summary

- **Both spectral and non linear measures are sensitive to perilesional dysfunction**
- **The magnitude of perilesional dysfunction is correlated with RH language activation**
- **Spectral measures are sensitive age**
- **Single subject maps can be computed to identify dysfunctional tissue within an individual**

Implications

- Non-invasive brain stimulation has been demonstrated as effective tools for rehabilitation
- This includes **excitatory perilesional stimulation** (Marangolo et al., 2013; Szaflarski et al., 2011) and **inhibitory RH stimulation** (e.g., Naser et al., 2010; Thiel et al., 2013)
- Target selection based on anatomical constraints or task activation
- Single subject mapping presented here can guide neurorehabilitative stimulation towards dysfunctional tissue



Chrysikou & Hamilton, 2011

Thank you for your time!

Thanks to

Baycrest

- Jed Meltzer
- Bernhard Ross
- Natasa Kovacevic

NIH

- Allen Braun

ACMEGS
AMERICAN CLINICAL MEG SOCIETY

Basic Assurance of Recording Quality

John Mosher, Cleveland

In (Gross et al. Neuroimage 2013), the authors present good general practice for conducting MEG research studies. We present here an expanded detailed presentation with a particular clinical emphasis on spontaneous recordings for epilepsy, from our years of experience in conducting over 1,200 patient exams. We emphasize the preparation of the patient and the setup of MEG instrument to ensure a quality clinical recording. Several practices are quite general for any MEG instrument, such as generally insisting on MRI compatible gowns, careful acquisition of landmarks on the patient's scalp, and the daily recording of empty room data. Other practices we will present are more specific to our vendor's protocols, but are translatable to the other vendors.

Basic Assurance of MEG Recording Quality

John C. Mosher, PhD, with
Gabrielle Hosten, Sumiya Shibata MD, and
Richard C Burgess MD PhD

Epilepsy Center, Neurological Institute, Cleveland Clinic
Cleveland, Ohio USA

Cleveland Clinic

Outline

- Machine Preparation
  - The well-oiled machine
- Patient Preparation
  - The hidden cell phone
- Patient Landmarks
  - Finding your patient
- Patient Positioning
  - As deep as possible
- Monitoring the Recording
  - Movement "compensation"
- Post-Processing
  - Consistency, consistency, consistency

Welcome to the MEG

- Unlike an MRI, your MEG measurement is a peaceful quiet exam.
- We give you pillow and blankets, then dim lights and ask that you take a nap for about an hour.

Why are you getting a MEG?

- "You're getting a MEG today for two primary reasons:
- (1) The helmet has over 300 sensors in it, so the first advantage is a pure numbers game: We have ten times as many sensors as your EEG array to detect abnormal activity.
- (2) Given we detect abnormal activity, the physics of MEG are actually easier to figure out where this activity arose.
- Bottom line: We get better detection and better localization of abnormal brain activity."

Contra-Indicated Patients

- Cochlear Implants:
  - PT has a ferrous magnetic coupler behind ear.
  - Absolutely will not work in MEG.
  - DO NOT ATTEMPT DeGaussing! (per manufacture)
- Some forms of "MRI-Conditional" shunts nonetheless have a true magnet:
  - Medtronic Strata NSC Adjustable Pressure Valve
  - 3T compatible, must be re-programmed after an MRI
  - Uses magnetic rotor to adjust ball-and-spring mechanism
  - Nearly impossible to achieve usable MEG results
- Otherwise, we have run: GPS ankle bracelets, drug pumps, active VNS, pacemakers, hidden cell phones, etc.

Machine Preparation

- Good camera, good microphone
  - Wall mounted microphone for global sound capture
  - Tilt-Pan-Zoom camera from full body to facial expression
- Daily tuning to keep stability
  - SQUIDs are based on active feedback controllers
  - "Fine" tuning exercises amplifier "parasitics"
- Empty room recordings confirm "normal" operation
  - Every day a patient is scheduled
  - Include chair if used for parent

Tilt-Pan-Zoom Camera, Sensitive Microphone

- DC power supply, no appreciable interference for value gained.

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Wooden Chair for Parent

- Ask parent not to rock or continuously pat child.
- Keep adjusting child back into array.

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Patient Preparation

- General recommendation for sleep deprivation
  - It's a boring exam, so sleep through it
  - Less patient fidgeting, more possible abnormal activity
- Change into gowns, no metal
  - Clothing adjustments, metal threads, etc. cause trouble
  - Pockets invite hidden cell phones
- 10-20 EEG electrodes to assist in abnormal detection
- Degauss all patients
  - Therefore not so important: MRI after the MEG

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General Degaussing – Shaking the Field

- Check with your Doctor first
  - Most patients are “MRI compatible” and therefore safe.
- Use CRT monitor degaussing coil (getting harder to find)
- Click ‘on’ and move away slowly about 1cm/sec
  - Do not click on and off, smooth motion only
- Repeat all three axes

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Spot Degaussing – Problem Non-Ferrous Metals

- Check with your Doctor first
  - Most patients are “MRI compatible” and therefore safe.
- Use a “tape” degausser
- For dental work and VNS electrode
- Click on and move away at 1cm/sec
- DO NOT APPLY DIRECTLY to VNS generators, pacemakers, other electronics
  - Tape degaussers are powerful in their centers

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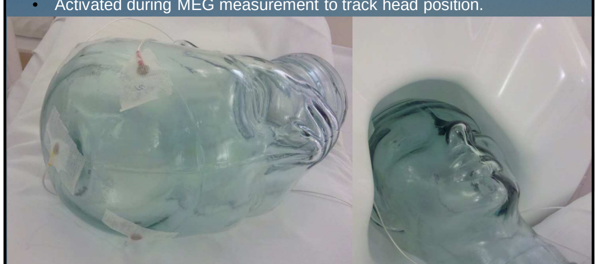
Head Positioning Coils

- Five localization coils arranged about the scalp and digitized with fiducials.
- Activated during MEG measurement to track head position.



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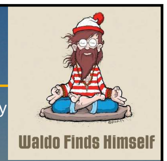
Patient Landmarks



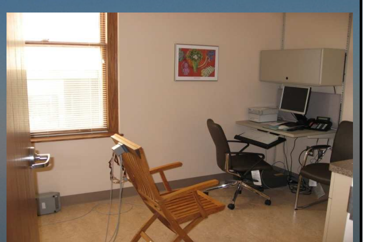
- Head Positioning Coils are located by the MEG array
  - Need precise location of coils on patient's scalp
  - Need three fiducials (nasion, ears) for coordinate system
  - Need hundreds more points for aligning MRI scalp
  - Allows inference as to where's Waldo in the helmet
- Many sites use the Polhemus Fastrak system
  - OEM with some vendors
- Proper operation of the Fastrak allows relatively precise localization

However:

- The Fastrak is a magnetic field transmitter, and therefore good practice must be followed in using it.
- Wooden chair with no metal in vicinity
- Technician should not wear a watch or necklace
- Check/recheck measurements in real-time
  - Neuromag has specific routine for this, use it!

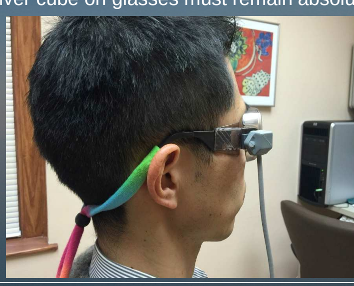
Recording Polhemus Data

- Fastrak Chair must be well-positioned, away from walls.
- Cables cleanly routed to box.
- Do not lean over transmitter on chair
  - Stay to sides of chair



Two-Point Fastrak Receiver

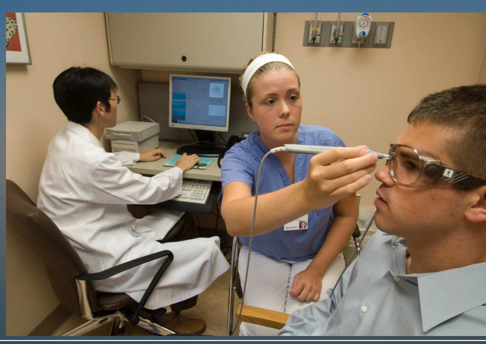
- More practical to use a two-receiver referential system.
- Receiver cube on glasses must remain absolutely still on face.



For Kids: The "DubStep" (invented by Anne-Sophie Dubarry)

- Allows Fastrak receiver coil to be affixed directly and firmly to the scalp.
- Copper feet for repeated removal with acetone.
- Kids never know it's there among the EEG and HPI electrodes.

Fastrak Stylus to acquire fiducials, EEG electrodes and 100 landmarks over the scalp



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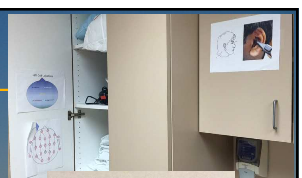
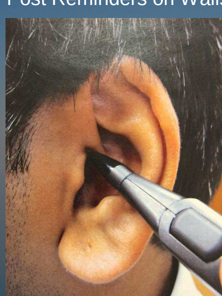
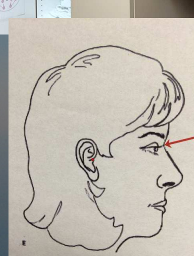
3 Point Fiducials

- Post Reminders on Walls







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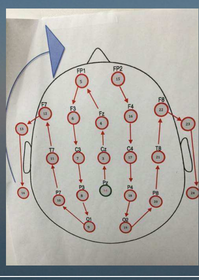
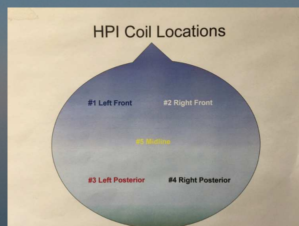
Consistent Coil Placement and Ordering

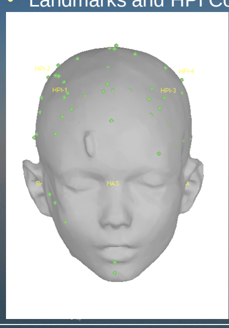
- 10-20 Ordering and HPI Numbering
  - Use Neuromag option to hard-code the ordering

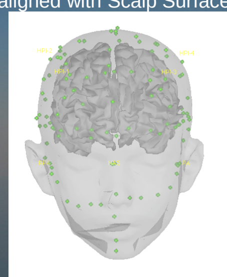




Collect 100 Landmark Points

- Landmarks and HPI Coils are aligned with Scalp Surface





Brainstorm: Absolute (“L1”) error between points and scalp surface

Patient Positioning

- Low lights to encourage sleep
- Supine position of patient for sliding deeply into helmet,
  - Upright chair allows slumping over time.
- Parent in the room to stabilize and re-insert child
- Placement of audio transducers (if any)
  - As far from helmet as possible, on bed, not moving
- EEG Cabling, good insertion, clean routing

Head Comfort

- MRI Compatible gel packs or cushions
  - May not accommodate larger heads

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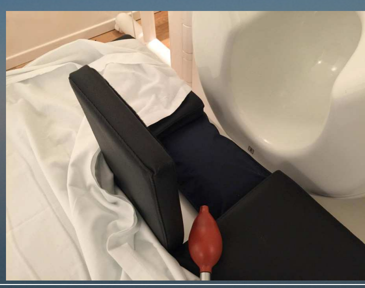
Neck Bracing and Head Tilt

- Rolled towel or blood pressure cuff to encourage head tilt
  - Temporal lobes are better positioned in the array



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Monitoring the Recording

- Real-time head position check, patient must be deep in the array.
- Record cardiac simultaneously to later track the heart vector and possible cardio-ballistic artifacts.
  - Optional: some like to record eye-blink EOG.
- View the channels looking for some form of localization of noise:
  - artifact in hair vs. contaminant on all channels
- Movement “compensation”
  - If patient shifts too much, start new file, checking head position
  - Do not rely too heavily on post-processing compensation for large shifts
- Neuromag: Custom SSP for real-time visualization
  - MGH software can make valid SSP vectors for any data set
  - CTF software allows real-time “3rd order” gradiometers
- Annotate real-time any unusual environmental observations
- Annotate real-time any observable seizures or claims by PT of aura
  - Ensure data time tags are synchronized to NTP “wall-clock” time
- Run an SEF protocol to confirm registration issues later

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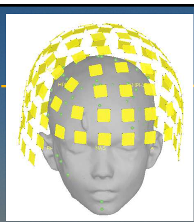
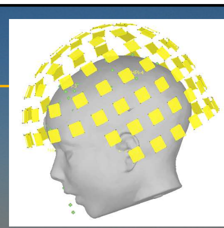
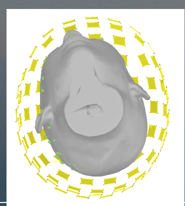




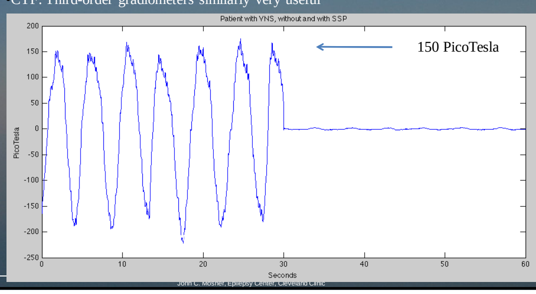


Confirm Alignment of Subject in the MEG Array

- At CCF, alignment image generated while patient is in the array, so that we can monitor and adjust the patient's position.
- See Brainstorm research software for comparable routine

Custom Real-Time Noise Rejection

- Patient's VNS or other metal usually causes strong respiration artifact.
- At CCF, we generate a new "SSP" with patient in the array to allow easier real-time viewing of the data.
- CTF: Third-order gradiometers similarly very useful



Post-Processing

- Devise consistent naming and ordering of files
  - "spont_<initials>_<run number>_raw"
  - "sef_<initials>_<run number>_raw"
  - "language_bapa_<initials>_<run number>_raw."
- These "string tokens" make scripts easier to devise. Initials help detect misplaced data.
- Consistent initial processing chain for all data
  - Set filters, noise rejection, etc the same way everytime
  - Right or wrong, it's consistent for the first pass, can be rerun with different if desired.
  - CCF: we have automated script to run Maxfilter from the command line the same way for every file

Summary

- Consistency in the preparation yields consistency in the data generated
- Anomalies therefore more identifiable as unique to the patient and not to variations in procedure
- Check / recheck Fastrak data in real-time to catch disturbances and ensure registration accuracy
- Ensure patient as deep as possible in the helmet
  - Source accuracy degrades rapidly outside the helmet confines
- Monitor patient and machine for performance
- Consistently process data on the first pass
  - Additional passes as needed for exceptional cases

Thanks

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  Gabby Hosten, Alec Furlan, and
  Barbara Walsh, Manager
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- **MEG Protocols:**
  Dr Patricia Klaas
  Dr Catherine Liegeois-Chauvel
- **Clinical MEG**: Dr Andreas Alexopoulos Dr Richard Burgess,
  - Clinical Director MEG Laboratory
- Dr Imad Najm,
  - Director Epilepsy Center

Lisa Nilsson Artwork

Systematic Review of Normal Variants

Stefan Rampp, Erlangen

Normal variants, while not occurring frequently, may appear similar to epileptic activity. Misinterpretation may lead to false diagnoses. In the context of presurgical evaluation, normal variants may lead to mislocalizations with severe impact on viability and success of surgical therapy. While the different variants are well known in EEG, little has been published in regard to their appearance in MEG. The presentation reviews benign epileptiform variants and provides examples in EEG and MEG. In addition, the potential of oscillatory configurations in different frequency bands to appear as epileptic activity are discussed.

Systematic Review of Normal Variants

S. Rampp

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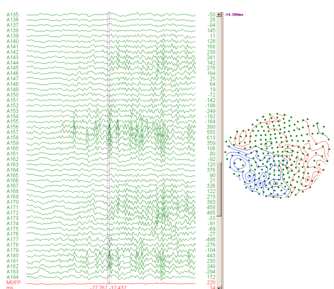
Normal variant or epileptic activity?

- Patient with frontal lobe epilepsy
- MRI normal
- EEG: unclear
- Therapy: AED
- MEG:
  Beta oscillations left frontal
  Interspersed spikes/accentuated oscillations?
- Epileptic oscillations/rhythmic spikes?
- Effects of Medication (AED!)?
- Normal variant?



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Benign epileptiform variants (BEV)

- BEV look like epileptiform patterns but are not associated with epilepsy
- Risk of misdiagnosis of epilepsy
  - Diagnosis of epilepsy
  - Classification
  - Multifocal
- Risk of mislocalization

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Types of BEV

- Sharp transients
  - Wickets
  - Benign epileptic transients of sleep (BETS)
    Benign sporadic sleep spikes/small sharp spikes
- Burst/trains
  - 6 Hz spike waves
  - 14 and 6 Hz positive spikes
  - Rhythmic temporal theta of drowsiness/psychomotor variant
  - Subclinical rhythmic electrographic discharge of adults (SREDA)
- Oscillations
  - Alpha (vs. spikes)
  - Beta (vs. spikes)
  - Mu activity (vs. spikes)
  - Delta/theta (vs. epileptic slow waves)
- (Physiologic activity, e.g. vertex waves)

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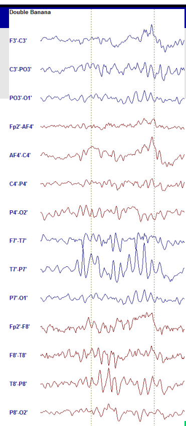
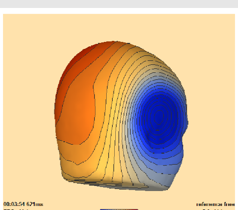
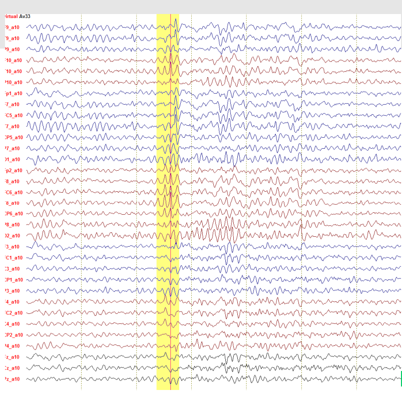
Wickets

- Sharp patterns
- Single or series (6-11Hz)
- Negative sharp, positive rounded
- No subsequent slow wave
- Temporal/parietal
- Unilateral or (independent) bilateral
- More frequent in drowsiness or sleep

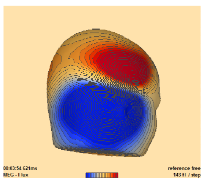


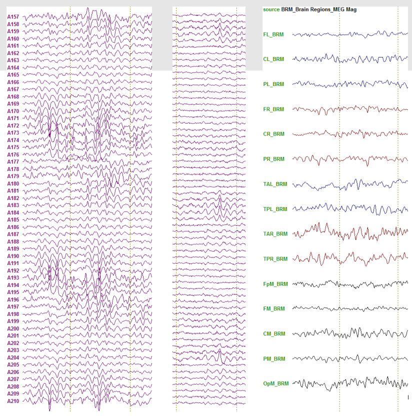
Wickets - EEG





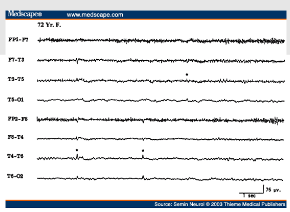
Wickets - MEG

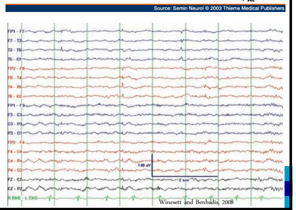




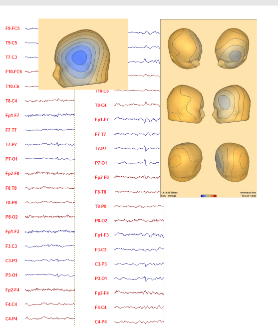
Benign sporadic sleep spikes (small sharp spikes) (BSSS)

- <50ms
- Do not disrupt background
- No (prominent) slow wave
- Temporal
- Bilateral (independent), shorter recordings may show only unilateral
- Drowsiness, sleep stage 1 or 2
- Disappear with deeper stages of sleep (≠ spikes)

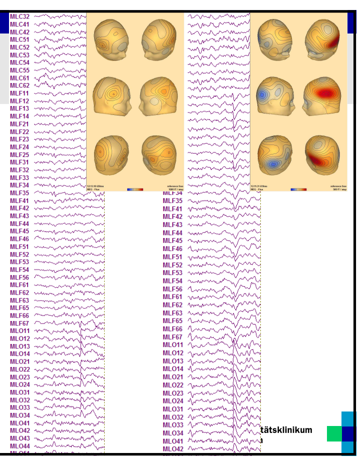




Benign sporadic sleep spikes (small sharp spikes) (BSSS)



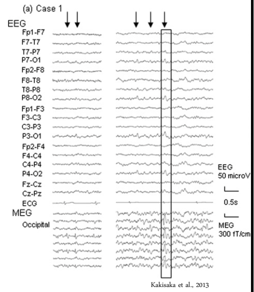
EEG



MEG

Positive Occipital Sharp Transients of Sleep (POSTS)

- Sharp patterns, „reverse check mark“
- 50-100 µV
- Typically in series (4-5Hz)
- Sleep stage 1 and 2
- More common during daytime naps(?)



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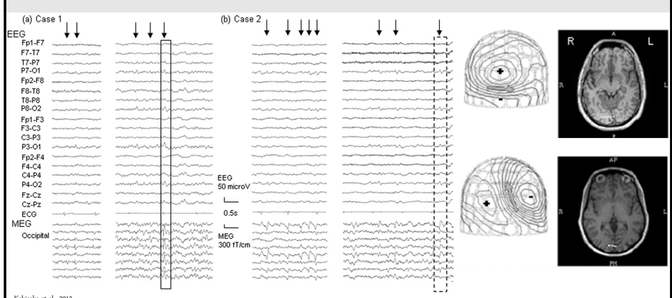
Positive Occipital Sharp Transients of Sleep (POSTS)



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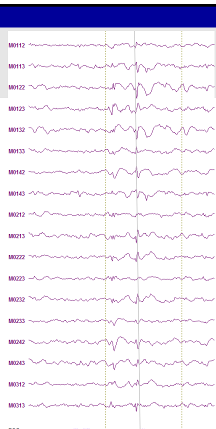
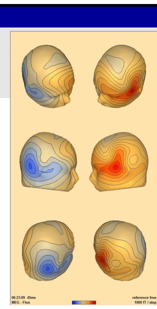
Epilepsy?





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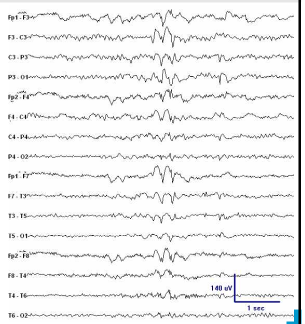
6 Hz spike waves (phantom spike and wave)

- Subtle spike, prominent wave
- 5-7Hz series
- <1 sec duration
- Bilateral synchronous
- Awake, drowsiness, not in sleep
- FOLD - Female Occipitally-predominant Low-amplitude Drowsiness (benign)
- WHAM - Wake High-amplitude Anterior Male (generalized seizure disorder?)



Santoshkumar et al., 2009

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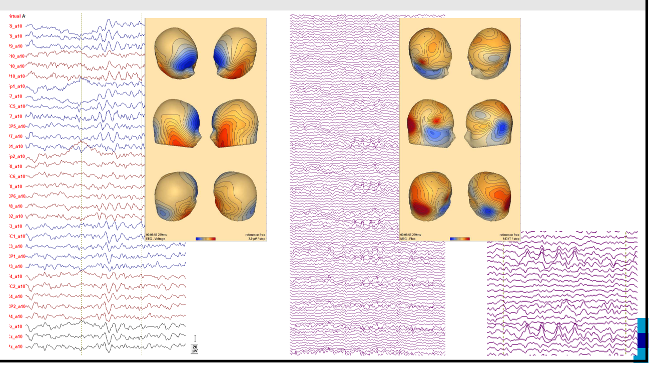
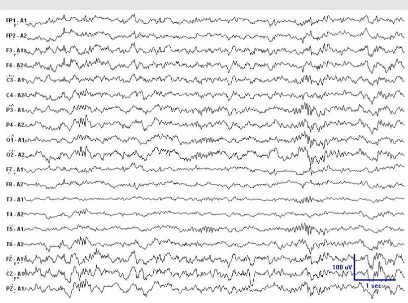
6 Hz spike waves (phantom spike and wave)



14 and 6 Hz positive spikes

- Positive sharp, negative smooth
- 13-17Hz or 6-7Hz
- Temporal posterior
- Drowsiness, light sleep
- Adolescents, young adults



Santoshkumar et al., 2009

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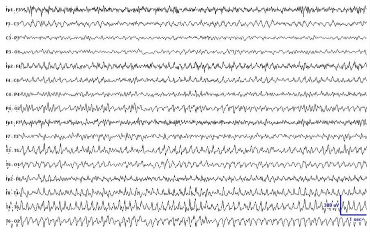
Rhythmic temporal theta of drowsiness (psychomotor variant)

- Bursts or runs of sharp patterns
- 5-7Hz
- Monomorphic (no evolution)
- Mid-anterior temporal
- Bilateral or independent, shifting emphasis
- Drowsiness (and relaxed wakefulness)



Santoshkumar et al., 2009

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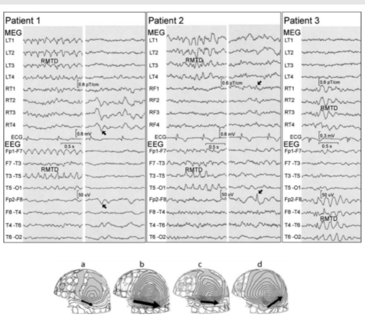
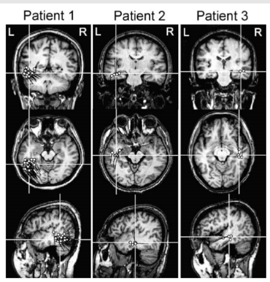
Rhythmic temporal theta of drowsiness (psychomotor variant)





Lin et al., 2003

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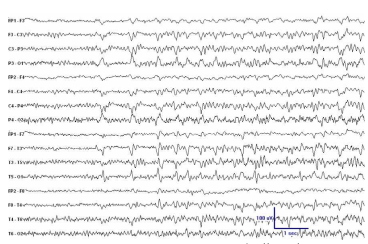
Subclinical rhythmic electrographic discharge of adults (SREDA)

- Mono-/biphasic waves mixed with rhythmic theta/delta
- Abrupt onset, gradual offset
- ~20s to minutes
- Parietal, temporal posterior
- Bilateral synchronous or unilateral
- Wakefulness, rarely during sleep
- Elderly, middle age



Santoshkumar et al., 2009

- Rare!
- No behavioral correlate

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Prevalence (Santoshkumar et al., 2009)

Author(s) (year of publication)	Study population (patients)	Duration of study (years)	State(s) of patient during EEG recording	BSSS (%)	WW (%)	14 and 6 Hz PS (%)	6 Hz SW(%)	RTTD (%)	SREDA (%)
Gibbs et al. (1963)	50,000	Not known	Awake, drowsy and sleep	–	–	–	–	0.5	–
Lombroso et al. (1966)	155 controls (13–15 yrs of age)	Not known	Awake and sleep	–	–	58	–	–	–
White et al. (1977)	599	2	24 hr sleep deprivation and naso-pharyngeal electrodes	20	–	–	–	–	–
Reiher and Lebel (1977)	4458	6	Awake and sleep	–	0.8	–	–	–	–
Hughes (1980)	61,467	30	Awake, drowsy and sleep	–	–	–	2.5	–	–
Westmoreland and Klass (1997)	108	16	Awake and sleep	–	–	–	–	–	0.04
Radhakrishnan et al. (1999)	1778	2	Awake, drowsy and sleep	8.16	0.96	5.68	2.76	0.79	–
Current study (2008)	35,249	35	Awake, drowsy and sleep	1.9	0.04	0.52	1.02	0.12	0.07

BSSS, benign sporadic sleep spikes; WW, wicket waves; 14 and 6 PS, 14 and 6 Hz positive spikes; 6 Hz SW,6 Hz spike-and-waves; RTTD, rhythmic temporal theta burst of drowsiness; SREDA, subclinical rhythmic electrographic discharge of adults.

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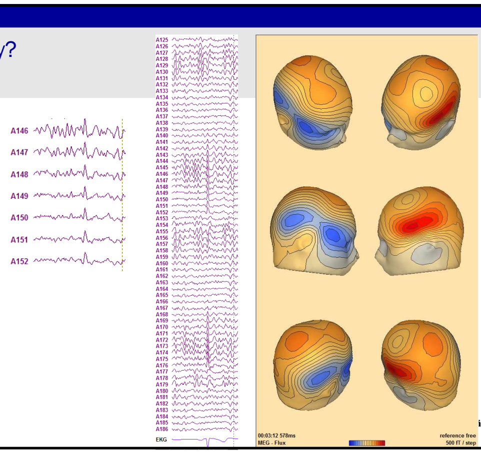
Epilepsy?



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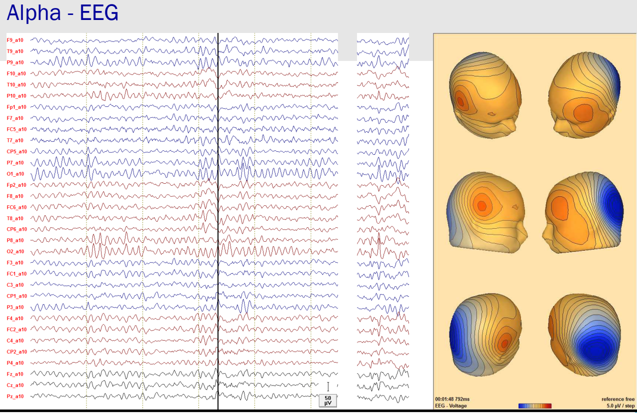
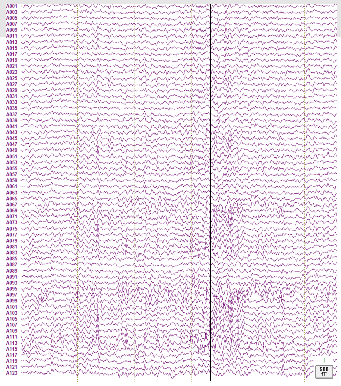
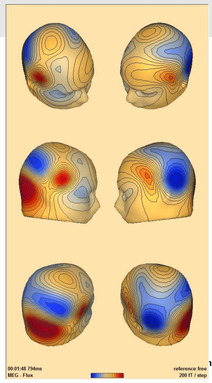
Alpha - EEG



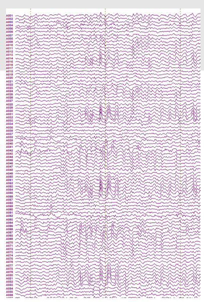
Alpha - MEG

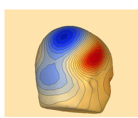


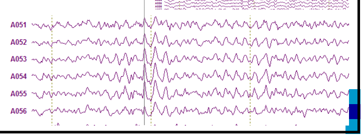


Mu activity

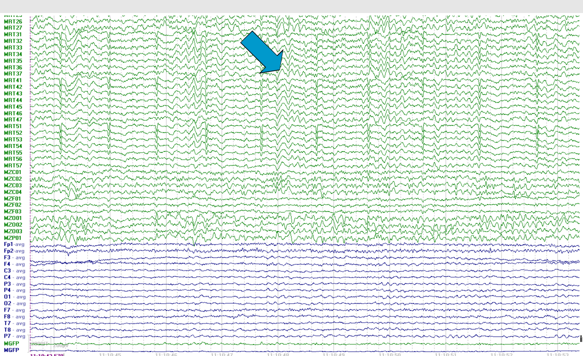
- Runs of sharp μ-like patterns
- Single patterns may occur
- Central topography
- Unilateral or bilateral alternating
- May occur without visible mu in the EEG!
- Wakefulness without somatosensory stimulation







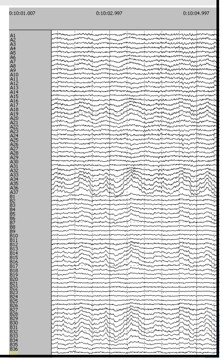
Delta/Theta oscillations



Delta/Theta oscillations

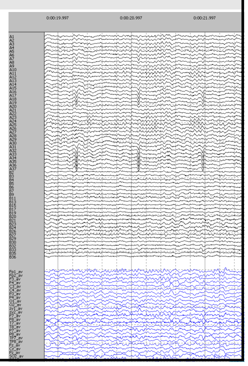
- Sleep
- Antidepressants
- Antipsychotics
- Opiates
- (Hypnotics (Etomidate))
- Anesthetics (e.g. propofol)
- AED (e.g. carbamazepine)

- Epilepsy-associated delta/theta!



Beta oscillations

- Sedatives/hypnotics (e.g. benzodiazepines, barbiturates)
- Anesthetics (e.g., propofol)
- AED
- (Antidepressants)
- (Hallucinogenic drugs)
- (Psychostimulants)

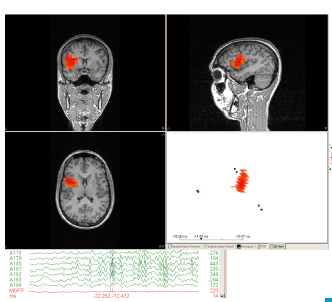


Normal variant or epileptic activity?

- MEG:
  Beta oscillations left frontal
  Interspersed spikes/accentuated oscillations?
- Epileptic oscillations/rhythmic spikes?
- Effects of Medication (AED!)?
- Normal variant?

=>Epileptic oscillations/rhythmic spikes!

- Focal, left frontal localization
- Repeated MRI due to MEG finding:
  Suspicion of cortical dysplasia left insula



Universitätsklinikum Erlangen

Practical advice

- Record simultaneous EEG!
- One spike is no spike!
- Double check series of patterns or oscillatory appearance!
- Compare drowsiness/sleep vs. wakefulness when in doubt
- Compare resting state vs. somatosensory stimulation

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Erlangen

Thank you for your attention!

Universitätsklinikum
Erlangen

Recognizing and Correcting MEG Artifacts

Richard C. Burgess, Cleveland

Recognizing and Correcting MEG Artifacts

Richard C. Burgess, MD, PhD

Magnetoencephalography (MEG) has significant advantages for localization due to its higher temporal and spatial resolution, along with its insensitivity to tissue inhomogeneities (e.g. skull, scalp), compared to electroencephalography (EEG). MEG is used primarily for precise localization, and the accuracy of this source localization task is highly dependent on the signal to noise ratio. Many of the sources of interference familiar to electroencephalographers plague MEG as well, although there are some (such as EMG) that are less disruptive to MEG than EEG. Since MEG is a recording of magnetic fields, there are also several artifacts not seen on EEG; magnetoencephalographers need to recognize and minimize these interfering signals.

Some of the problematic interfering sources include:

External interference from magnetic environments that is specific to the clinical environment (monitoring instruments, frequent transportation of patients and equipment, building construction, etc.)

Artifacts caused by nearby sources (vagal nerve stimulator, magnetic particles left on the head after craniotomy, dental materials, etc.)

In order to focus on the brain magnetic field and exclude extraneous magnetic noise, several strategies are employed:

Locating the MEG within a magnetically shielded room.

Employing gradiometers which measure differential magnetic fields coupled to SQUIDs.

Additional compensation using active field coils.

A variety of post-acquisition digital subtraction techniques.

In most mapping and cognitive-related protocols, averaging is employed to improve SNR. During spontaneous MEG recordings in epilepsy patients, however, averaging of interictal activity is not desirable, and alternative methods of noise reduction are sought.

Interference suppression methods include:

Reference sensors (Vrba and Robinson 2001)

Signal space projection (SSP) (Uusitalo and Ilmoniemi 1997)

Signal space separation (SSS) (Taulu and Kajola 2005)

Spatiotemporal signal space separation (tSSS) (Taulu and Simola 2006)

The most recent technique, the tSSS method, recognizes and removes both external interference and the artifacts produced by the nearby sources, even those on the scalp.

The basic separation into brain-related and external interferences signals is accomplished with signal space separation based on sensor geometry and Maxwell's equations only.

The artifacts from nearby sources are extracted by a simple statistical analysis in the time domain, and projected out.

In addition to the classical sorts of interfering signals, problems can occur during the source localization process that lead to localization errors. These vulnerable steps include:

Artifacts from post-processing to remove noise or to correct head position

Coregistration with anatomical images

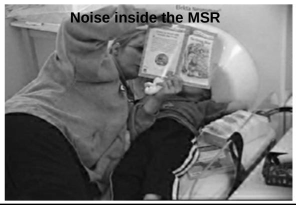
Errors during management of the source localization algorithm

When these components of the interpretation process produce erroneous results, they too must be considered "artifacts" which demand vigilance to identify and remove them.

Recognizing and Correcting MEG Artifacts

Annual Meeting of the American Clinical MEG Society
February 11, 2016

Cleveland Clinic Richard C. Burgess, MD, PhD ACMEGS



Noise Sources in Magnetoencephalography

- Interference from sources outside the shielded room
  - Elevators and moving vehicles
  - Motors and power lines
  - Construction activities
- Noise sources in the shielded room
  - Other people (parent, nurse, neuropsychologist)
  - Devices (projectors, cameras, stimulators, EEG cables)
- Physiological or non-physiological sources inside the patient
  - EKG, orthodontia
  - Implants (VNS, artifical joints)
- Noise from inside the head
  - Ferrous particles left in the head after craniotomy
  - Background brain noise unrelated to the signal of interest
  - Activity from brain regions not of interest
- Intrinsic sensor noise
- Artifacts from other apparatus
  - Crosstalk from other recording devices (EEG)
  - Evoked response stimulators

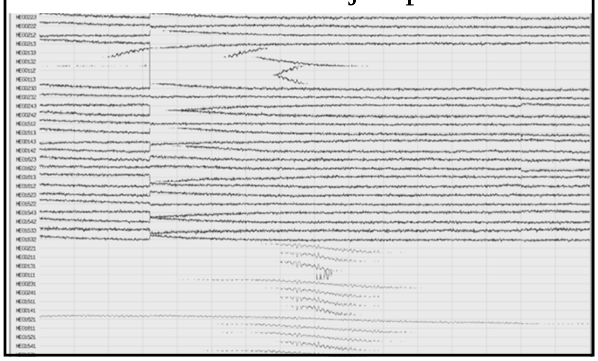
Elimination of magnetic interference in Magnetoencephalography

- **Magnetically shielded room**
- **Gradiometers: measurement of *differential* magnetic fields**
- **Real-time active compensation using reference sensors and external feedback coils (Vrba and Robinson 2001)**
- **Post-processing to remove noise**
  - **Signal space projection (SSP) (Uusitalo and Ilmoniemi 1997)**
  - **Signal space separation (SSS) (Taulu and Kajola 2005)**
  - **Spatiotemporal signal space separetion (tSSS) (Taulu and Simola 2006)**

Other factors which corrupt the MEG (aka "artifacts")

- **Inadequate positioning of the patient**
- **Changes in the head position during the recording**
- **Incorrect co-registration**
- **Introduction of spurious signals during post-processing**
- **Errors in fitting**

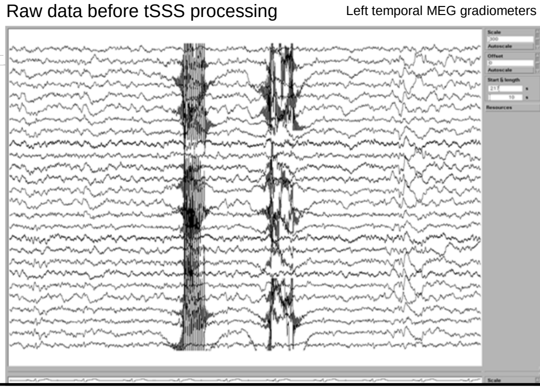
Sensor Noise: Flux jumps



What is this artifact ?

Raw data before tSSS processing

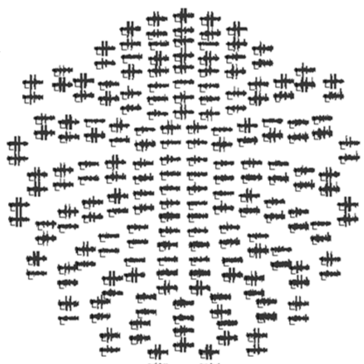
Left temporal MEG gradiometers



What is this artifact ?

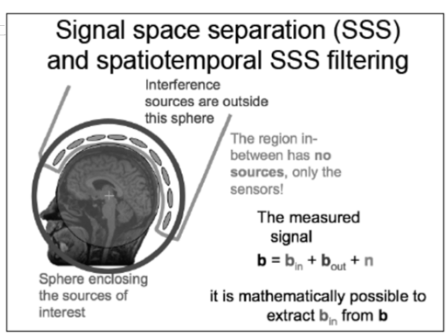
Filtered data *after* tSSS processing — Left temporal MEG gradiometers

Interference distributed over all sensors suggests that it is *not* from the head



Interference from sources *outside* the patient

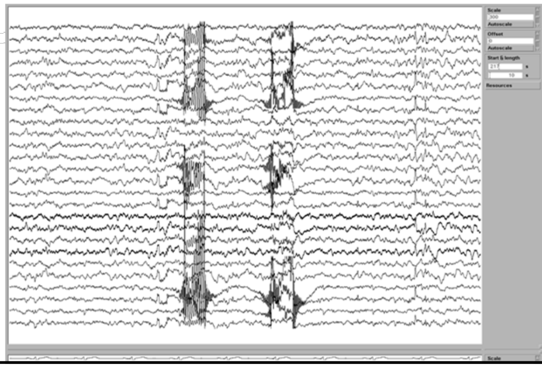
Post-Processing to Eliminate Magnetic Interference



IPhone Artifact

Raw data before tSSS processing

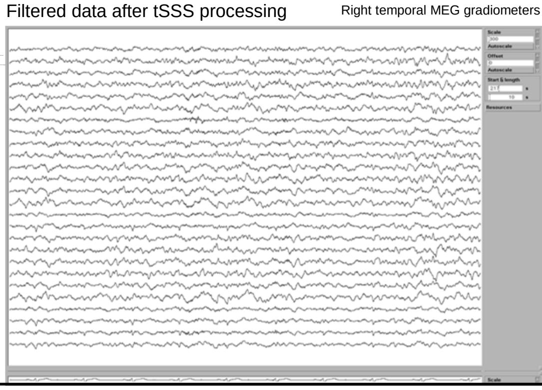
Right temporal MEG gradiometers



IPhone Artifact

Filtered data after tSSS processing

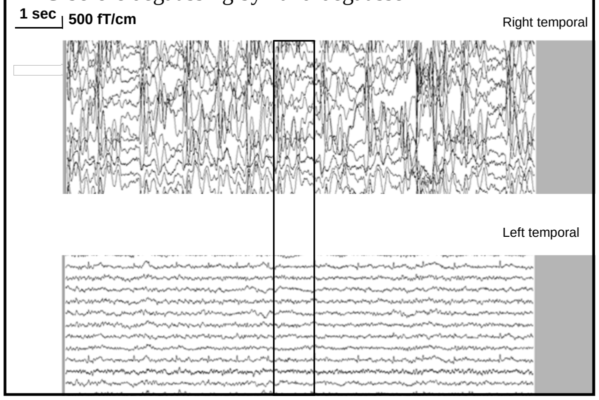
Right temporal MEG gradiometers



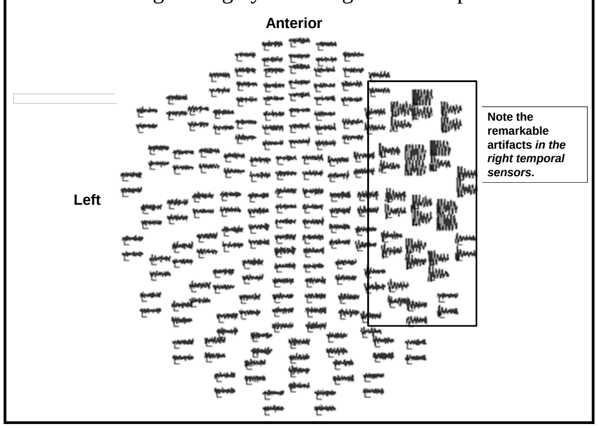
Magnetic artifacts from inside the patient

- **Metallic foreign bodies**
- **Neurosurgical clips or plates**
- **Orthodontia**

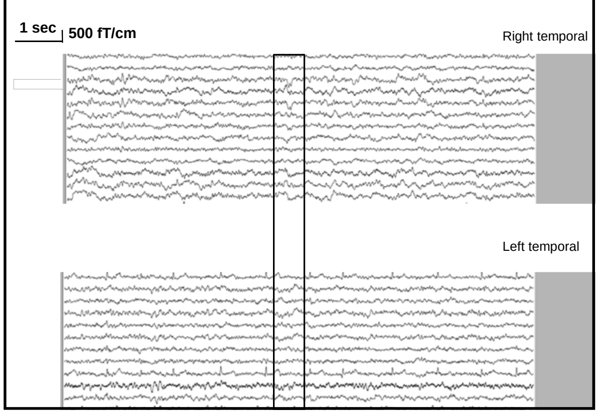
Artifact from metal surgical plate in right side of skull
MEG before degaussing by hand-degausser



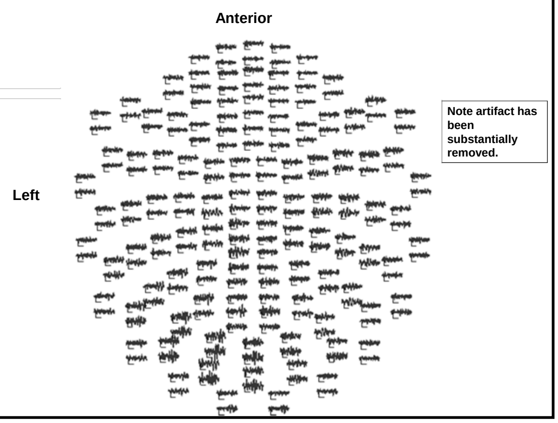
MEG before degaussing by hand-degausser – Top view



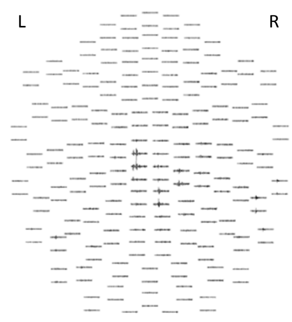
MEG after degaussing by hand-degausser: No artifact



MEG after degaussing by hand-degausser



Retained bullet fragment artifact: Top View of Sensors

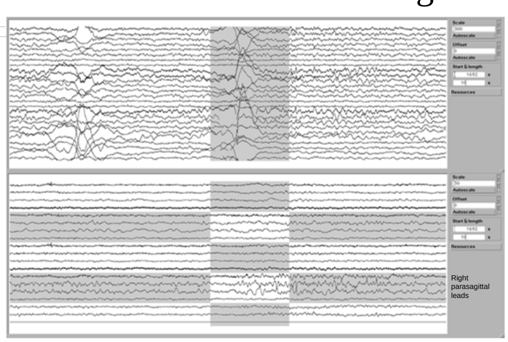


(MR#23621550)

Artifact due to retained bullet fragment

MEG
Right temporal sensors

EEG
Longitudinal bipolar

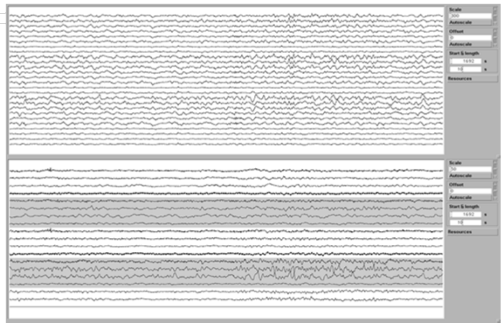


(MR#23621550)

Artifact due to retained bullet fragment- *After* tSSS Filtering

MEG
Right temporal sensors

EEG
Longitudinal bipolar

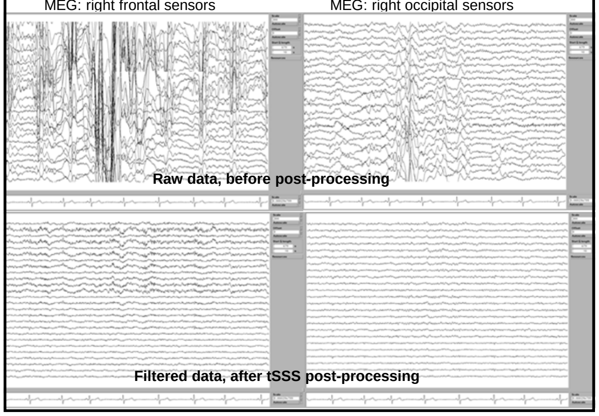


(same data segment)

(MR#23621550)

Artifact caused by dental braces

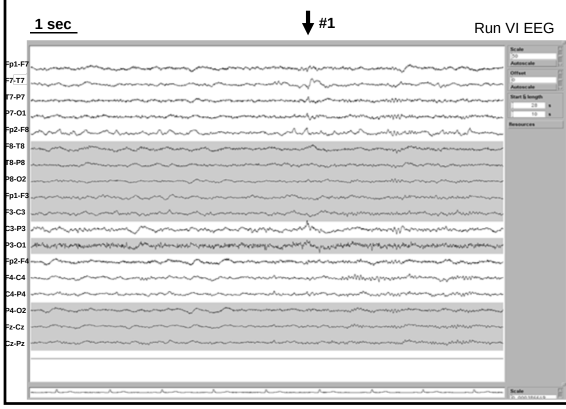
MEG: right frontal sensors | MEG: right occipital sensors



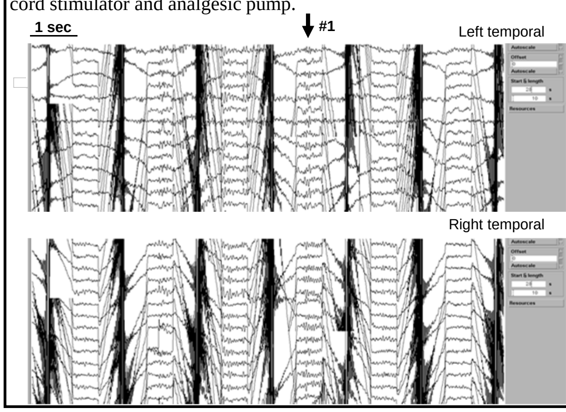
Magnetic artifacts from inside the patient

- **Implanted electronic devices**
  - **Pacemaker**
  - **Pumps**
  - **VNS**
- **Intracranial devices**
  - **Shunts**
  - **Cochlear implants**
  - **Responsive Neural Stimulators**

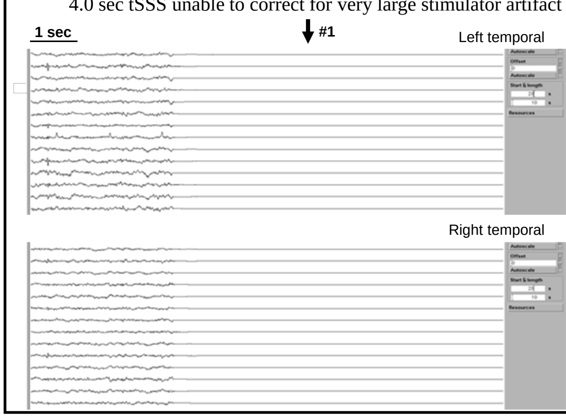
EEG: Sharp wave, FT9



MEG: Large artifacts (raw data, i.e. pre-tSSS) due to implanted spinal cord stimulator and analgesic pump.



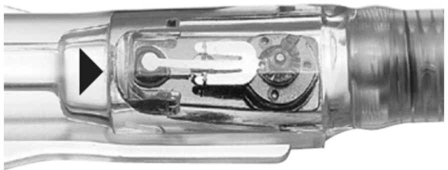
MEG: No data, Left temporal sensors
4.0 sec tSSS unable to correct for very large stimulator artifact



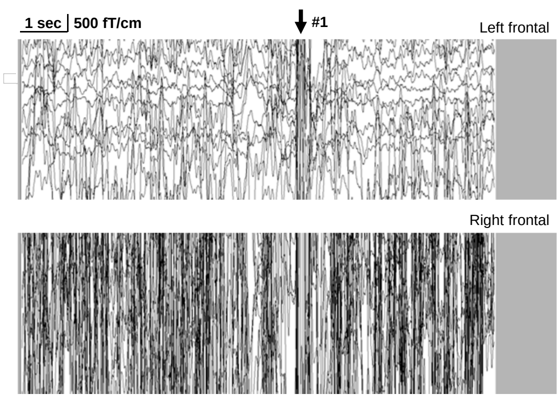
Programmable Non-magnetic VP Shunt

- **Metallic parts, somewhat magnetizable**
- **But does not contain *permanent* magnet**

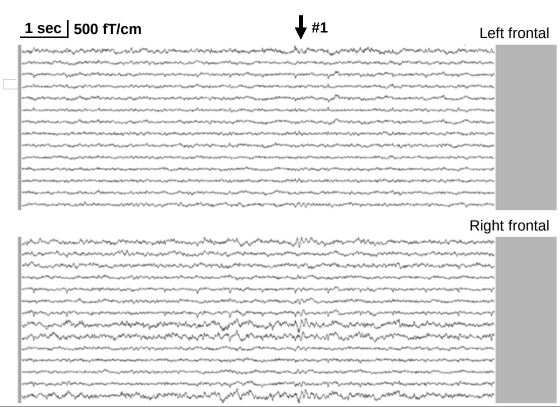
Codman – Hakim Programmable Shunt Valve



VP Shunt Artifacts, Right frontal sensors (Raw data, Pre-tSSS)



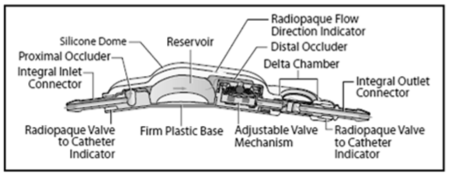
VP Shunt Artifacts, Right frontal sensors (After filtering with tSSS)



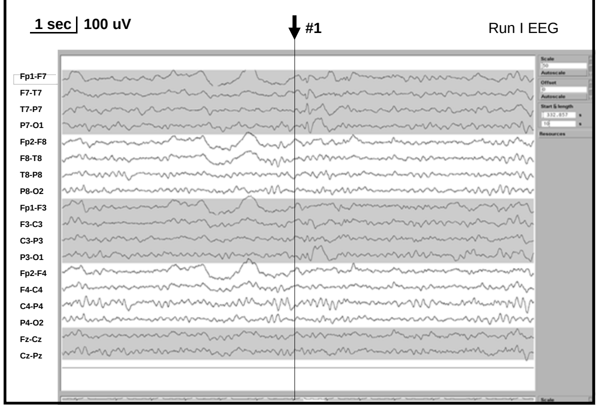
Programmable Magnetic VP Shunt

- **Flow is controlled by adjusting the tension using a patented "magnetic rotor"**
- **This device contains a *permanent* magnet**

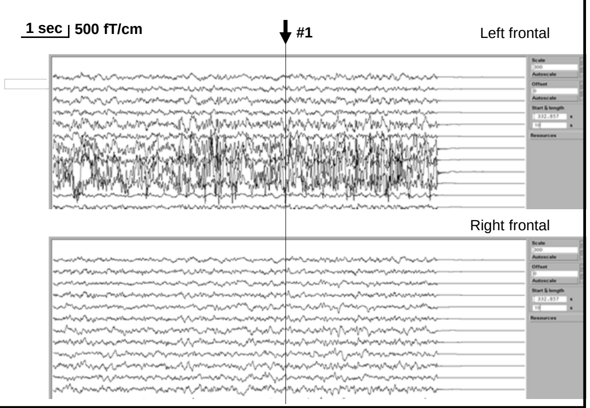
Strata Adjuxtable Pressuret Valve



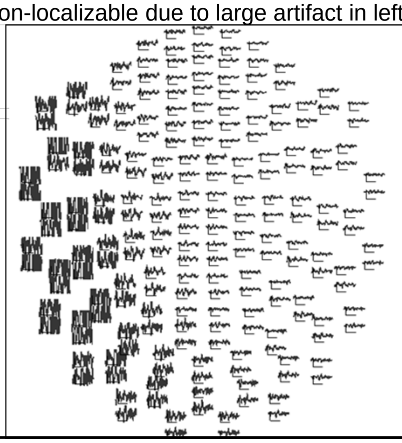
EEG: Spike Regional left frontotemporal, Maximum T7



MEG: Large artifacts in left frontal sensors



Dipole non-localizable due to large artifact in left sensors



Is it impossible to record MEG in patients with implants?

FROM THE WEB-SITE OF AN AMERICAN MEG LAB IN THE NORTHEAST (2010):

"The following implants/items ARE NOT allowed into the MEG:

- **Braces**
- **Cochlear Implants**
- **Defibrillators (IAED)**
- **Pacemakers**
- **PCA Pumps**
- **Programmable VP Shunts**
- **Vagal Nerve Stimulators"**

FROM A PUBLICATION BY AN AMERICAN EPILEPSY SURGERY PROGRAM IN THE SOUTHWEST (J. Neurosurg 107 (6 Suppl Pediatrics); 519-520, December 2007):

"Patients with epilepsy and an implanted vagus nerve stimulation (VNS) device who are referred for consideration of definitive epilepsy surgery (removal of the epileptogenic cortex) may require magnetoencephalography (MEG), a study requiring explantation of the pulse generator, as part of their evaluation. Upon completion of MEG, if pulse generator replacement proves desirable, atraumatic retrieval of the electrode connector pin and body is easy."

Implanted Sources of Interference

IMPLANT		NUMBER of PATIENTS
Intracranial plates and clips		12
CSF Shunts		4
Braces or permanent metallic bridges		81
Non-dental mandibular implants		2
ActiveDevices:	VNS	91
	Pacemakers	3
	RNS (Neuropace)	1
	Bilateral cochlear implant	1
Other (VC filters in chest, plates in extremities, etc.)		61

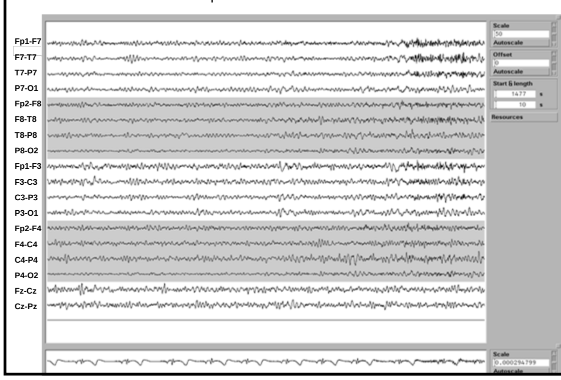
Cleveland Clinic Epilepsy Center, 2008-2014

Patient with multiple implants

- **20 y.o. RH female with seizure onset age 13**
- **Three seizure types:**
  - **Dialeptic → right version → right arm tonic → GTC**
  - **Bilateral limb myoclonus**
  - **Generalized myoclonic with eye blinking and shoulder shrugging**
- **S / P VNS implantation 2 yrs ago with no benefit**
- **Scalp VEEG: Interictal and ictal discharges generalized**
- **Multiple body piercings, three of which were unremoveable (one in left ear)**

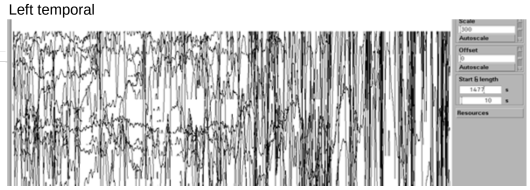
EEG:

Run I: Double banana bipolar EEG

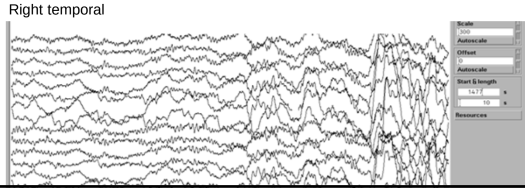


MEG without tSSS (temporal signal space separation)

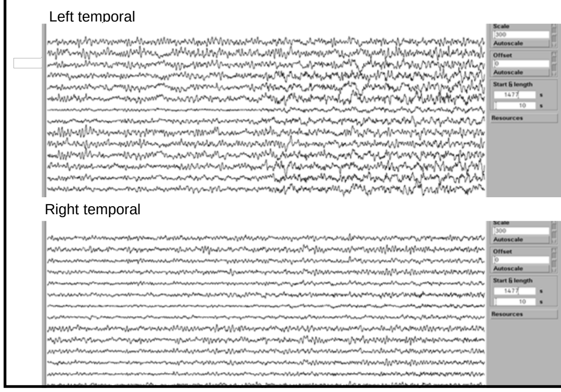
Left temporal



Right temporal



MEG with tSSS (same time segment with same amplitude scale)



Post-processing with tSSS filtering is of proven benefit

- **“Without tSSS, and wearing braces, it was not possible to obtain a discernable evoked response, a dipole fit, or a dipole fit result that was not significantly shifted from the reference position.”**
- **“We have further shown that tSSS is a required pre-processing step for data recorded …. these techniques enable the use of MEG for pre-surgical evaluation in a much larger clinical population than previously thought possible.”**

(Feasibility of clinical magnetoencephalography (MEG) functional mapping in the presence of dental artefacts. Hillebrand A, Fazio P, de Munck JC, van Dijk BW. Clin Neurophysiol; 2013 Jan;124(1):107-13.)

Post-processing both improves the yield of spikes and refines their localization accuracy

Clinical Neurophysiology 124 (2013) 1283–1289

Contents lists available at SciVerse ScienceDirect

Clinical Neurophysiology

journal homepage: www.elsevier.com/locate/clinph

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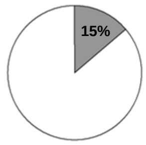
Implanted medical devices or other strong sources of interference are not barriers to magnetoencephalographic recordings in epilepsy patients

Kazutaka Jin[a,b], Andreas V. Alexopoulos[b], John C. Mosher[b], Richard C. Burgess[b,*]

[a] Department of Epileptology, Tohoku University Graduate School of Medicine, Sendai, Japan
[b] Epilepsy Center, Neurological Institute, Cleveland Clinic, Cleveland, OH, USA

VNS

MEG Patients with Implanted VNS



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Clinical Neurophysiology

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Utility of temporally-extended signal space separation algorithm for magnetic noise from vagal nerve stimulators

Yosuke Kakisaka[a,b], John C. Mosher[a], Zhong I. Wang[a], Kazutaka Jin[c], Anne-Sophie Dubarry[a], Andreas V. Alexopoulos[a], Richard C. Burgess[a,*]

[a] Epilepsy Center, Department of Neurology, The Cleveland Clinic, Cleveland, OH 44195, USA
[b] Department of Pediatrics, Tohoku University School of Medicine, Sendai, Japan
[c] Department of Epileptology, Tohoku University School of Medicine, Sendai, Japan

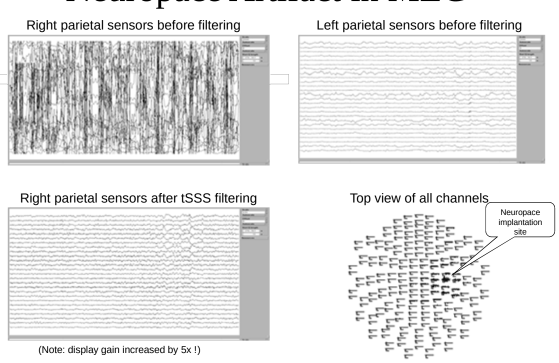
MEG can be obtained even with intracranial implanted devices

Feasibility of magnetoencephalography recording in an epilepsy patient with implanted responsive cortical stimulation device

Zhong Irene Wang, Andreas V. Alexopoulos, Dileep Nair, Balu Krishnan, John C. Mosher, Richard C. Burgess, and Yosuke Kakisaka

Clinical Neurophysiology, 2013-08-01, Volume 124, Issue 8, Pages 1705-1706

Neuropace Artifact in MEG



(Wang et al, 2013)

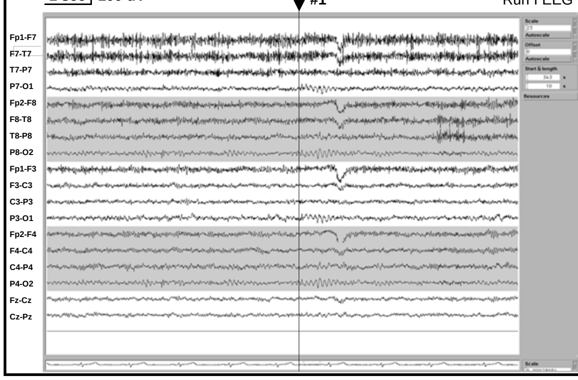
MRN 35387498

Artifacts due to post-processing

- **Rare**
- **Most often occur as a result of processing a huge transient**
- **tSSS processing may "spread" an artifact occurring in a restricted number of channels**
- **Changes in the statistical properties of the signal between one epoch and the next may result in a "boundary artifact"**

Nothing on EEG Example #1, tSSS artifact

1 sec | 100 uV **#1** Run I EEG

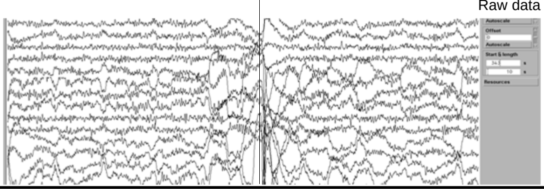


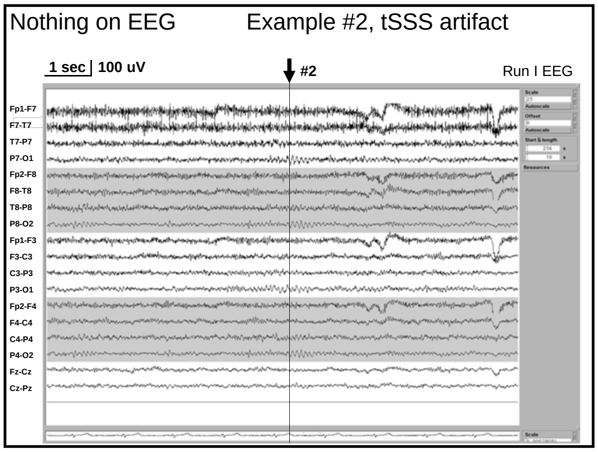
MEG: Artifact, Left frontal sensors **(artifact could plausibly be misinterpreted as spike)**

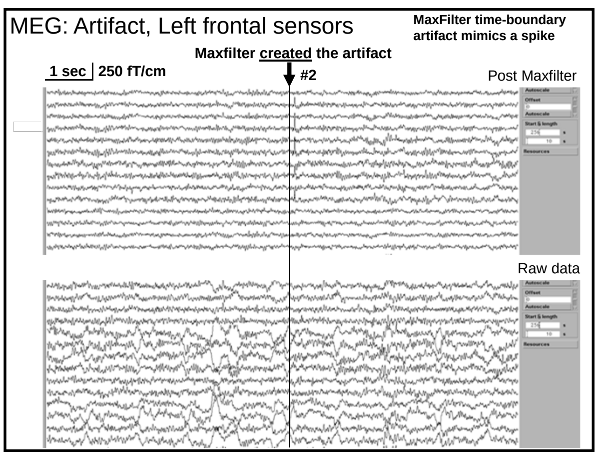
Maxfilter <u>modified</u> the artifact

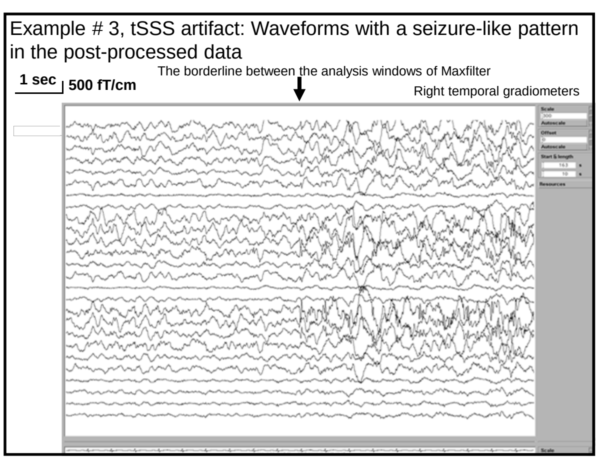
1 sec | 250 fT/cm **#1** Post Maxfilter

Raw data




Nothing on EEG
Example #2, tSSS artifact
1 sec
100 uV
#2
Run I EEG
Fp1-F7
F7-T7
T7-P7
P7-O1
Fp2-F8
F8-T8
T8-P8
P8-O2
Fp1-F3
F3-C3
C3-P3
P3-O1
Fp2-F4
F4-C4
C4-P4
P4-O2
Fz-Cz
Cz-Pz


MEG: Artifact, Left frontal sensors
MaxFilter time-boundary artifact mimics a spike
Maxfilter created the artifact
1 sec
250 fT/cm
#2
Post Maxfilter
Raw data

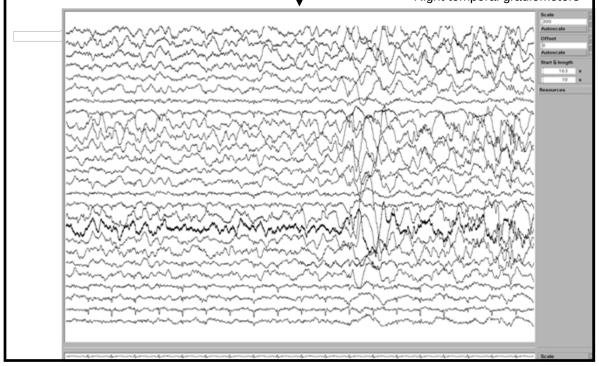

Example # 3, tSSS artifact: Waveforms with a seizure-like pattern in the post-processed data
1 sec
500 fT/cm
The borderline between the analysis windows of Maxfilter
Right temporal gradiometers

Before tSSS processing: No seizure-like pattern in the raw data

1 sec 500 fT/cm

The borderline between the analysis windows of Maxfilter

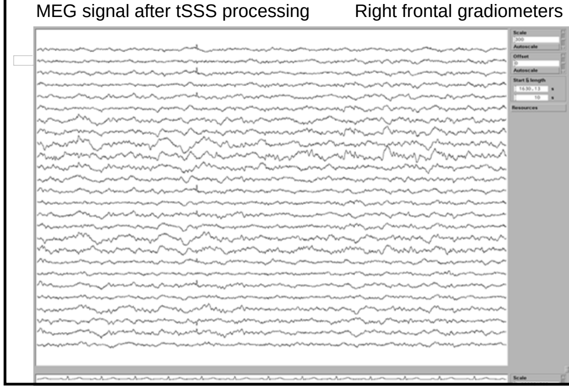
Right temporal gradiometers



Example #4: Is this brief discharge a spike?

MEG signal after tSSS processing

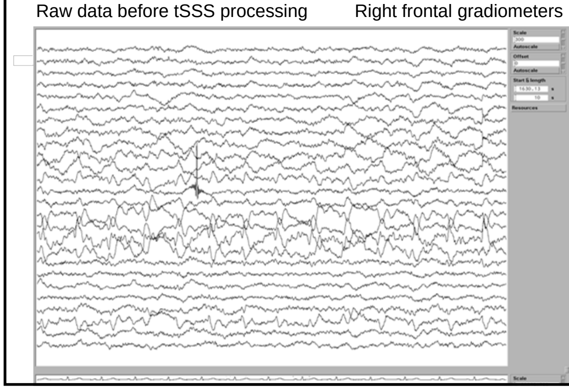
Right frontal gradiometers



Example # 4: Artifact on a single sensor !

Raw data before tSSS processing

Right frontal gradiometers

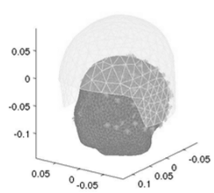


Problems due to head position in the array

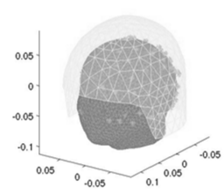
- **Attenuation due to increased brain to sensor distance**
- **Misleading waveform appearance in sensor space**
- **Inadequate SNR in the attenuated regions**
- **Insufficient inferior sensors when not fully inserted**
- **Seen most often in uncooperative children with small heads**

Head inadequately inserted into array

Initial head position (data discarded)
Head Center: -1.5, 19.0, -83.2 mm



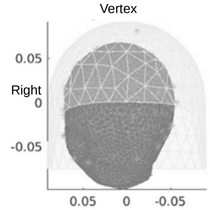
Final head position (sustained 63 min)
Head Center: 3.1, 12.6, -49.2 mm



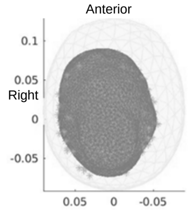
Head displaced towards one side

Eighteen month old patient with a small head, deviated to the right. Produces a long distance between the sensors and the brain on the left.

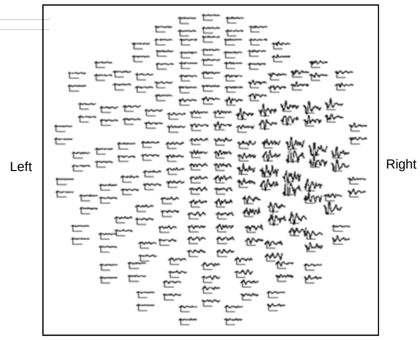
Coronal View
Vertex



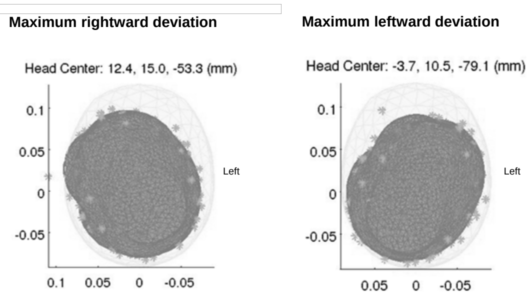
Axial View
Anterior



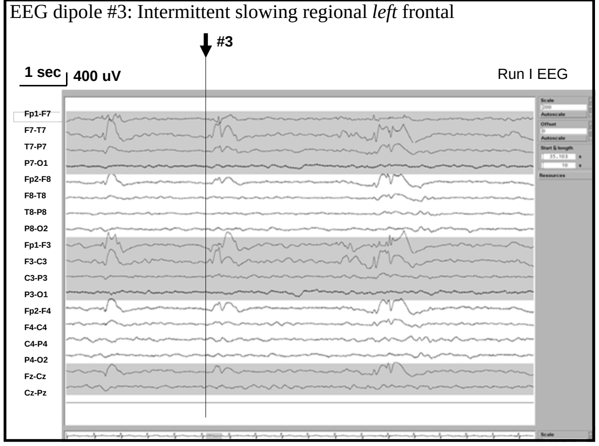
Note the signal attenuation in the left-sided sensors



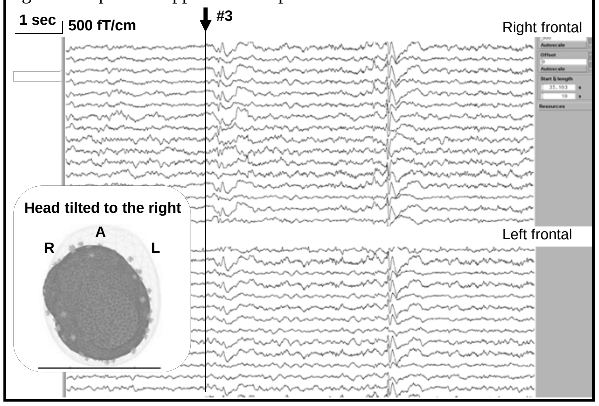
Discordance of location in sensor space vs head space due to substantial head rotation inside the MEG array



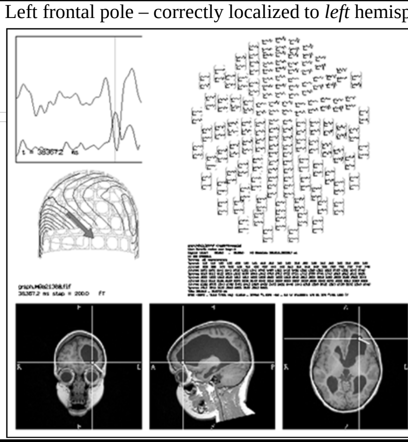
EEG dipole #3: Intermittent slowing regional *left* frontal



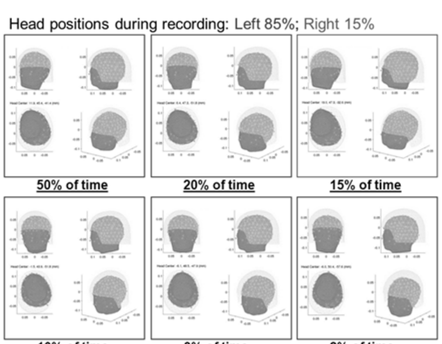
Leads to considerable surprise when the most active sensors are in the right hemisphere – opposite the dipole source localization.



Dipole #3: Left frontal pole – correctly localized to *left* hemisphere

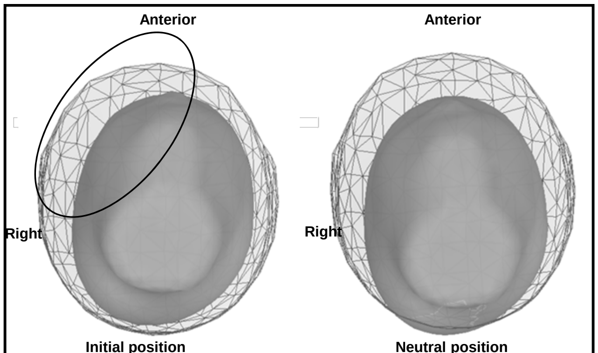


Considerable patient displacement may occur during MEG



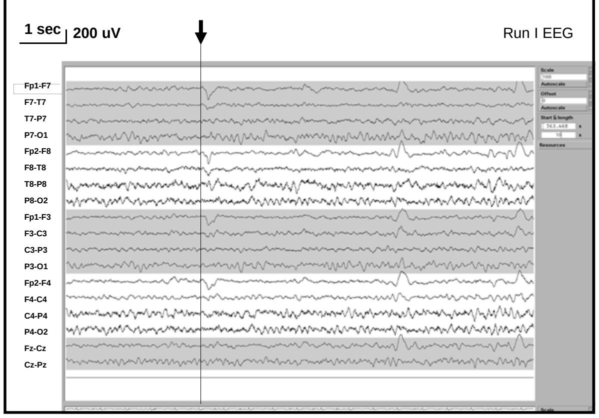
Problems due to head position in the array

- **Slow displacement from original position, *not* sudden movement artifact**
- **May lead to mislocalization if not corrected**
- **Continuous movement compensation (cHPI) capability available on some systems**

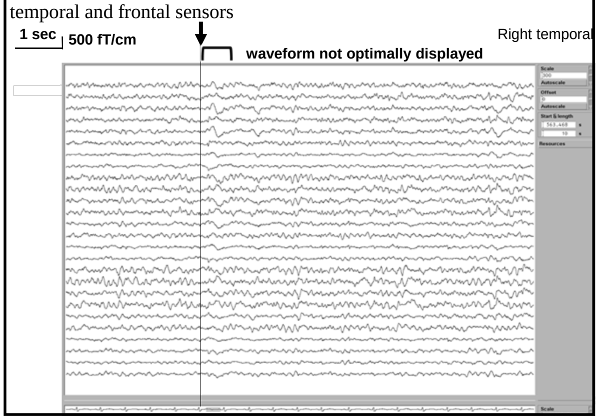


The patient's head was small relative to the helmet. There was some space between the inner wall of the helmet and the patient's right fronto-temporal region. Necessitated head position correction.

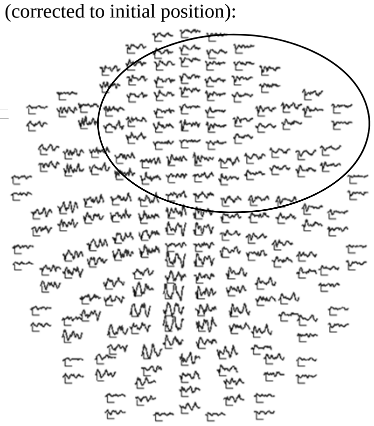
EEG dipole : Spike regional right fronto-temporal



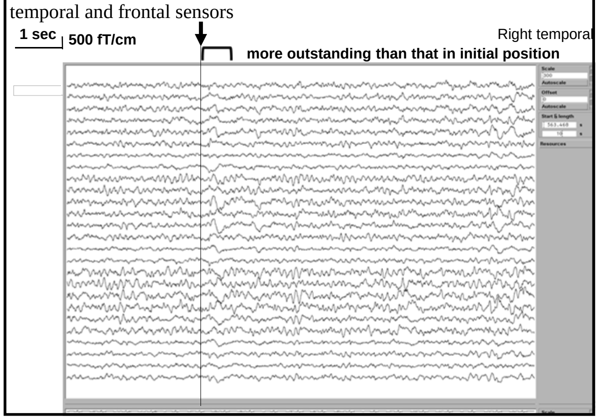
MEG dipole (corrected to initial position): Spike maximum in the right temporal and frontal sensors



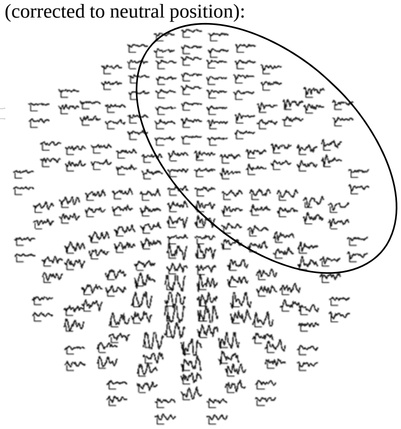
MEG dipole (corrected to initial position):



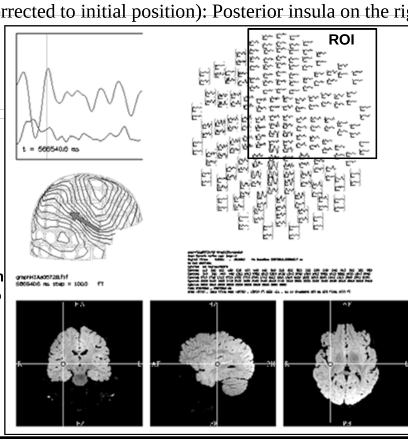
MEG dipole (corrected to neutral position): Spike maximum in the right temporal and frontal sensors



MEG dipole (corrected to neutral position):

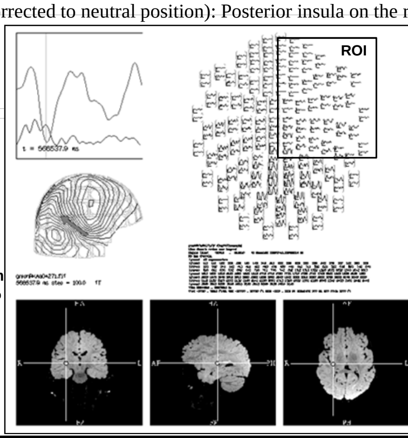


Dipole (corrected to initial position): Posterior insula on the right



Q:338.0 nAm
GOF: 82.5 %
CV: 1153.2 mm^3

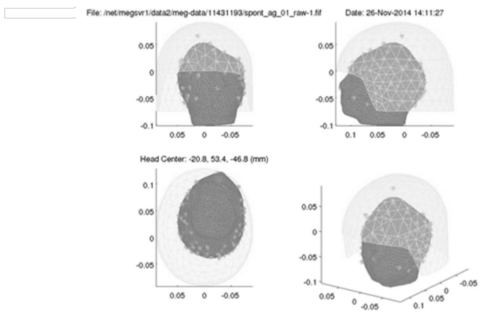
Dipole (corrected to neutral position): Posterior insula on the right



Q:399.4 nAm
GOF: 89.3 %
CV: 1432.3 mm^3

The localization result of the dipole analysis was the same whether continuous HPI data was corrected to the initial position or to the neutral position.

When the head must be corrected *too* far, the signal may become more noisy

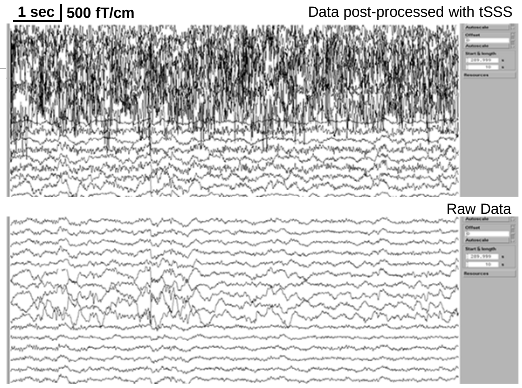


MEG artifact due to movement compensation: Comparison of raw data and post-processed data

1 sec | 500 fT/cm

Data post-processed with tSSS

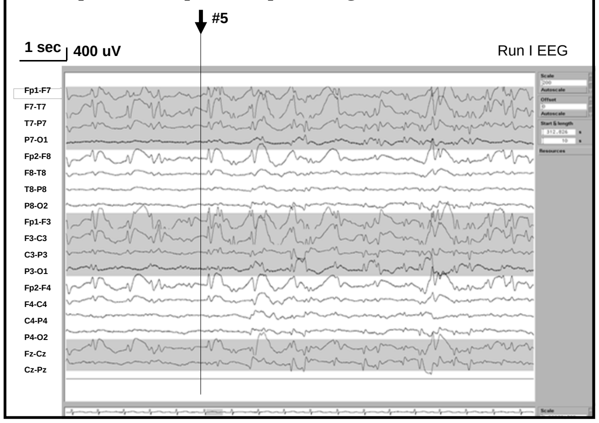
Raw Data



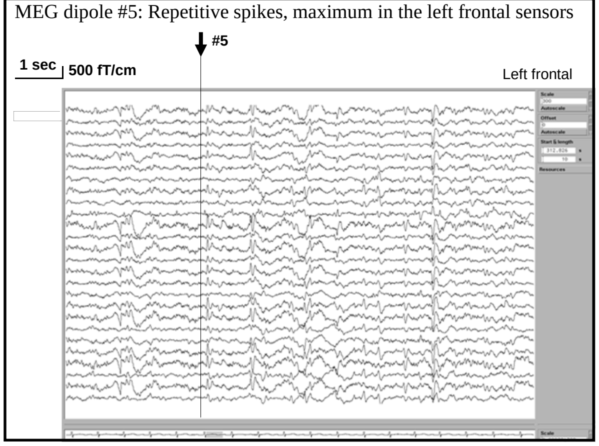
Errors during the fitting process

- **You *will* get an answer; a "fit" can be obtained for any waveform, any timepoint**
- **A single equivalent current dipole will, by definition, provide a *single* point**
- **Baseline noise covariance must be taken into account**
- **Statistics and magnetic field pattern can help you decide when to reject a fit**
- **Be cautious when selecting the time point, baseline, and region of interest; these are subjective**

EEG dipole #5: Repetitive spikes, regional bilateral frontal

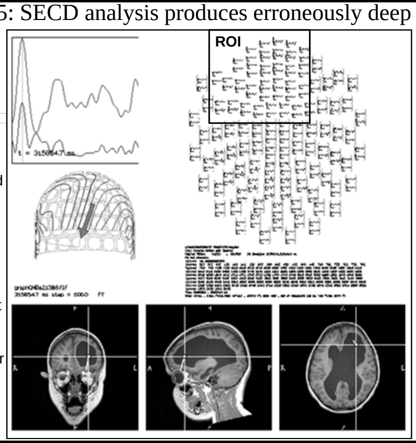


MEG dipole #5: Repetitive spikes, maximum in the left frontal sensors

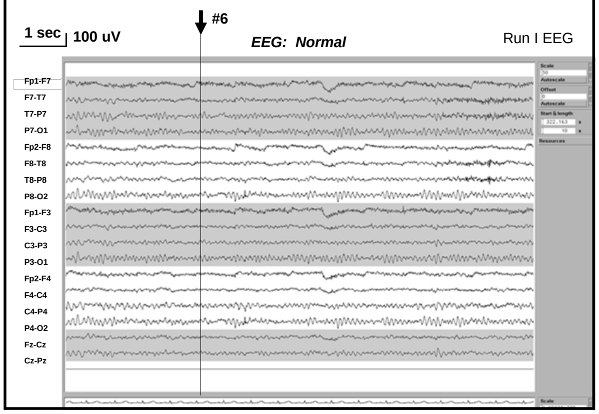


Dipole #5: SECD analysis produces erroneously deep source

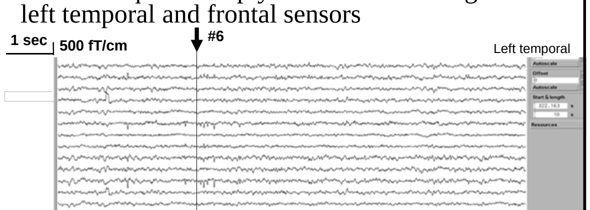
The impossible location (inside the anterior part of the left lateral ventricle) and excessive amplitude (621.1 nAm) of the modeled dipole indicates that the source is too widely distributed for a SECD model.



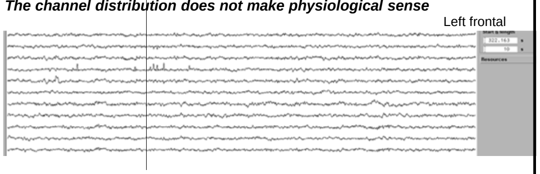
Why is this activity not from the brain?



MEG: Frequent sharply contoured discharges in the left temporal and frontal sensors

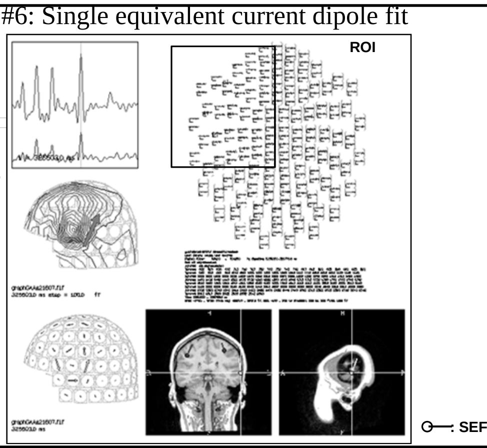


The waveform morphology and repetition pattern is dissimilar from spikes
The channel distribution does not make physiological sense



MEG #6: Single equivalent current dipole fit

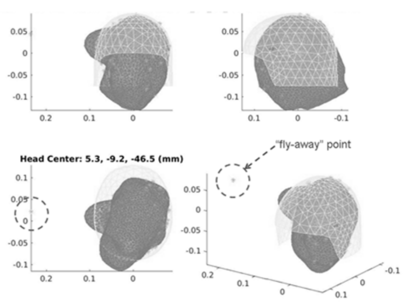
The magnetic field pattern is not physiological, and the fitting statistics preclude localization.



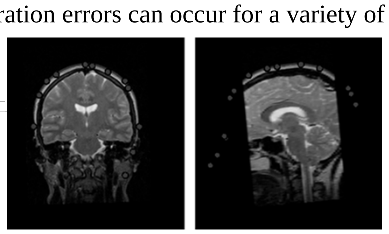
Careful coregistration of the MEG results with MRI is of crucial importance for localization

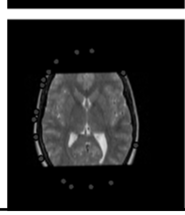
79

Erroneously acquired points lead to co-registration errors



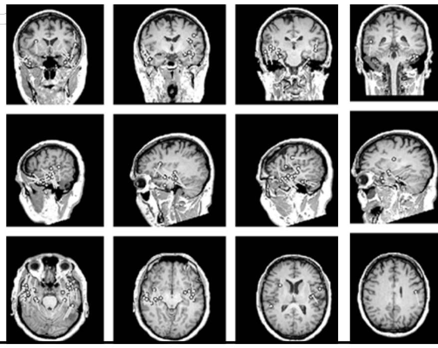
Coregistration errors can occur for a variety of reasons





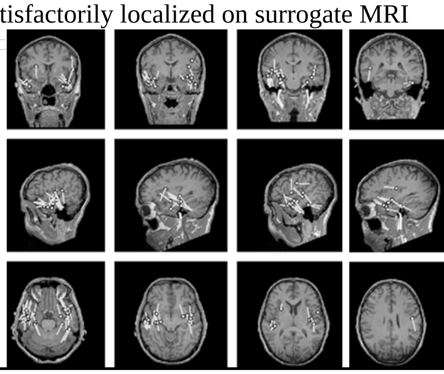
Coregistration to MRI: Pink dots (◯) represent the points on the scalp which were registered during this MEG recording. For the areas of missing slices, visual extrapolation was employed, as shown.

On occasion, it may be necessary to use a surrogate MRI, at least temporarily



NOTE: Size-matched surrogate MRI is used.

Dipole sources, primarily in the anterior and middle portions of both temporal lobes, were satisfactorily localized on surrogate MRI

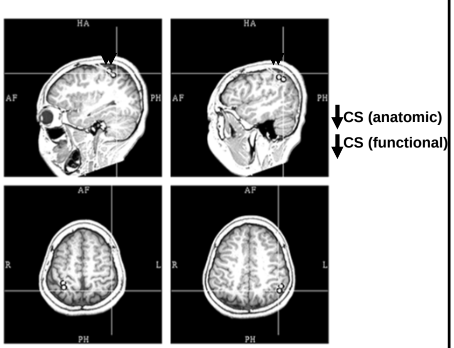


NOTE: Dipoles on patient's own MRI.

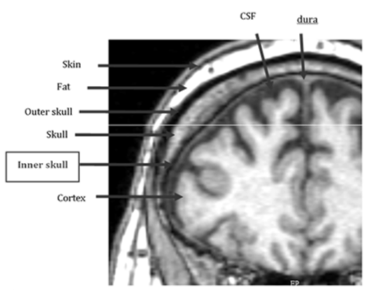
Importance of Patient-Specific MRI

Bilateral SEF co-registered to age-matched surrogate MRI

Response to median nerve stimulation. Note posterior displacement.



For establishing the head sphere center coordinate:
Where should we draw the sphere?
Along the inner skull.



ACMEGS Meeting

Beyond the Spike: Alternative Markers for the Epileptic Network

Stefan Rampp, Erlangen

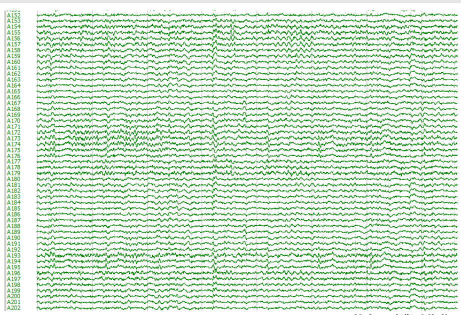
In recent years, novel markers for the epileptic network beyond interictal spikes and ictal seizure correlates have been described. Fast activity, from high gamma oscillations to ripples and fast ripples may be correlated to the pathomechanisms of epilepsy. Detection is possible using mainly invasive recordings, however recent advances may offer methods for non-invasive evaluation. Slow wave at the other end of the frequency spectrum are detected using both invasive and non-invasive means. While this type of activity also occurs associated e.g. with large lesions and after intracranial surgery, certain subtypes may be utilized to localize the epileptic network. Complimentary to such frequency-based markers, alterations of the connectivity structure provide further insights in location and dynamics of epilepsy related areas. The presentation will give an overview of such alternative markers for the epileptic network. Current methods and clinical applications are presented and illustrated with case examples.

Beyond the Spike: Alternative Markers for the Epileptic Network

Stefan Rampp

Universitätsklinikum Erlangen

Example



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High frequency band

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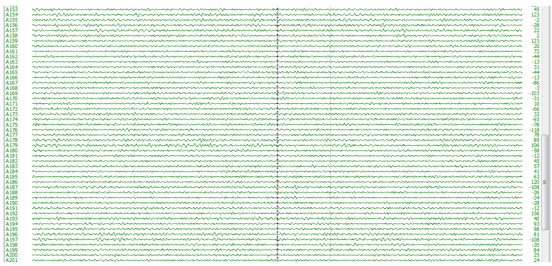
High frequency zoomed (1 sec window)



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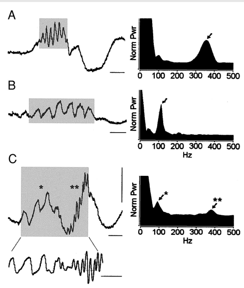
High frequency oscillations - a marker for epileptogenicity?

- Fast Ripples: 250-500 Hz
- Ripples: 80-250 Hz
- (High) gamma: 60-120 Hz (50-100 Hz)

- Overlap with physiological oscillations
- Specificity for epilpsy: FR > R > HG



Staba et al., J Neurophysiol. 2002

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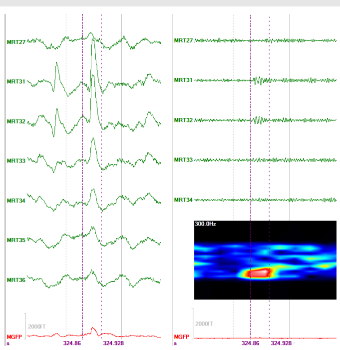
Spike-associated ripple oscillations in MEG

- 43y male patient
- EEG ictal/interictal: temporal and frontal right
- MEG: Spikes right frontal



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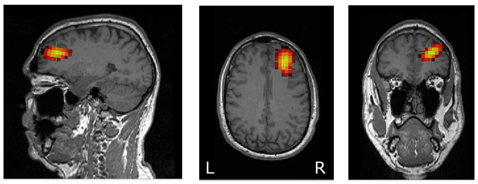
Spike-associated ripple oscillations in MEG

- Source localization of MEG ripple oscillation
- Concordant with seizure onset in V-EEG



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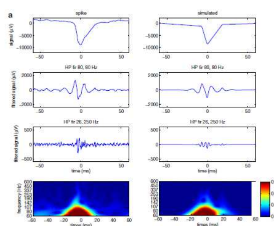
"Pitfalls of high-pass filtering for detecting epileptic oscillations: A technical note on 'false' ripples" (Bénar et al., 2010)

- High-pass filtering of sharp transients and harmonics of non-sinusoidal patterns may produce ‚false' HFO
- Filtered traces should be compared to raw data
- Time-frequency transforms and sparse decompositions are helpful



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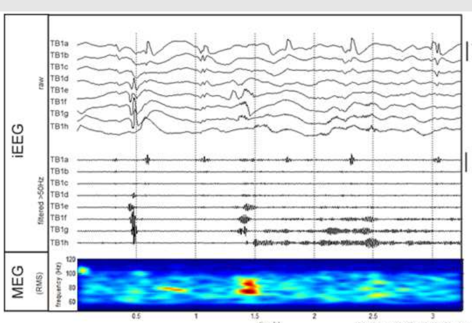
High gamma in simultaneous iEEG and MEG



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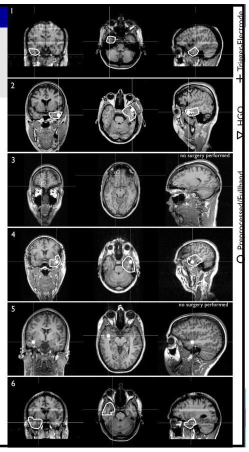
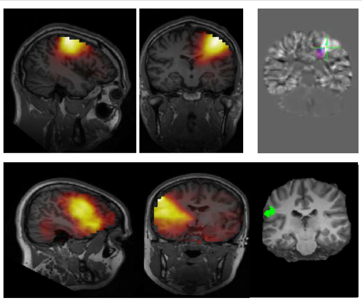
High gamma in simultaneous iEEG/MEG

- High gamma oscillations (HGO) in averaged MEG: 5/6 patients
- HFO source localization concordant with SOZ and/or resection: 4/5 patients



Automated high gamma detection



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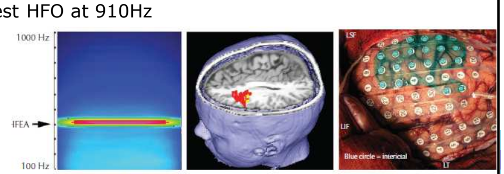
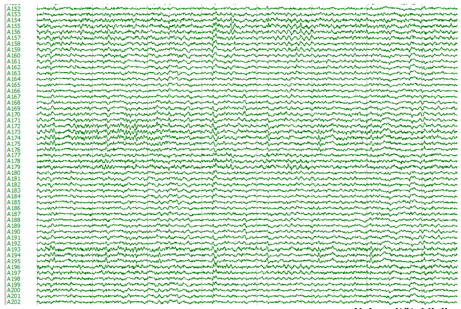
Fast ripple oscillations in MEG (Xiang et al., 2009)

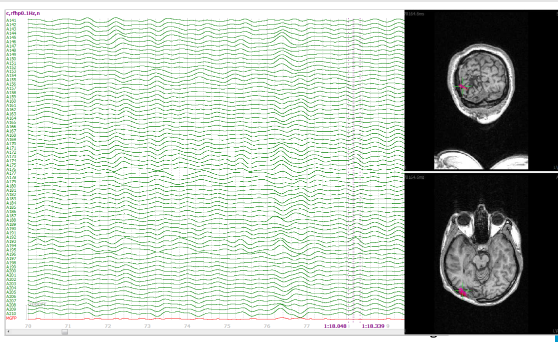
- 26/30 HFO between 100-1000Hz
- 21/30 HFO localizations concordant with MRI lesion
- 9/11 operated patients MEG HFO concordant with iEEG
- 8/11 seizure free after surgery (at least 1 month) and concordant HFO localizations
- Fastest HFO at 910Hz



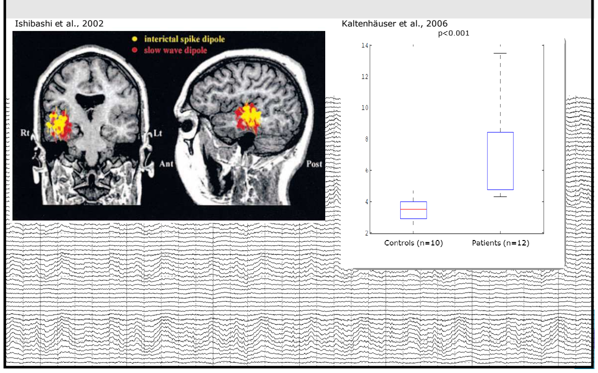
Example



Example – slow wave

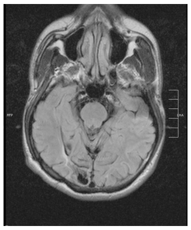


Epileptic slow waves (delta/theta)



Patient

- Male patient
- Focal epilepsy since 20 years
- Semiology: optic, vision loss, but also epigastric, staring, stereotyped movements of both arms
- Cystic lesion occipital right
- First surgery 19 years ago
- EEG:
  - Interictal: 90% temporal right, 10% occipital right
  - Ictal: unclear, temporal and occipital
- MEG: 90% occipital right near lesion, 10% temporal right
- Invasive EEG: Occipital seizure onset



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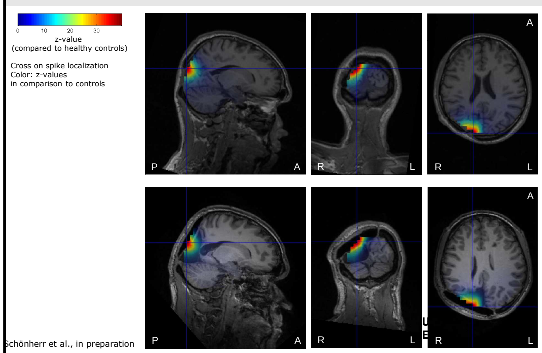
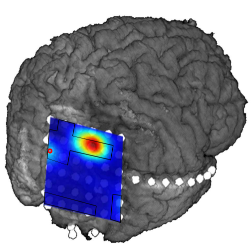
Spikes and focal delta



Schönherr et al., in preparation

Focal delta in invasive EEG

- Invasive evaluation (subdural EEG)
- 1h of awake data
- Artifacts manually excluded
- Spectral analysis
- Visualization of relative power in delta band



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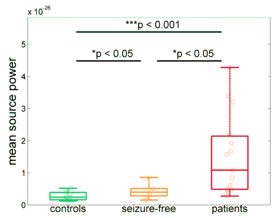
Schönherr et al., in preparation

Focal delta in patients with recurrent seizures

- 15 patients with recurrent seizures
- 14/15 focal distribution
- 11/15 increase of focal delta at spike localizations
- Distance delta peak and spike localization in these: 2.4cm (+-1.28cm)
- +15 seizure free patients after surgery
- +15 controls



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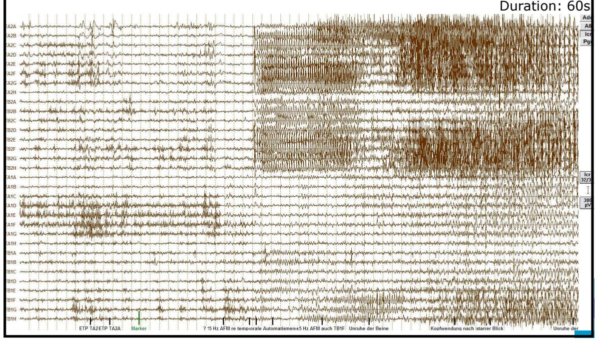
Seizure, intracranial EEG, highpass 1Hz

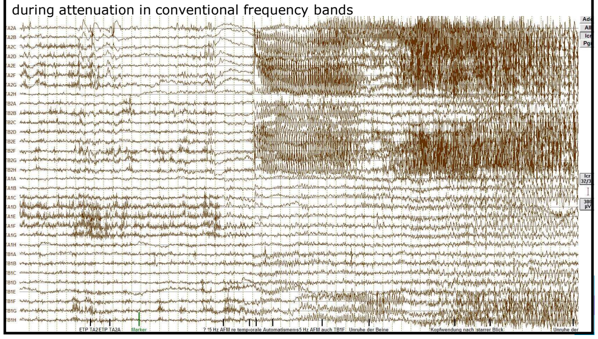
Duration: 60s



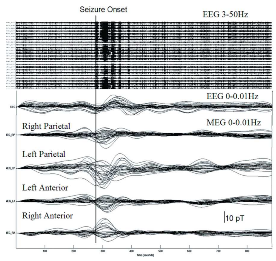
Open filters

Baseline shift in TA2
during attenuation in conventional frequency bands

Duration: 60s



ISA in MEG – Bowyer et al., 2012



- ISA even before seizures
- ISA in all 12/12 patients
  - 115 +- 71s before in 11/12
  - At seizure onset in 1/12
- ISA amplitude (before/after seizure) correlates with duration of epilepsy
- Technically challenging!

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What actually is ISA?

- Cortical spreading depression?
- Large flux of K-ions to extracellular space
- Slow spreading wave of neuronal suppression after initial hyperexcitation
- Also in migraine, TBI, anoxia, ...
- Glial component?

Intracranially recorded ictal direct current shifts may precede high frequency oscillations in human epilepsy

Kyoko Kanazawa [b], Riki Matsumoto [a], Hisaji Imamura [b], Masao Matsuhashi [c], Takayuki Kikuchi [d], Takeharu Kunieda [d], Nobuhiro Mikuni [e], Susumu Miyamoto [d], Ryosuke Takahashi [b], Akio Ikeda [a,*]

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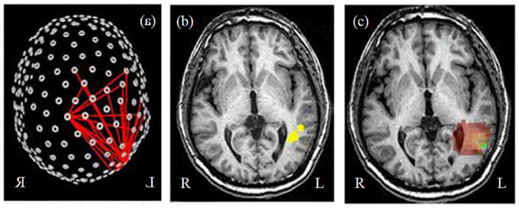
Connectivity: The idea

itsklinikum

Neuromagnetic coherence of epileptic activity: An MEG study

Ting Wu[a,c,1,*], Sheng Ge[b,1], Rui Zhang[c], Hongyi Liu[c], Qiqi Chen[c], Ruirui Zhao[a], Yan Yin[a], Xiuxiu Lv[a], Tianzi Jiang[a]

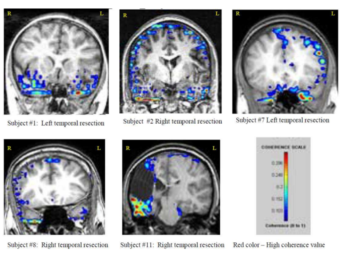
- 23/30 concordant with ECD
- 26/30 concordant with SAM
- 23/30 concordant ECD, SAM, Coherence (15 with iEEG)
- 23/30 concordant with iEEG



MEG Coherence Imaging in Localization of Epileptogenic Focus

Neetu Shukla [1,2], Brien J Smith [1,3], John E Moran [1], Kost Elisevich [1,3], Karen M Mason [1], Gregory L Barkley [1,3], Norman Tepley [1,2] and Susan M Bowyer [1,2,3]
[1] Henry Ford Hospital, Detroit, MI, USA; [2] Oakland University, Rochester, MI, USA ;
[3] Wayne State University, Detroit, MI, USA.

- 19/26 patients coherence concordant with resection
- 5/6 without spikes



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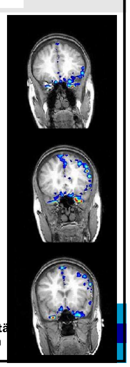
An Assessment of MEG Coherence Imaging in the Study of Temporal Lobe Epilepsy

Kost Elisevich, M.D., Ph.D.[1], Neetu Shukla, M.S.[2], John Moran, Ph.D.[3], Brien Smith, M.D.[3,4], Lonni Schultz, Ph.D.[5], Karen Mason, R.EEG/MEG T.[5], Gregory L Barkley, M.D.[3,4], Norman Tepley, Ph.D.[3], Valentina Gumenyuk, Ph.D.[3], and Susan M. Bowyer, Ph.D.[2,3,4]

Engel Class	EC D		Coherence analysis	
	Match*	No Match	Match*	No Match
Ia	9	13	16	6
Ib	1	0	1	0
Ic	1	0	1	0
Id	2	0	2	0
IIa	0	1	1	0
IIb	1	0	1	0
IIIa	2	0	1	1
Total	16	14	23	7



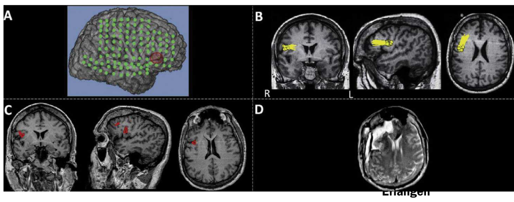
Universitä[tsklinikum] Erlangen

Epileptic focus localization based on resting state interictal MEG recordings is feasible irrespective of the presence or absence of spikes

B. Krishnan [a], I. Vlachos [b], Z.I. Wang [a], J. Mosher [a], I. Najm [a], R. Burgess [a], L. Iasemidis [b], A.V. Alexopoulos [a,*]

[a] Cleveland Clinic Epilepsy Center, Cleveland, OH, USA
[b] Biomedical Engineering, Louisiana Tech University, LA, USA

- 5 patients, ETLE
- Directional connectivity, maximum information **inflow**
- Source space
- Succesful in 3/5
- Independent of spikes



Summary

- Alternative markers are associated with the epileptic network: ISA, focal delta, HGO, HFO, connectivity
- Information beyond spikes and seizures (?)
- CAVE: ‚False‘ epileptic ripples

Next steps:

- Better methods and tools
- Clinical validation
- Standards!

ACMEGS

AMERICAN CLINICAL MEG SOCIETY

Integration of MEG with Other Brain Imaging Modalities and Intracranial EEG

Irene Wang, Cleveland

MRI-negative pharmacoresistant focal epilepsy patients constitute a most challenging group for epilepsy surgical management. In this talk we will review our previous studies assessing the concordance between MEG and structural imaging (such as MRI postprocessing), functional imaging (such as SPECT), and invasive techniques (such as stereotactic EEG). Correlation between multi-modal concordance and seizure-outcomes will be discussed. We will also introduce our experience of using a novel multi-modal image integration system to assist implantation planning and surgical resection. Our studies reveal the importance of incorporating the MEG results into evaluation of MRI-negative patients to accurately target subtle epileptogenic pathology.

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Integration of MEG with Other Brain Imaging Modalities and Intracranial EEG

Irene Wang, PhD
Cleveland Clinic Epilepsy Center

Outline

- MEG & MRI Postprocessing
- MEG & SPECT
- MEG & SEEG
- Multi-modal Imaging Integration

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MEG & MRI Postprocessing

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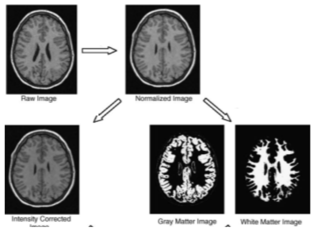
Voxel-based Morphometry (VBM)

- Registration to a standard stereotaxic space
- Correction for intensity nonuniformity
- Tissue classification
- Comparison to control
- Can be optimized to be **applied on individual patients**



(Huppertz et al., Epi Res 2005)

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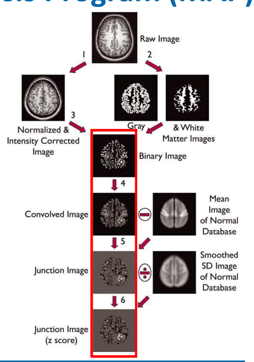
Morphometric Analysis Program (MAP)

- MAP is a specific VBM package optimized to be applied on an individual level.
- MAP is especially sensitive to subtle abnormalities associated with blurring in the gray-white matter junction.
- Such areas may be associated with an underlying cortical dysplasia.



(Huppertz et al., Epilepsia 2008)

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Illustrative Case

- LH 30-year-old male, initial seizure at age 12
- Aura -> L Face (+/- arm) Tonic/Clonic -> GTC
- Aura: tingling sensation deep in throat spreading to left face
- Frequency: up to 10 / day
- Consciousness preserved entirely during these events

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Illustrative Case

- Scalp EEG:
  - no interictal abnormalities
  - non-localizable EEG seizures
- PET and SPECT: nonspecific
- MRI:
  - 2003 MRI: Normal
  - 2008 MRI: Normal
  - [redacted]

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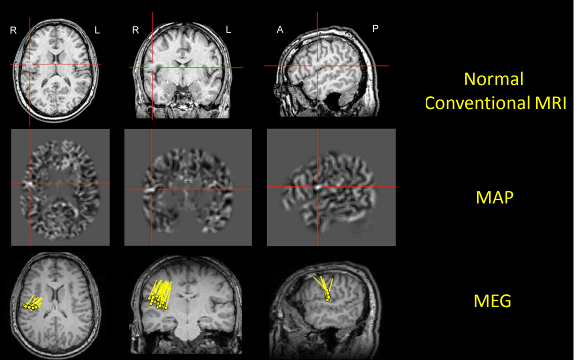
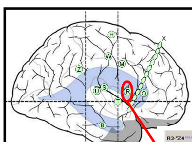
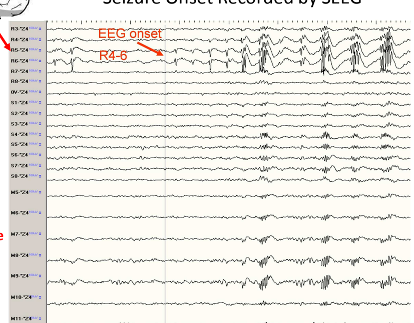
(Wang et al. Epilepsy Research, 2012)

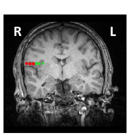


(Wang et al. Epilepsy Research, 2012)



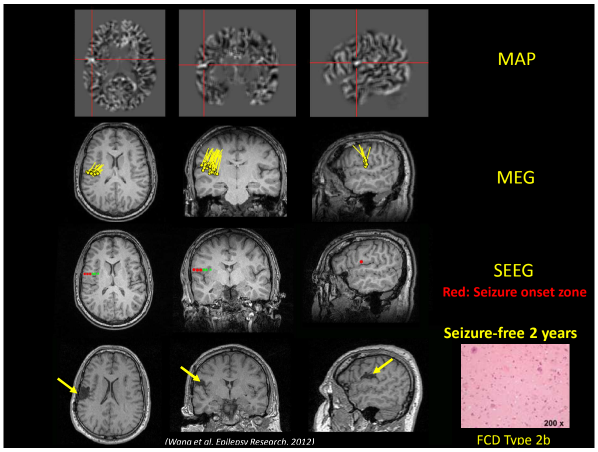
Seizure Onset Recorded by SEEG

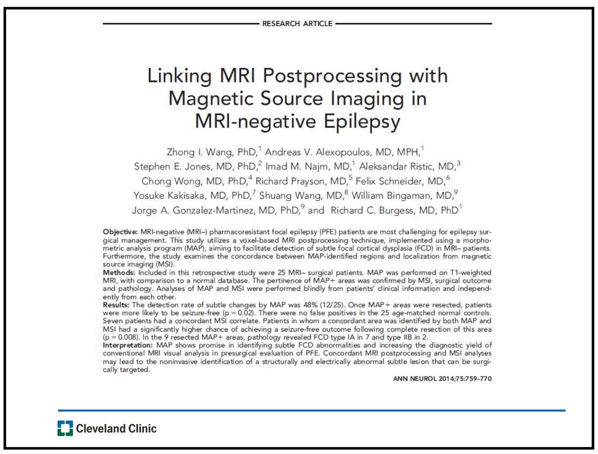




Red: Seizure onset zone

(Wang et al. Epilepsy Research, 2012)





RESEARCH ARTICLE

Linking MRI Postprocessing with Magnetic Source Imaging in MRI-negative Epilepsy

Zhong I. Wang, PhD,[1] Andreas V. Alexopoulos, MD, MPH,[1] Stephen E. Jones, MD, PhD,[2] Imad M. Najm, MD,[1] Aleksandar Ristic, MD,[3] Chong Wong, MD, PhD,[4] Richard Prayson, MD,[5] Felix Schneider, MD,[6] Yosuke Kakisaka, MD, PhD,[7] Shuang Wang, MD,[8] William Bingaman, MD,[9] Jorge A. Gonzalez-Martinez, MD, PhD,[9] and Richard C. Burgess, MD, PhD[1]

Objective: MRI-negative (MRI–) pharmacoresistant focal epilepsy (PFE) patients are most challenging for epilepsy surgical management. This study utilizes a voxel-based MRI postprocessing technique, implemented using a morphometric analysis program (MAP), aiming to facilitate detection of subtle focal cortical dysplasia (FCD) in MRI– patients. Furthermore, the study examines the concordance between MAP-identified regions and localization from magnetic source imaging (MSI).
Methods: Included in this retrospective study were 25 MRI– surgical patients. MAP was performed on T1-weighted MRI, with comparison to a normal database. The pertinence of MAP+ areas was confirmed by MSI, surgical outcome and pathology. Analyses of MAP and MSI were performed blindly from patients' clinical information and independently from each other.
Results: The detection rate of subtle changes by MAP was 48% (12/25). Once MAP+ areas were resected, patients were more likely to be seizure-free ($p = 0.02$). There were no false positives in the 25 age-matched normal controls. Seven patients had a concordant MSI correlate. Patients in whom a concordant area was identified by both MAP and MSI had a significantly higher chance of achieving a seizure-free outcome following complete resection of this area ($p = 0.008$). In the 9 resected MAP+ areas, pathology revealed FCD type IA in 7 and type IIB in 2.
Interpretation: MAP shows promise in identifying subtle FCD abnormalities and increasing the diagnostic yield of conventional MRI visual analysis in presurgical evaluation of PFE. Concordant MRI postprocessing and MSI analyses may lead to the noninvasive identification of a structurally and electrically abnormal subtle lesion that can be surgically targeted.

ANN NEUROL 2014;75:759–770

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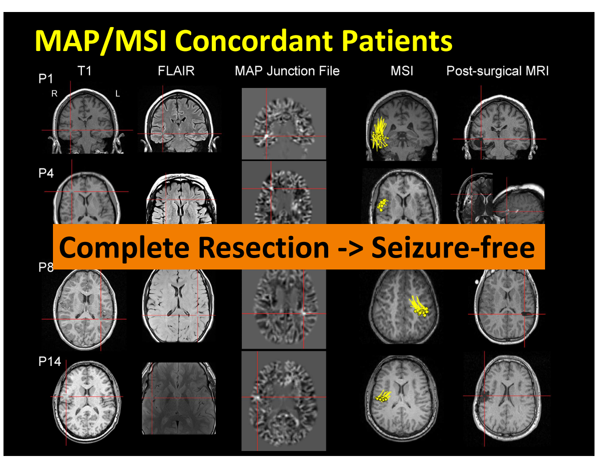
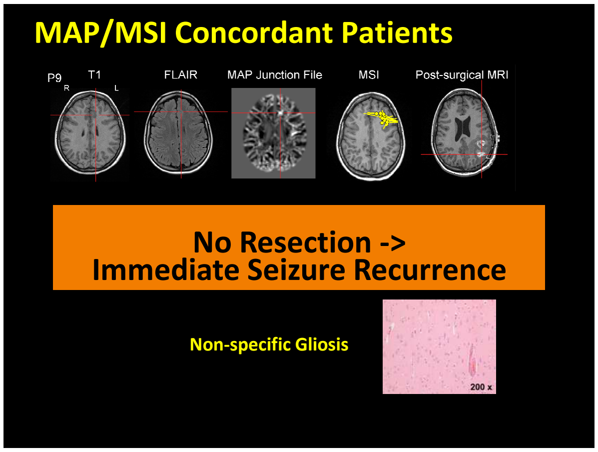
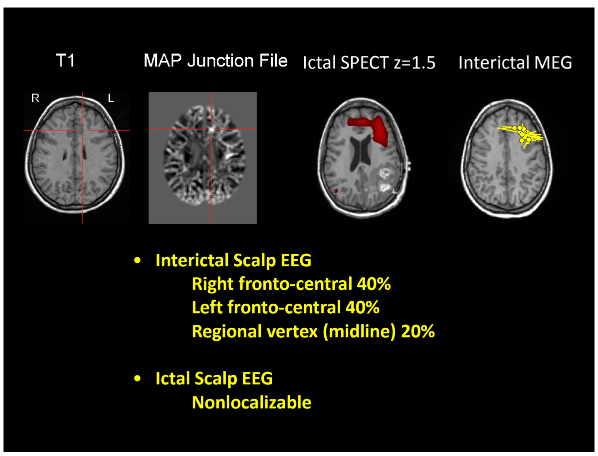
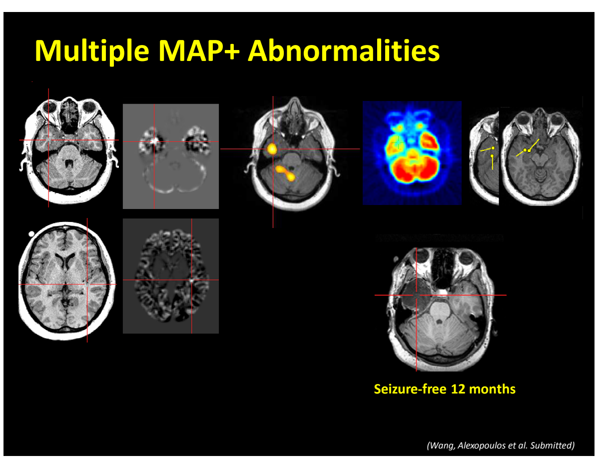
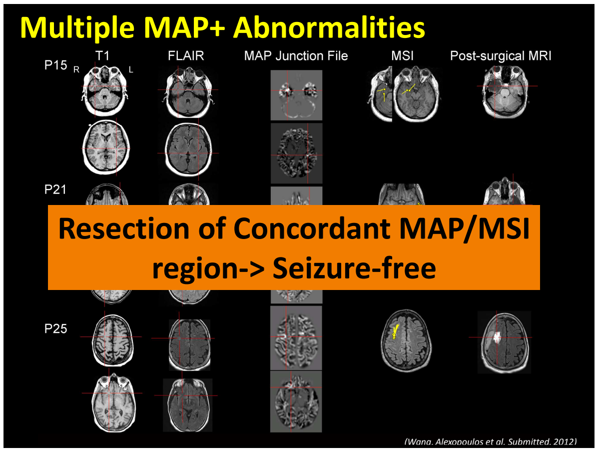



MAP/MSI Concordant Patients
P9
T1
R
L
FLAIR
MAP Junction File
MSI
Post-surgical MRI
No Resection ->
Immediate Seizure Recurrence
Non-specific Gliosis
200 x


T1
MAP Junction File
Ictal SPECT z=1.5
Interictal MEG
R
L
• Interictal Scalp EEG
Right fronto-central 40%
Left fronto-central 40%
Regional vertex (midline) 20%
• Ictal Scalp EEG
Nonlocalizable


Multiple MAP+ Abnormalities
Seizure-free 12 months
(Wang, Alexopoulos et al. Submitted)



Results

MAP	Seizure Free	Not Seizure Free
Resected	6	0
Not Resected Negative	8	11
N=25	14	11

p = 0.02 (Fisher's exact test)

(Wang, Alexopoulos et al. Submitted, 2012)

Results

MEG	Seizure Free	Not Seizure Free
Resected	9	2
Not Resected Negative	5	9
N=25	14	11

p = 0.04 (Fisher's exact test)

(Wang, Alexopoulos et al. Submitted, 2012)

Results

MAP/MEG	Seizure Free	Not Seizure Free
Resected	7	0
Not Resected Negative	7	11
N=25	14	11

p = 0.008 (Fisher's exact test)

(Wang, Alexopoulos et al. Submitted, 2012)

MEG & SPECT

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Epilepsy & Behavior 24 (2012) 234–240

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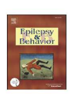

Magnetic source imaging in non-lesional neocortical epilepsy: Additional value and comparison with ICEEG

Felix Schneider [a,b,*], Andreas V. Alexopoulos [a], Zhong Wang [a], Salah Almubarak [a], Yosuke Kakisaka [a], Kazutaka Jin [a], Dileep Nair [a], John C. Mosher [a], Imad M. Najm [a], Richard C. Burgess [a]

[a] Cleveland Clinic Epilepsy Center, Neurological Institute, 9500 Euclid Avenue, Desk S-51, Cleveland, OH 44195, USA
[b] Universitätsmedizin Greifswald, Ernst-Moritz-Arndt-University, Department of Neurology, Epilepsy Center, Sauerbruchstrasse, 17489 Greifswald, Germany

Epilepsia, 54(2):359–369, 2013
doi: 10.1111/epi.12004

FULL-LENGTH ORIGINAL RESEARCH

Magnetic source imaging and ictal SPECT in MRI-negative neocortical epilepsies: Additional value and comparison with intracranial EEG

*†[1]Felix Schneider, *[1]Z. Irene Wang, *Andreas V. Alexopoulos, *‡Salah Almubarak, *Yosuke Kakisaka, *§Kazutaka Jin, *Dileep Nair, *John C. Mosher, *Imad M. Najm, and *Richard C. Burgess

*Cleveland Clinic Epilepsy Center, Neurological Institute, Cleveland, Ohio, U.S.A.; †Department of Neurology, Epilepsy Center, University of Greifswald, Greifswald, Germany; ‡National Neuroscience Institute, King Fahad Medical City, Neurophysiology, Riyadh, Saudi Arabia; and §Tohoku University Graduate School of Medicine, Epileptology, Sendai, Japan

Table 4. Diagnostic measures for EZ localization based on the epilepsy surgery outcome

Test	Sens (95% CI)	Spec (95% CI)	PPV (95% CI)	NPV (95% CI)	OR (95% CI)	p-Value[a]	p-Value[b]
ICEEG	0.883 (0.453–1.214)	0.25 (−0.133–0.633)	0.455 (0.079–0.83)	0.667 (−0.014–1.347)	1.67 (0.115–24.256)	0.865	0.46
MSI	0.667 (0.186–1.148)	0.5 (0.058–0.942)	0.5 (0.058–0.942)	0.667 (0.186–1.148)	2 (0.224–17.894)	0.569	0.35
SISCOM	0.667 (0.186–1.148)	0.5 (0.058–0.942)	0.5 (0.058–0.942)	0.667 (0.186–1.148)	2 (0.224–17.894)	0.569	0.35
ICEEG + MSI	0.667 (0.186–1.148)	0.875 (0.583–1.167)	0.8 (0.353–1.247)	0.778 (0.431–1.124)	14 (0.944–207.598)	0.038	0.06
ICEEG + SISCOM	0.667 (0.186–1.148)	0.75 (0.367–1.133)	0.667 (0.186–1.148)	0.75 (0.367–1.133)	6 (0.582–61.842)	0.138	0.14
ICEEG + MSI + SISCOM	0.5 (−0.01–1.01)	1	1	0.727 (0.392–1.063)	0	0.022	0.05

Sens, sensitivity; Spec, specificity; PPV, positive predictive value; NPV, negative predictive value; OR, odds ratio; CI, confidence interval; EZ, epileptogenic zone.
[a]Spearman correlation.
[b]Fisher's exact test.

MEG & SEEG

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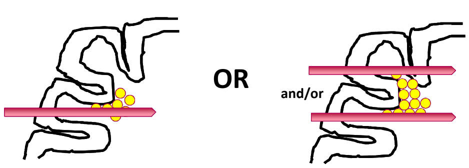
Definition of SEEG contacts "in the MEG cluster"

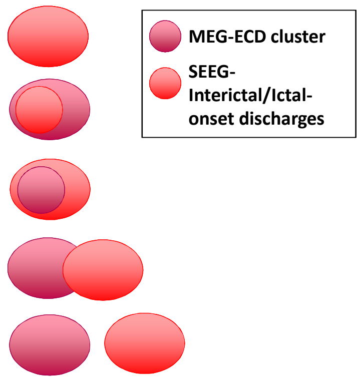
- SEEG contacts are located in the same gyrus with a cluster, or in the same sulcus and adjacent gyri



1 gyrus 1 sulcus and adjacent 2 gy

Classification of concordance

- Concordant (M=S)
- Concordant + (M>S)
- Concordant – (M<S)
- Partial (M≈S)
- Discordant (M≠S)



Sampling of MEG by SEEG

	Full Sampling	No or Partial Sampling	Total
Seizure free	16	6	22
Not seizure free	10	18	28
Total	26	24	50

p=0.012

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Concordance and Outcome

	Concordance MEG cluster with SEEG inter-ictal spikes		
	Concordant	Partial	Total
Seizure free	8	1	9
Not seizure free	3	10	12
Total	11	11	22

p=0.0075

	Concordance MEG cluster with SEEG ictal onset		
	Concordant	Partial	Total
Seizure free	6	0	6
Not seizure free	2	10	12
Total	8	10	18

p=0.0015

MEG Resection and Outcome

	Complete	Partial or No	Total
Seizure free	10	13	23
Not seizure free	1	26	27
Total	11	39	50

p=0.0012

SEEG onset Resection and Outcome

	Complete	Partial	Total
Seizure free	13	10	23
Not seizure free	12	15	27
Total	25	25	50

p=0.57

Conclusions

- Conclusively positive MEG increases the chances of sampling the epileptic area with SEEG.
- Therefore, MEG clusters should never be ignored when planning the SEEG strategy.
- Given the favorable results when MEG and SEEG are concordant, we could hypothesize that some of the patients with partial concordance could become seizure free with appropriately revised targeting.

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Multi-modal Image Integration

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Multi-modal Integration

- Image Fusion: MRI (T2, FLAIR), PET, SPECT, MEG, MAP, vasculature (CTA)
- Talairach grid
- Realistic rendering of cortical surface
- Export trajectory to neuronavigation system

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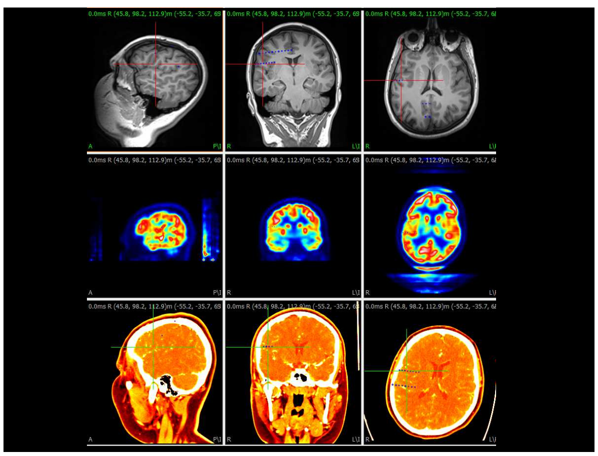
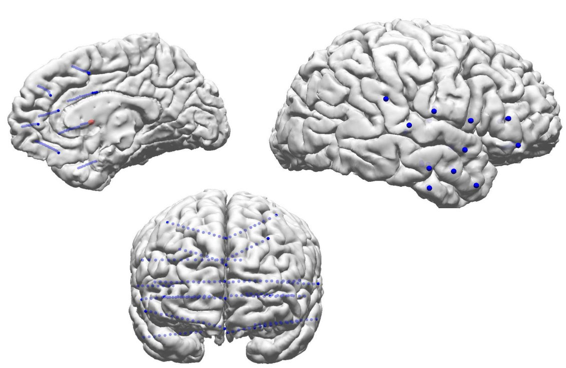


Cortical Surface



Localizing Language Function with MEG

Catherine Leigeois-Chauvel, Cleveland

Non-invasive assessment of hemispheric dominance for receptive language using magnetoencephalography (MEG) is now a well-established procedure used across several epilepsy centers in the context of pre-surgical evaluation of children and adults, while they are awake, alert, and attentive. Several tasks (e.g. recognition memory task for spoken words, picture naming, verb generation, semantic decision) are used to localize the receptive language cortex and make the subsequent estimation of hemispheric dominance based on hemispheric differences in the degree of activity in the temporo-parietal cortex. All these tasks need the cooperation of the patient to reliably reveal the eloquent areas.

The analysis of intracerebral evoked responses -- recorded from the auditory cortex in epilepsy patients during the pre-surgical evaluation -- has shown that the temporal processing of the voiced syllable /ba/ compared to voiceless syllable /pa/ took place specifically in the left auditory cortex, therefore providing an electrophysiological marker of the hemispheric dominance for language (Liegeois-Chauvel et al. 1999). This result has been replicated with high density surface EEG (Trebuchon et al. 2005).

We will present some preliminary MEG data from control subjects and epilepsy patients listening passively to these syllables, showing that this perceptive task could be very helpful for lateralizing language, even in non-cooperative patients or children.

LOCALIZING LANGUAGE FUNCTION WITH MEG

C Liegeois-Chauvel[1,3,4]

P Klaas[4], S. Shibata[4], C Zielinski[3], E Cavalli [2,3], J Ziegler[2,3] , JM Badier[1,3]

JC Mosher[4]

1 Institut de Neurosciences des Systèmes

2 Laboratoire de Psychologie Cognitive

3 BLRI Brain & Language Research Institute

Aix*Marseille université

4 Cleveland Clinic

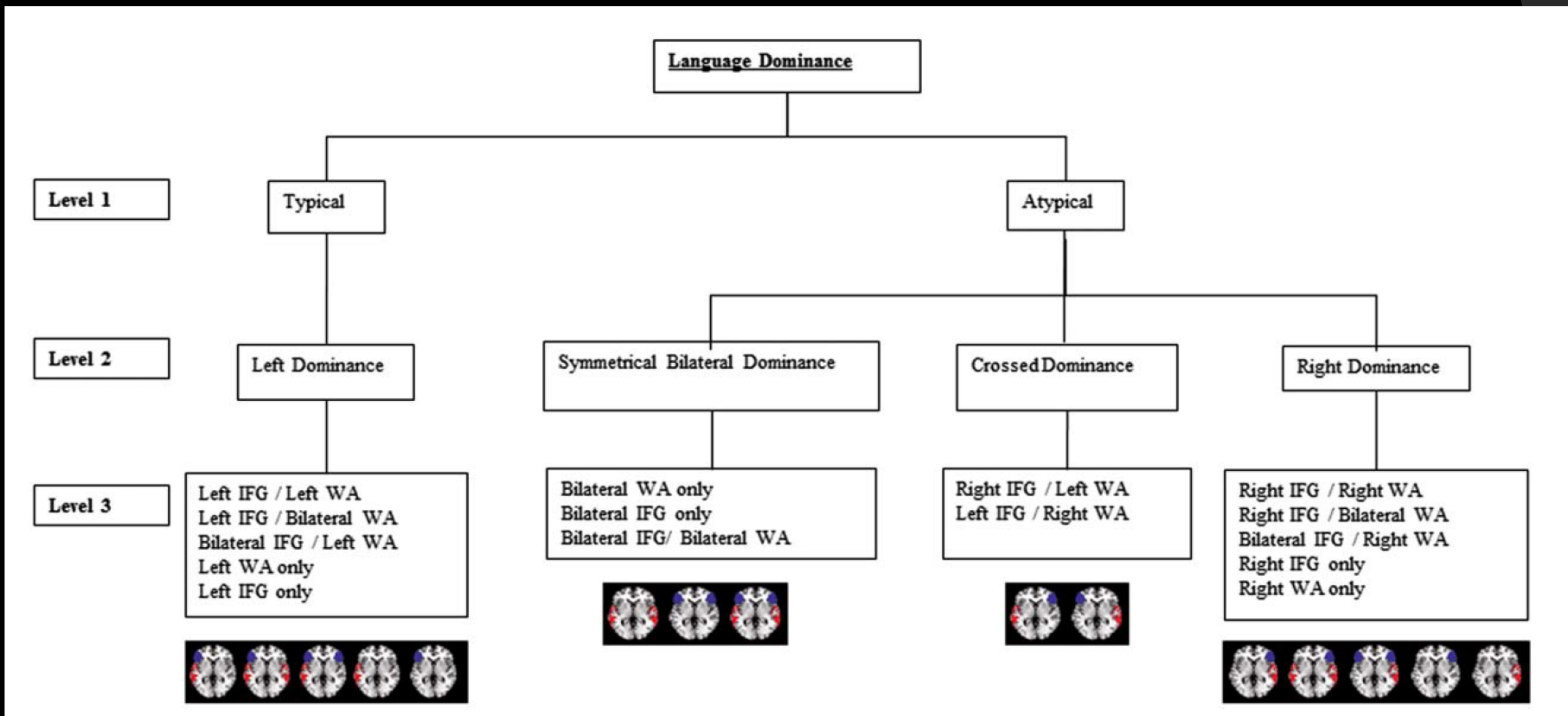
Importance of hemispheric language assessment in epilepsy surgery

Unlike the abrupt changes that occurs following brain injury disrupting language network, converging evidence suggests that the chronic nature of epileptic activity can result in a developmental shift of language from the left to the right hemisphere or re-routing of language pathways from traditional to non traditional areas within the dominant left hemisphere.

According to the literature, the atypical language representation occurs in 20 to 30% of epilepsy patients and only about 5 % of healthy volunteers

Characterization of Atypical Language Activation Patterns in Focal Epilepsy

Madison M. Berl, PhD,[1,2] Lauren A. Zimmaro, BA,[2,3] Omar I. Khan, MD,[3]
Irene Dustin, CNP,[3] Eva Ritzl, MD,[3,4] Elizabeth S. Duke, BS,[2,3]
Leigh N. Sepeta, PhD,[2] Susumu Sato, MD,[3] William H. Theodore, MD,[3] and
William D. Gaillard, MD[2,3]



Annals of Neurology, 2014

3

Brain Activation Tasks using MEG

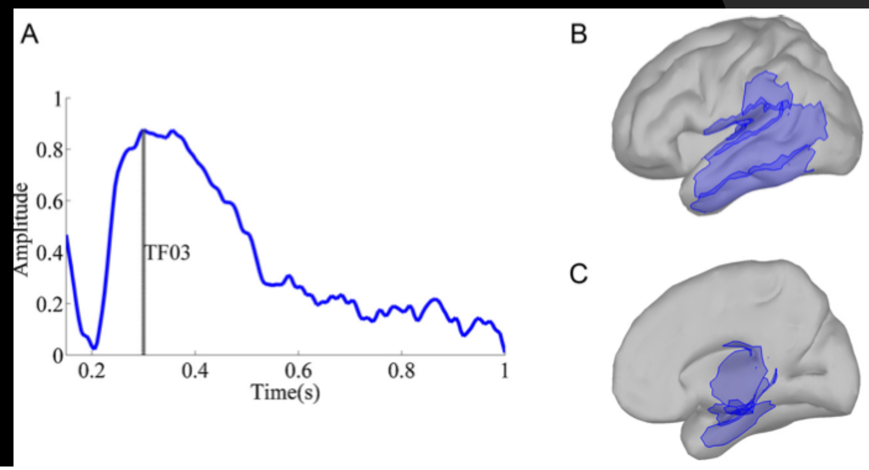
Receptive language function

- **Continuous auditory words recognition task (Papanicolaou et al, 2004)**
- Picture Naming Task and Verb Generation (Bowyer et al., 2005)
- Oddball stimulation with one-syllable words (Kim & Chung, 2008)
- Auditory verb generation task (Findlay et al, 2012)
- Semantic decision task (Tanaka et al, 2013)
- Verbal Fluency and verbal memory tasks (Primoradi et al. 2016)

Language Lateralization and Localization

Temporo-spatial principal analysis

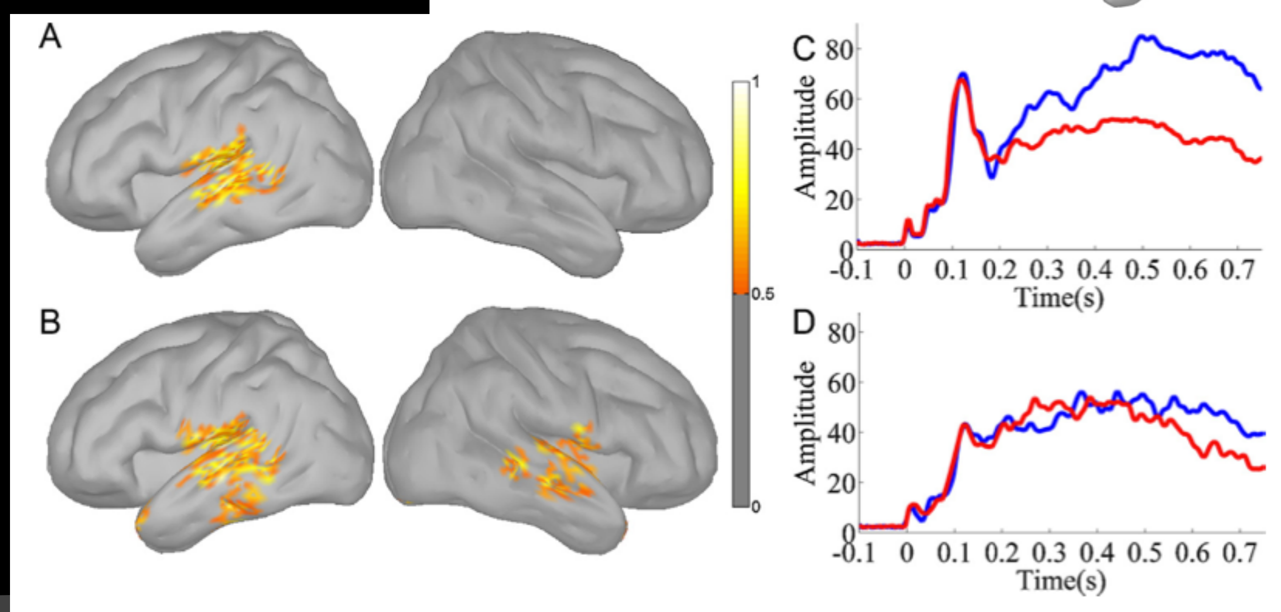
Healthy subjects



Weighted minimum norm estimates

Healthy subjects

Epilepsy patients

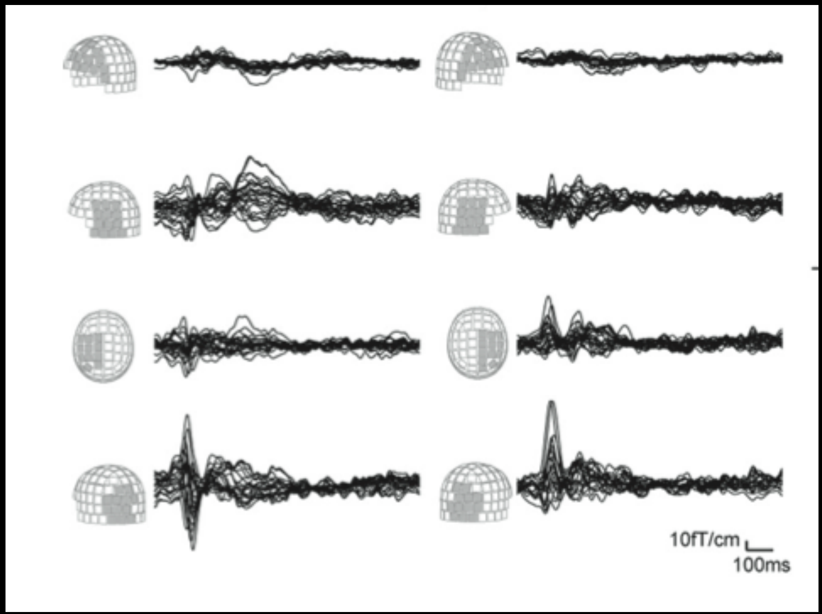


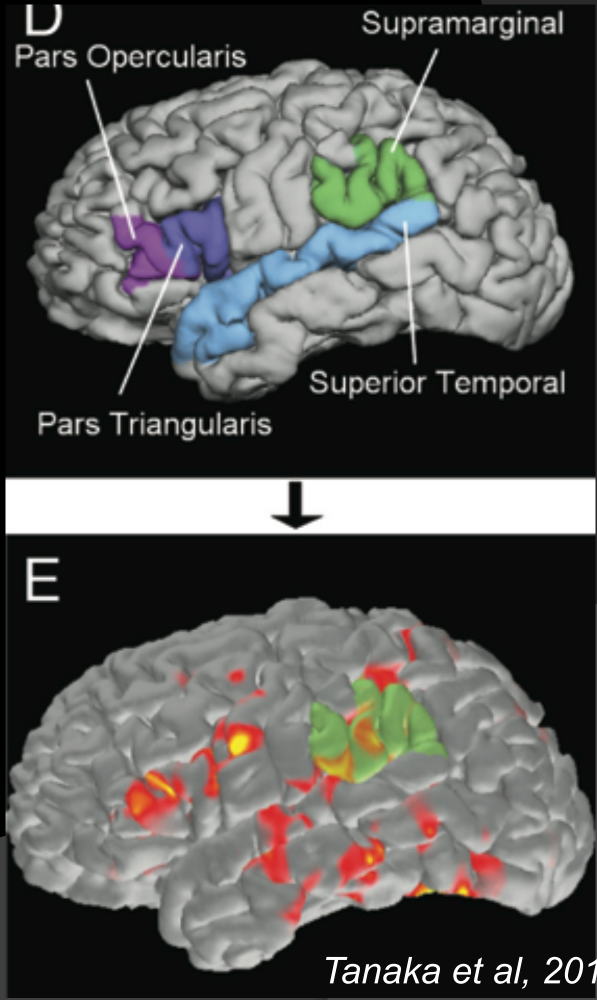
Pirmoradi et al, 2016

Language Lateralization and Localization

<u>dSPM method</u>

Time window analysis 250-550ms



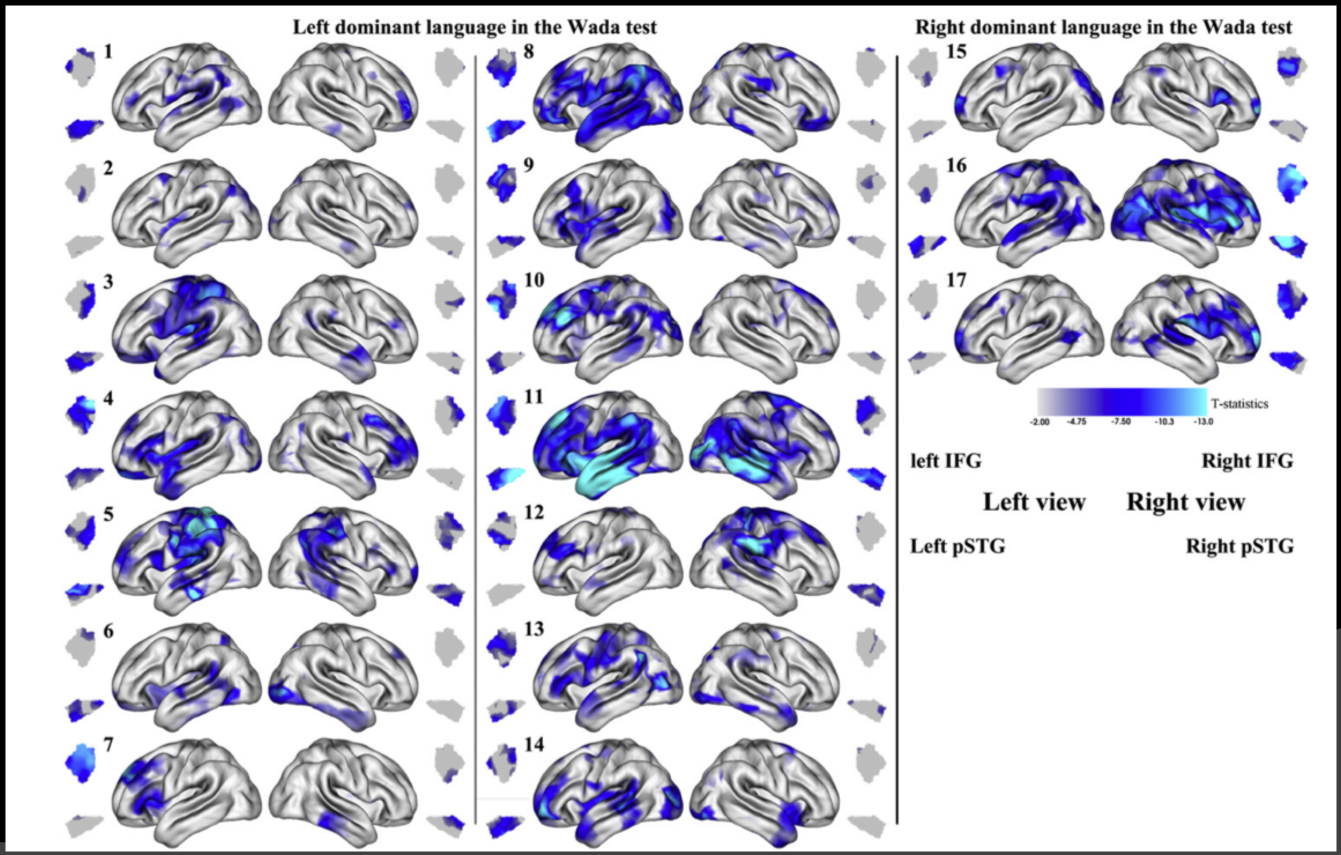


Language lateralization seems to be more correlated with the size of the activated cortex than the strength of activation

Tanaka et al, 2013

Language Lateralization and Localization

Decrease in beta band oscillatory activity for deviant stimuli



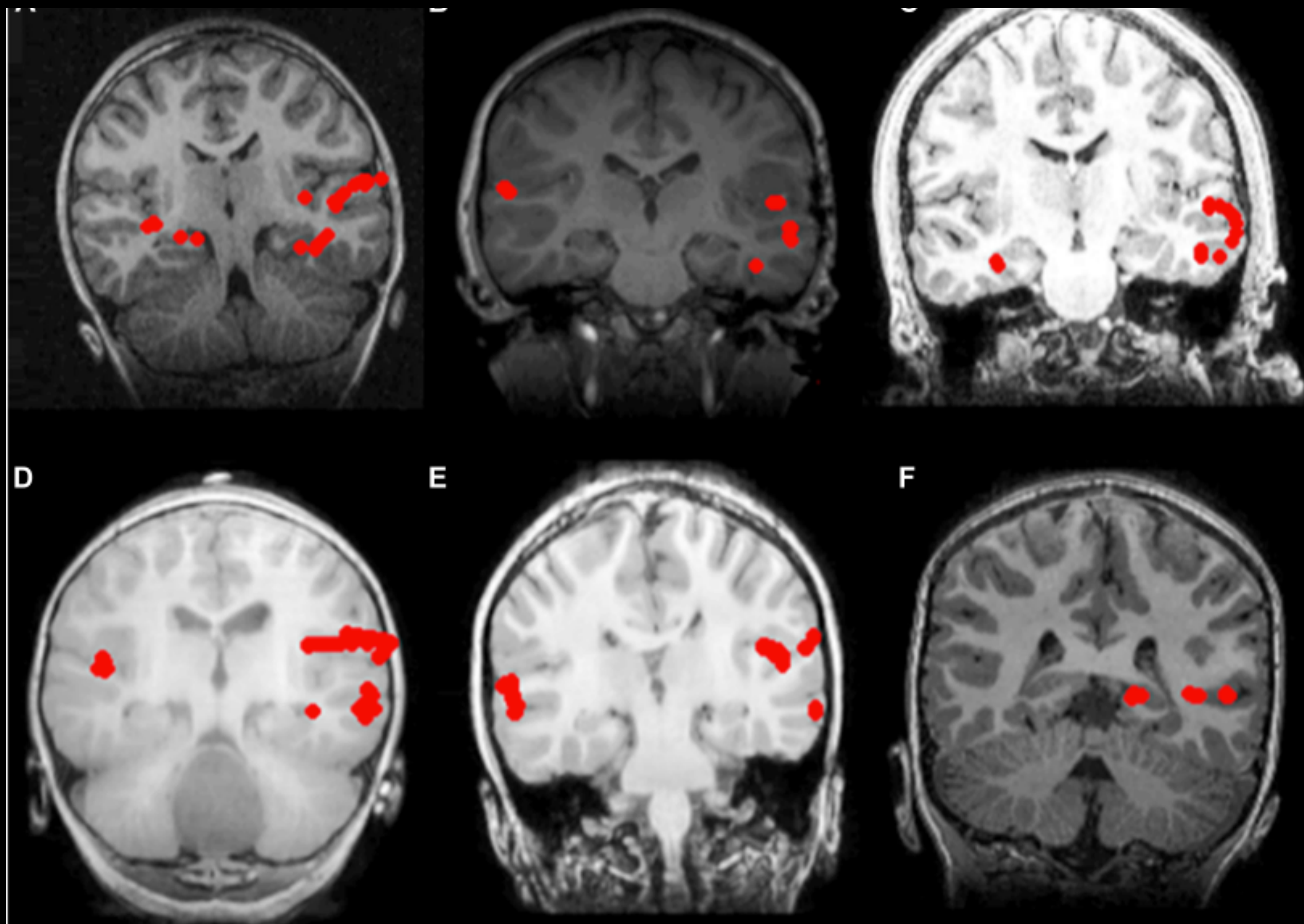
Kim & Chung, 2008

Challenging questions

➤ Is it possible to develop a reliable task for passive receptive language mapping ?

➤ Is it possible to assess language in non-cooperative patients or children ?

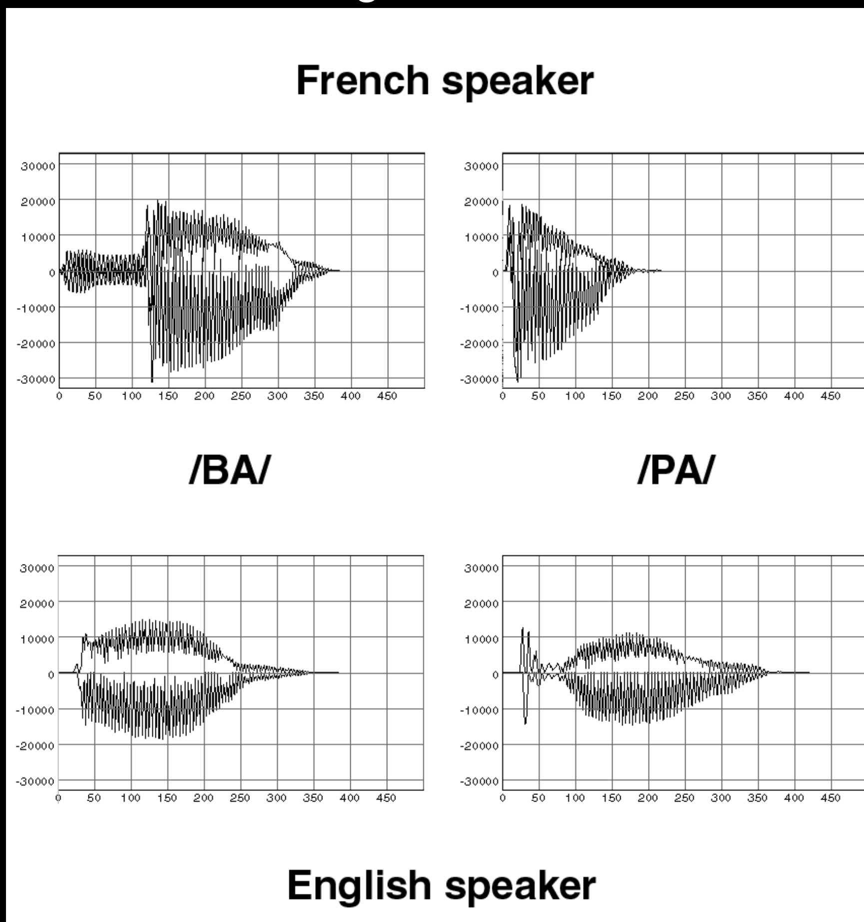
Receptive language mapping with MEG with and without sedation



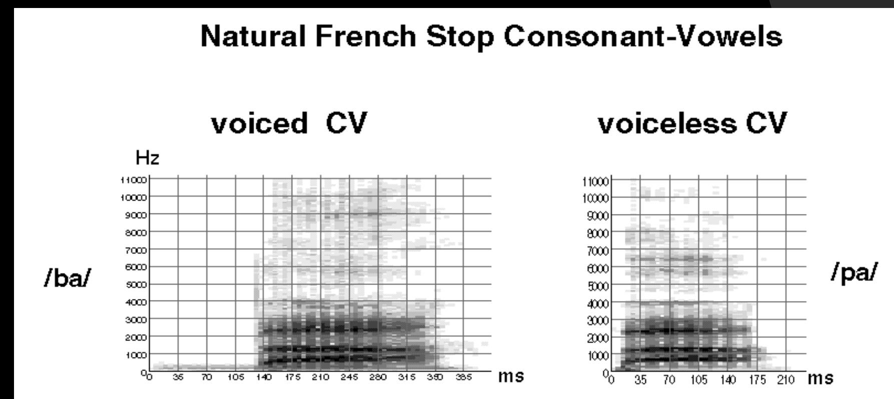
Rezai et al, 2014

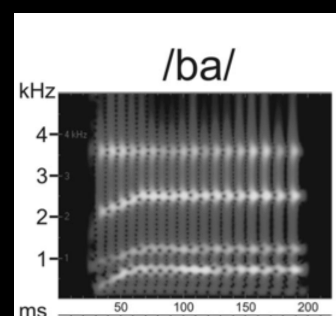
Receptive language assessment using passive listening to /ba/ & /pa/ syllables

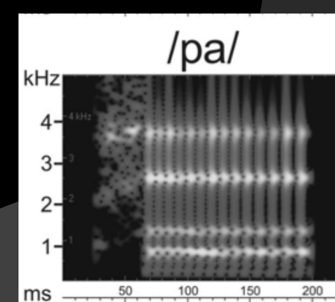
Oscillograms



Time Frequency



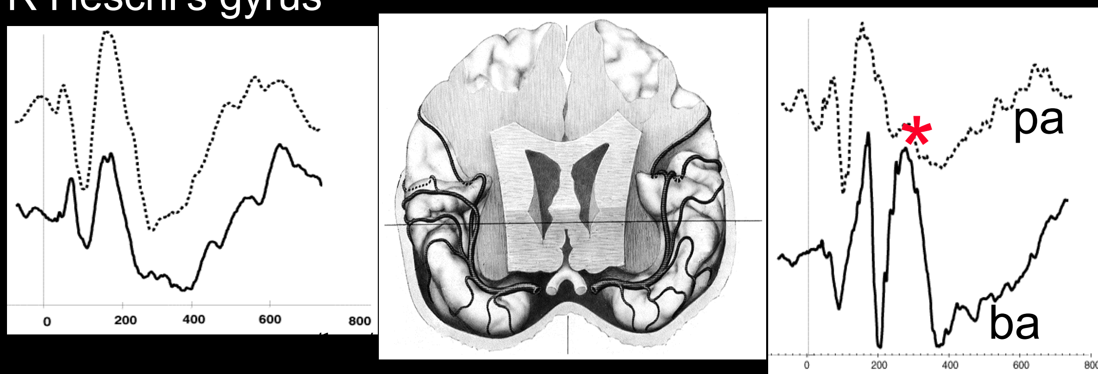




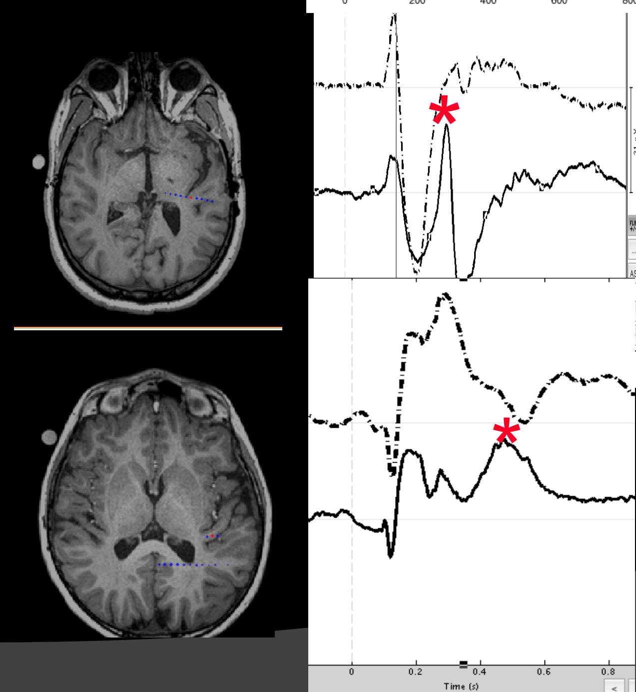
Acoustic Temporal Processing of Syllables Regardless the Native Language

R Heschl's gyrus

L Heschl's gyrus



Liégeois-Chauvel et al.,1999



Native French speaker

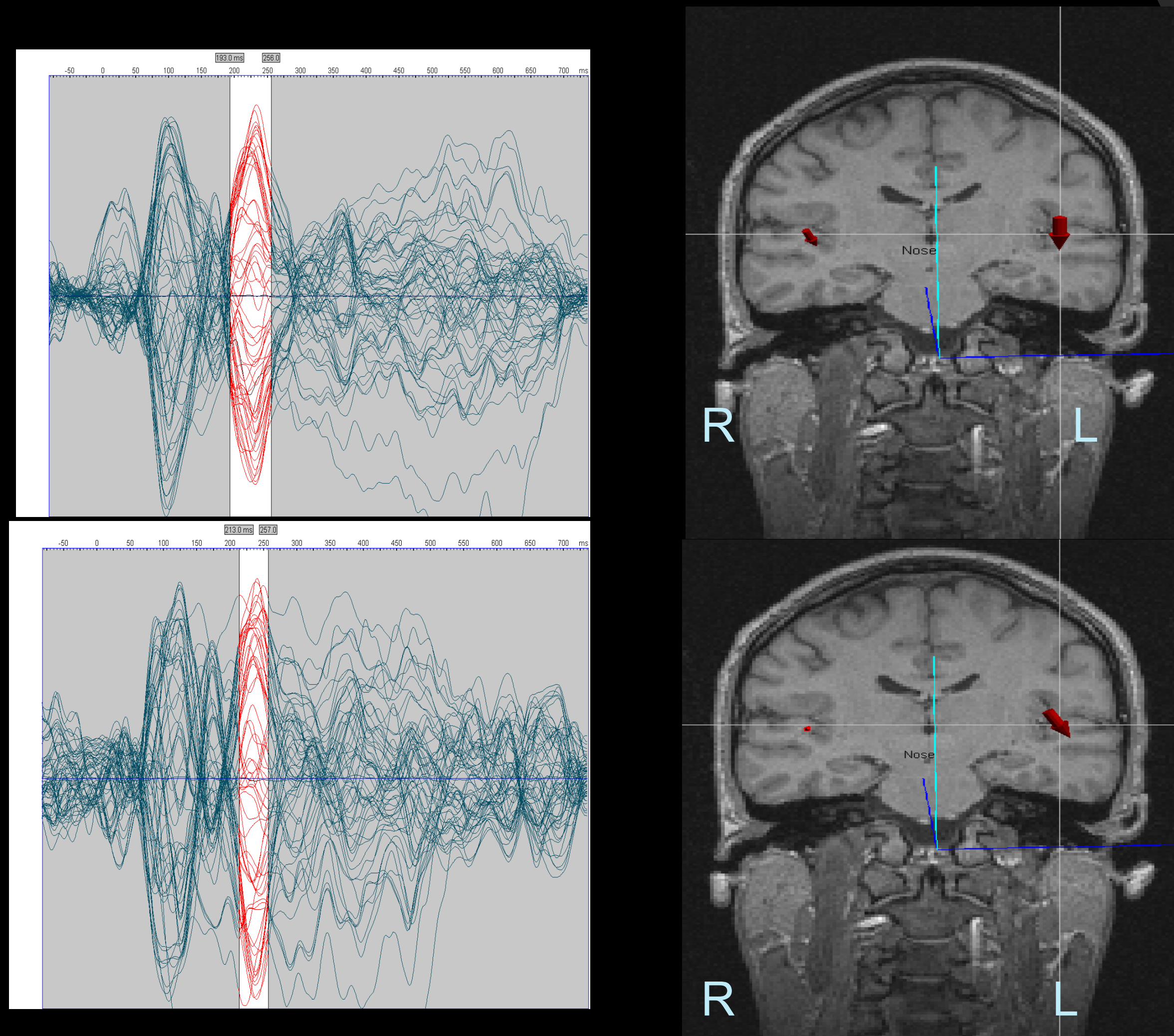
Native American speaker

Native arabic child speaker

High Density Surface EEG and dipole fitting

R. /ba/ stimulation

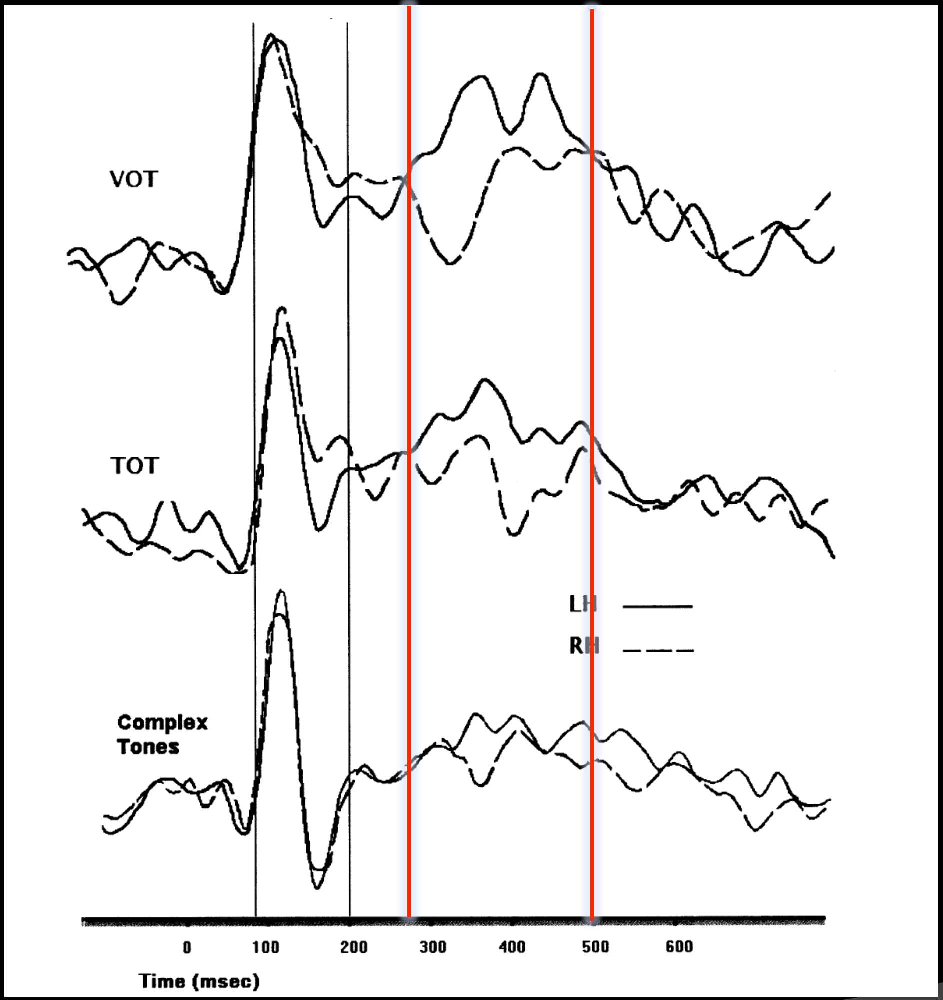
L. /ba/ stimulation

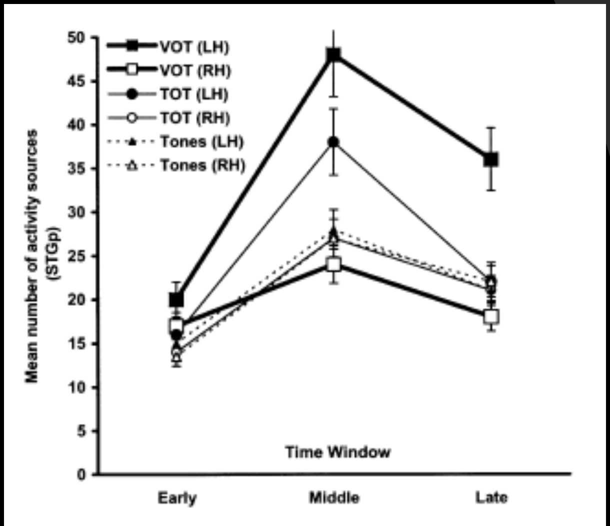


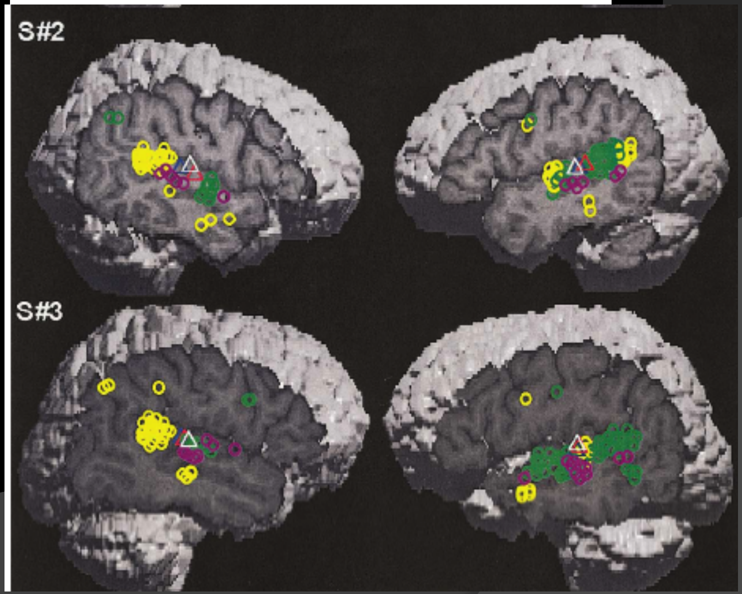
Processing of VOT takes place in the left auditory cortex regardless ear stimulated

Trebuchon et al, 2005

Superiority of left hemisphere for VOT processing using MEG







Papanicolaou et al, 2003

Language Lateralization Cleveland Clinic

- Determine the auditory threshold for pure tones, ba/pa, word recognition
- Pure tones delivered to the left and right ear

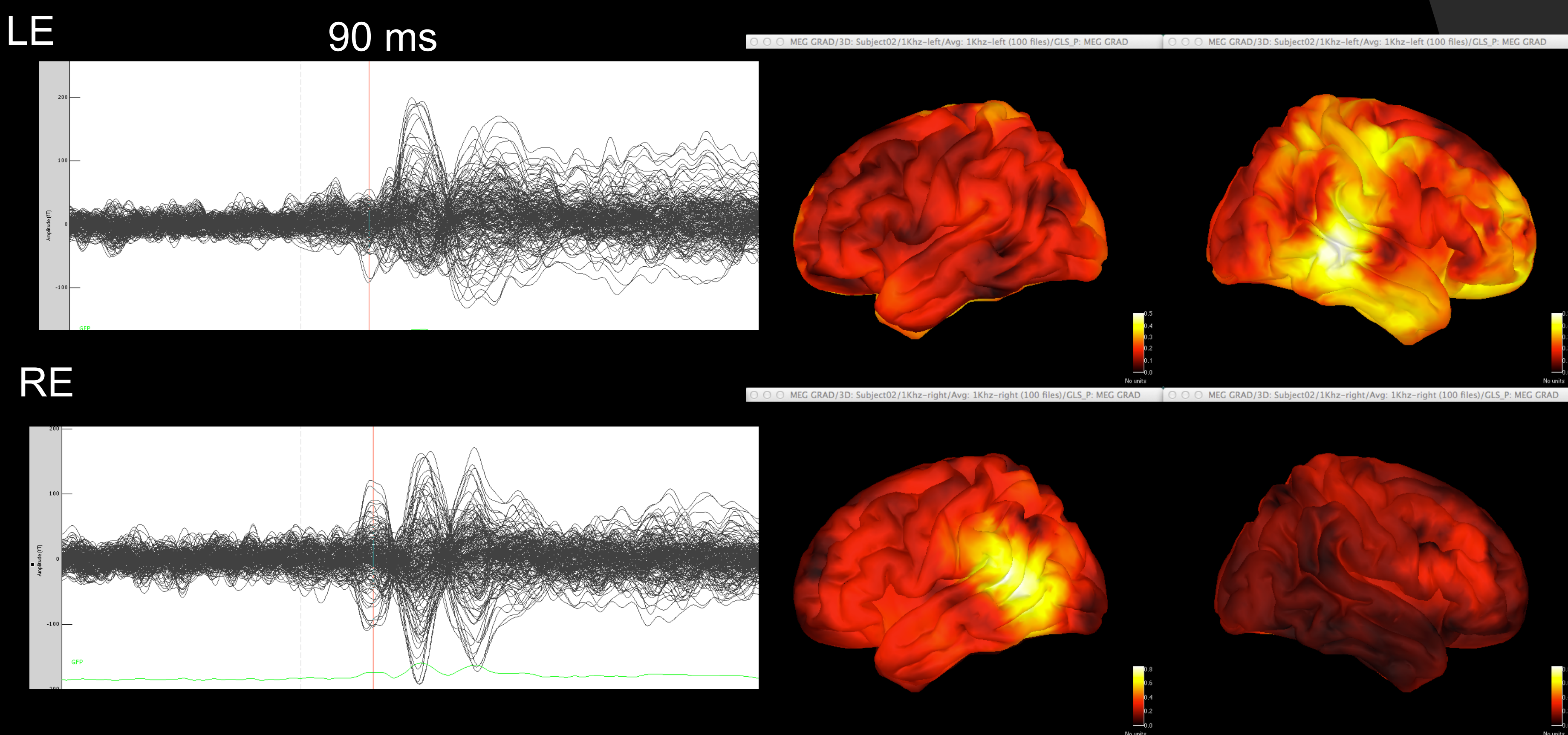
- TASKS
  - Ba/ pa bilaterally delivered
  - Word recognition

- Data processing

  Dipole fitting

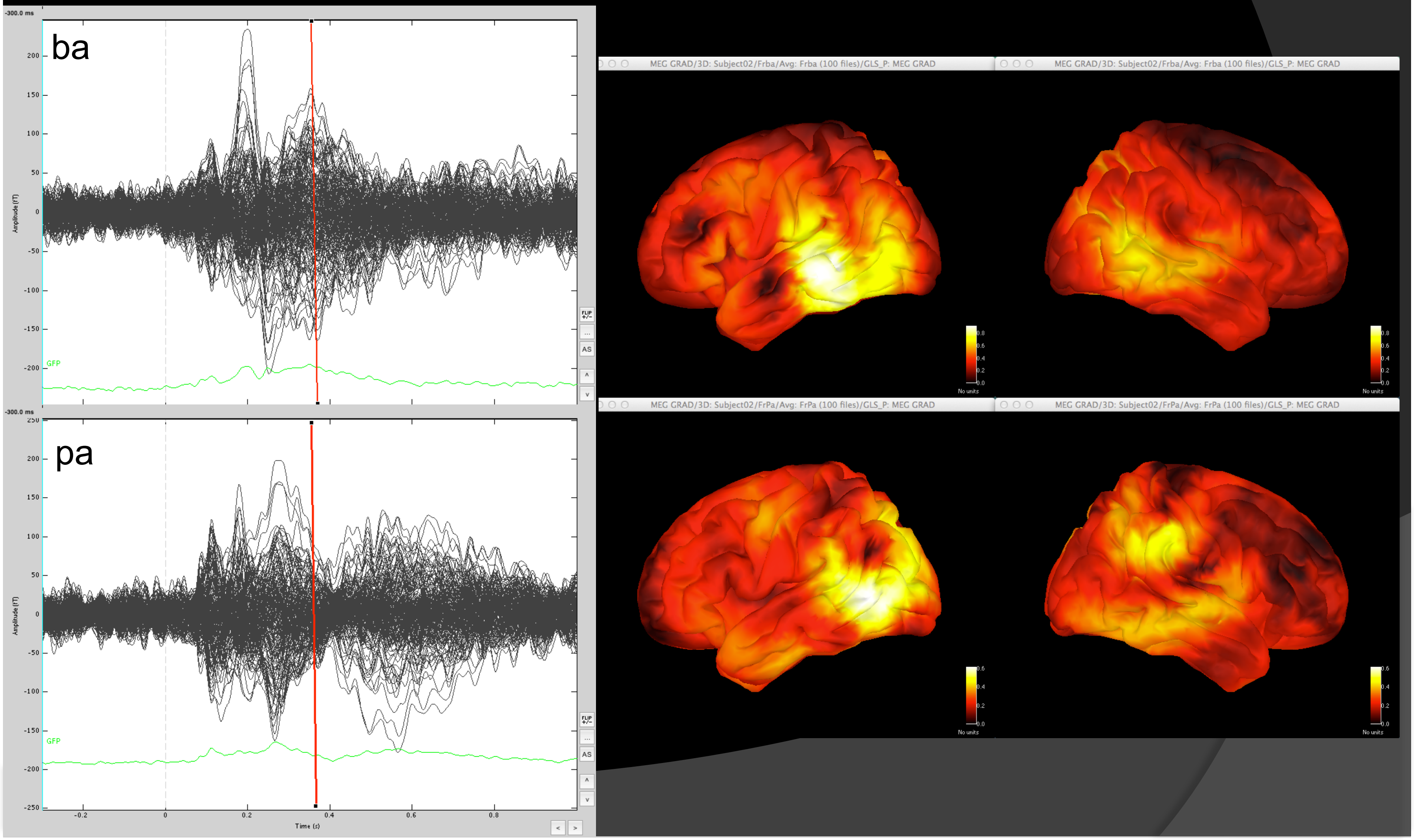
  Brainstorm

AUDITORY EVOKED FIELD
to pure tones



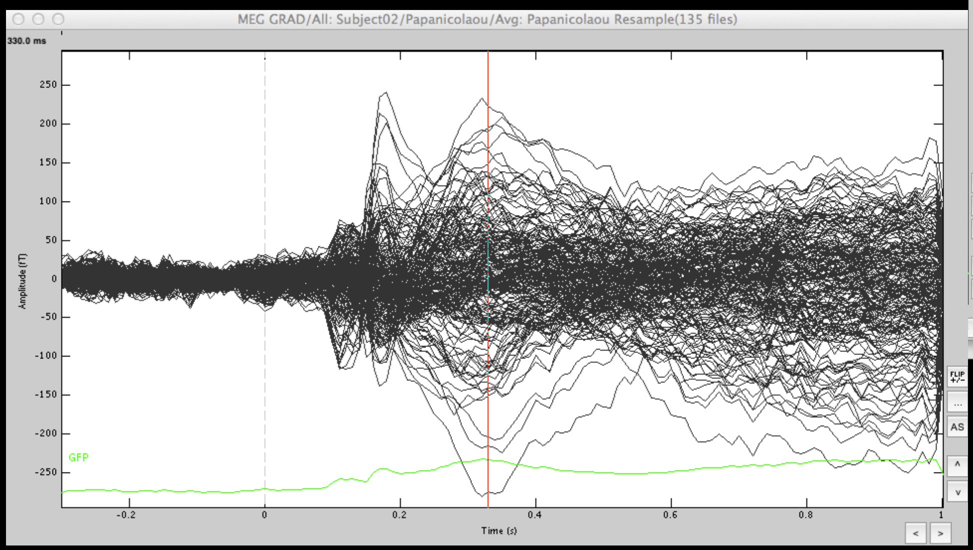
AUDITORY EVOKED FIELD
to syllables

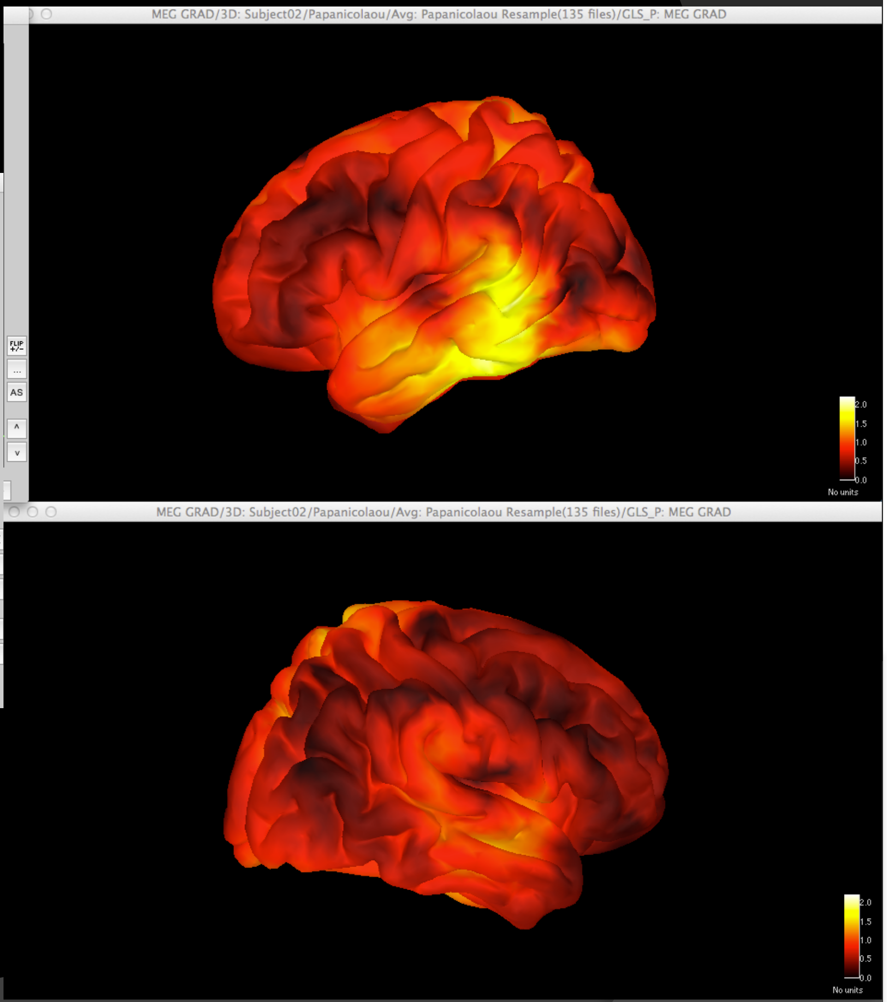
350 ms



AUDITORY EVOKED FIELD
to words

N400

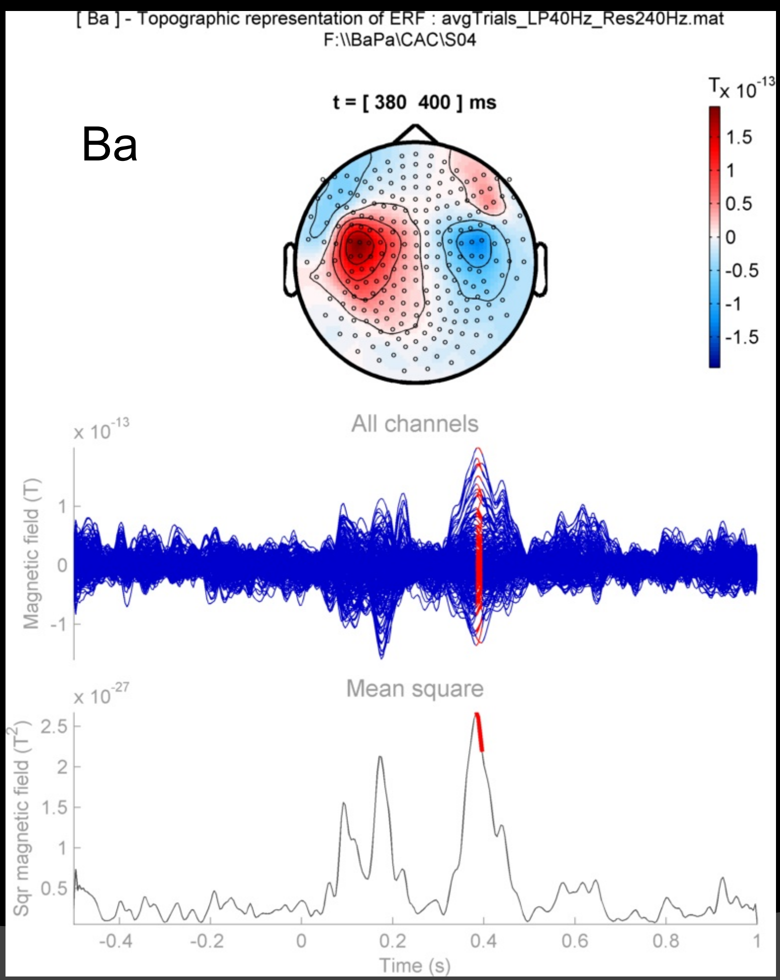


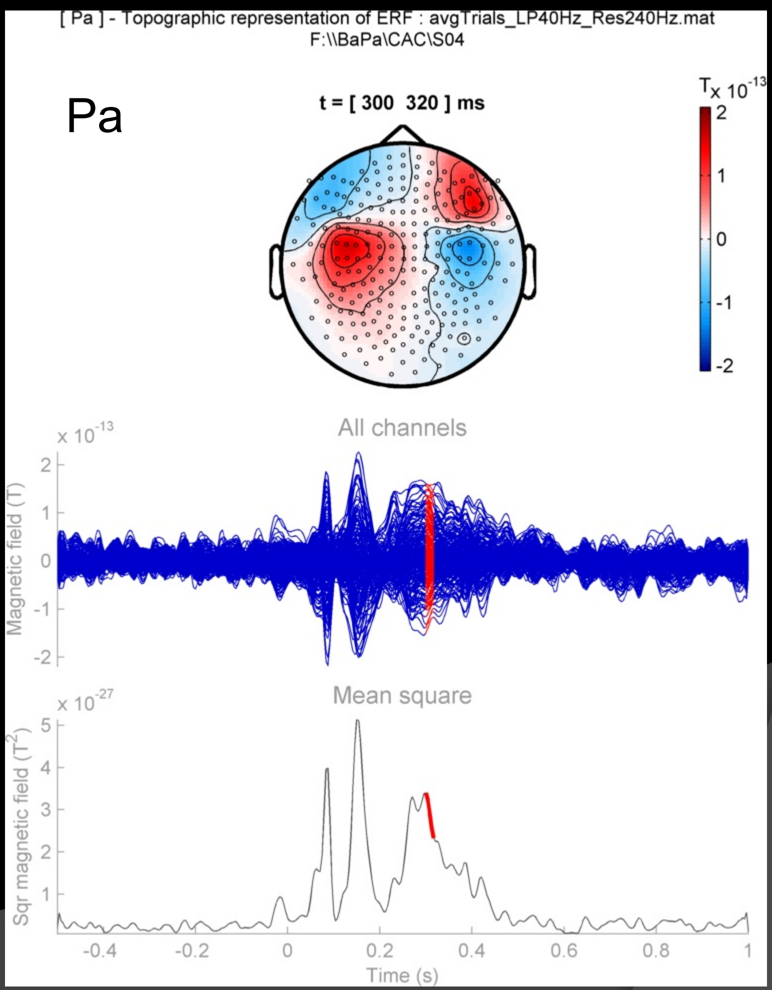


Language Lateralization
MEG Center- Marseille (France)

- Determine the auditory threshold for pure tones
- 200 "Ba" and 200 "Pa » randomly delivered
- **MEG Data Set**
  Healthy subjects
  Simultaneous recordings SEEG-MEG in epilepsy patients
- Data Processing
  Source reconstruction: estimation of the field at the source level from the surface data and a head model: Beamforming

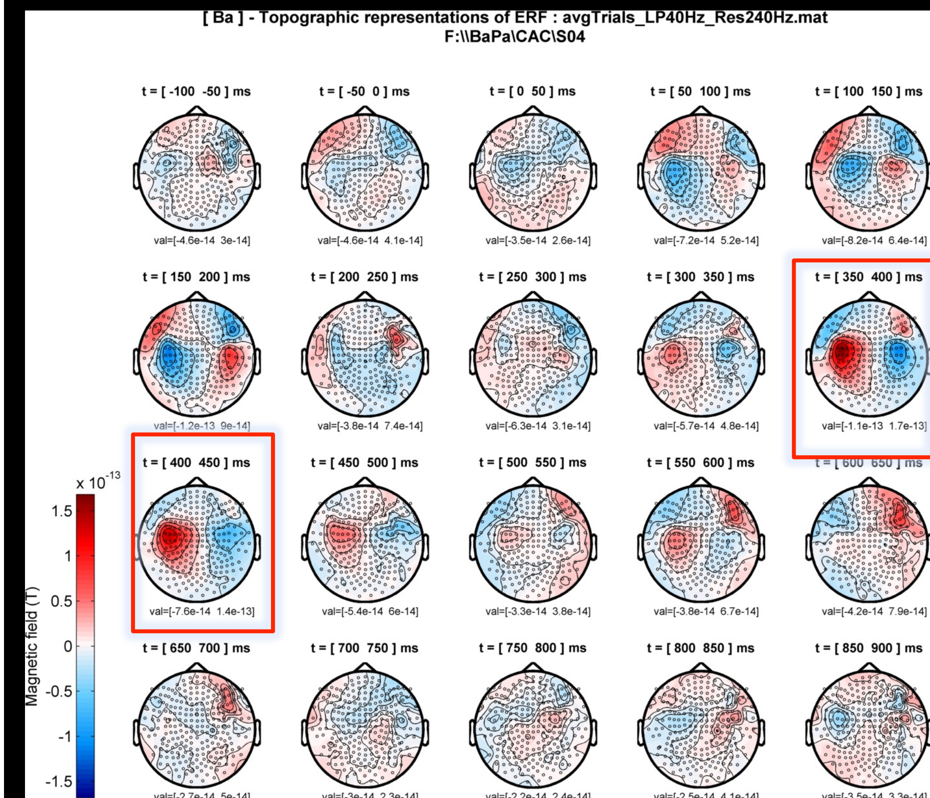
Topography at the latency of the Release component of Ba



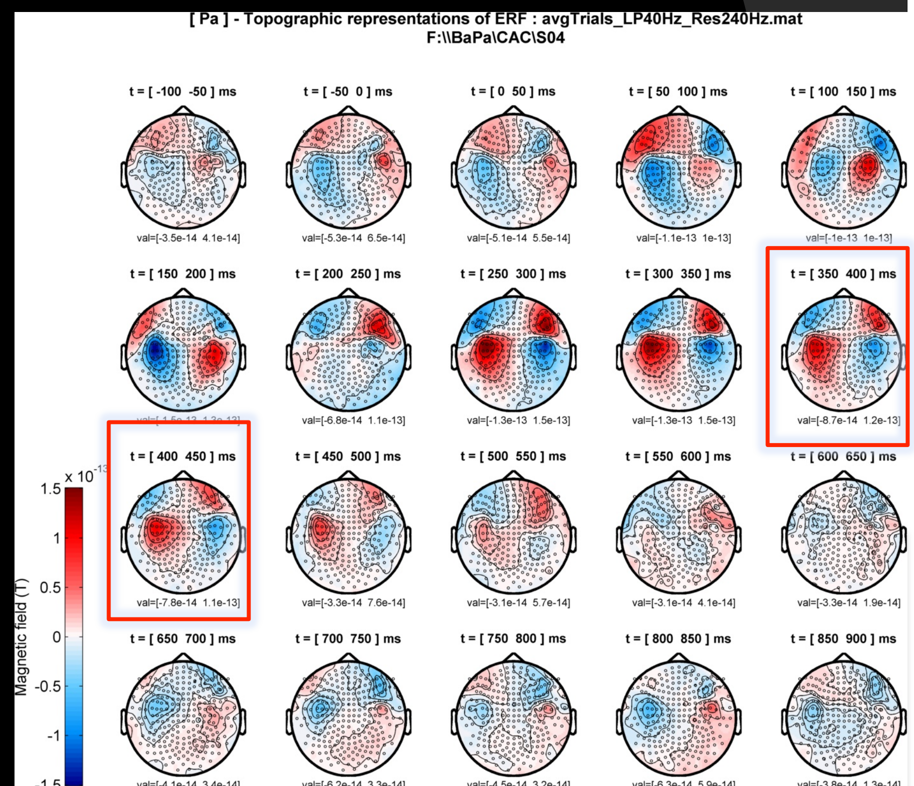


Topographic representation of ERF

Ba

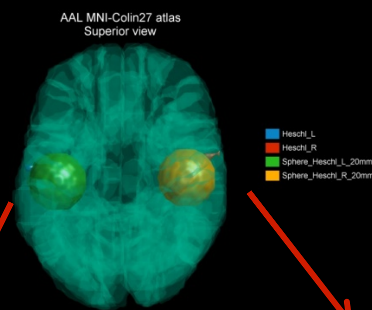


Pa



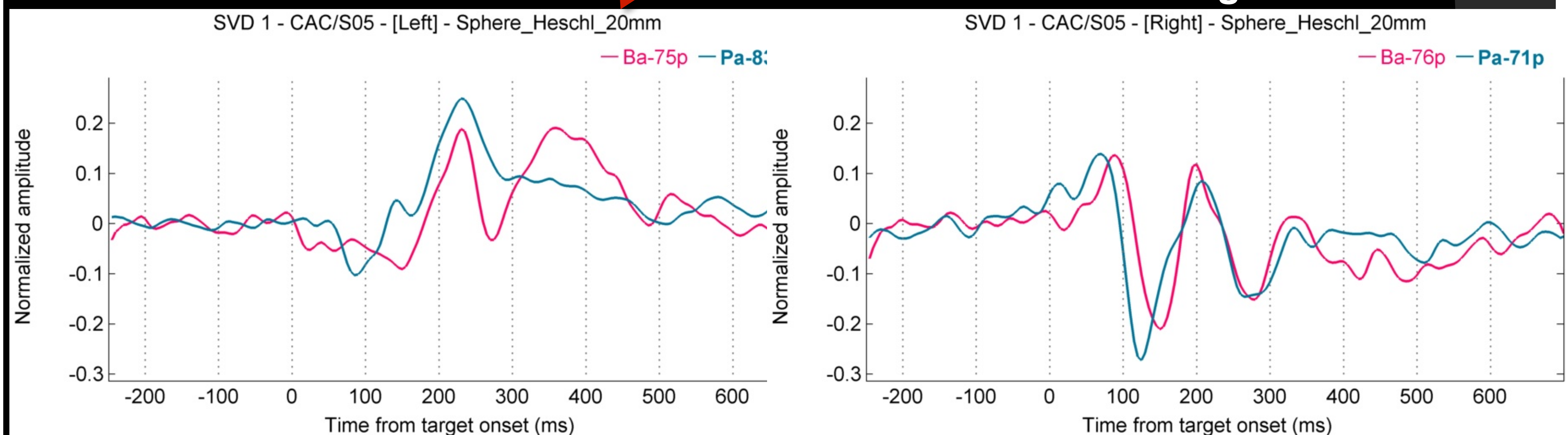
Source Signal reconstruction from the Left and Right Heschl's gyrus

Example of {beamforming + ROI + SVD}



Healthy Subject

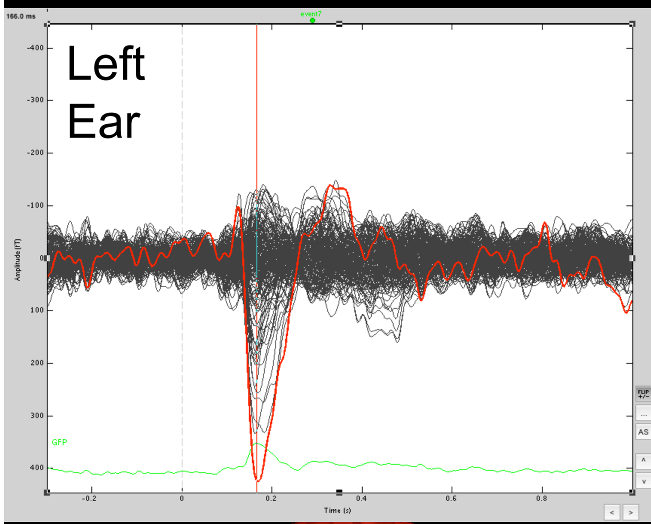
Left **Right**

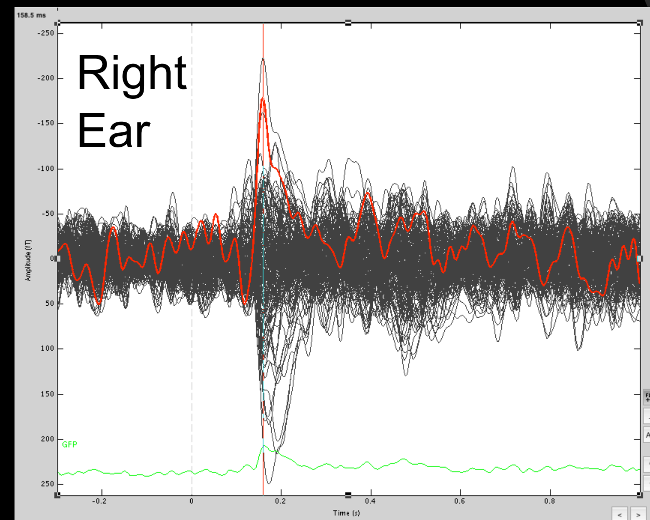


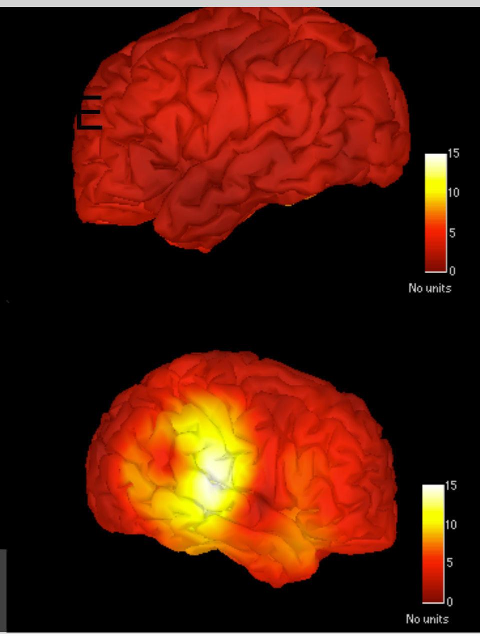
Ba: Release component ~300 ms at the Left side

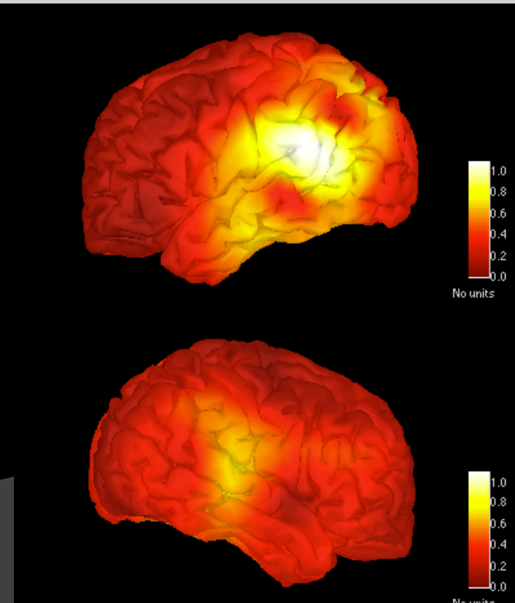
AUDITORY EVOKED FIELD
to pure tones

Patient









Fitting Dipoles for Ba and Pa stimulation

Number of dipoles with GOF > 80% and CV < 1000mm^3:

Ba Laterality Index (R-L)/(R+L)

80-150: 1.00

160-250: 0

300-500: -0.25

500-800: 0.16

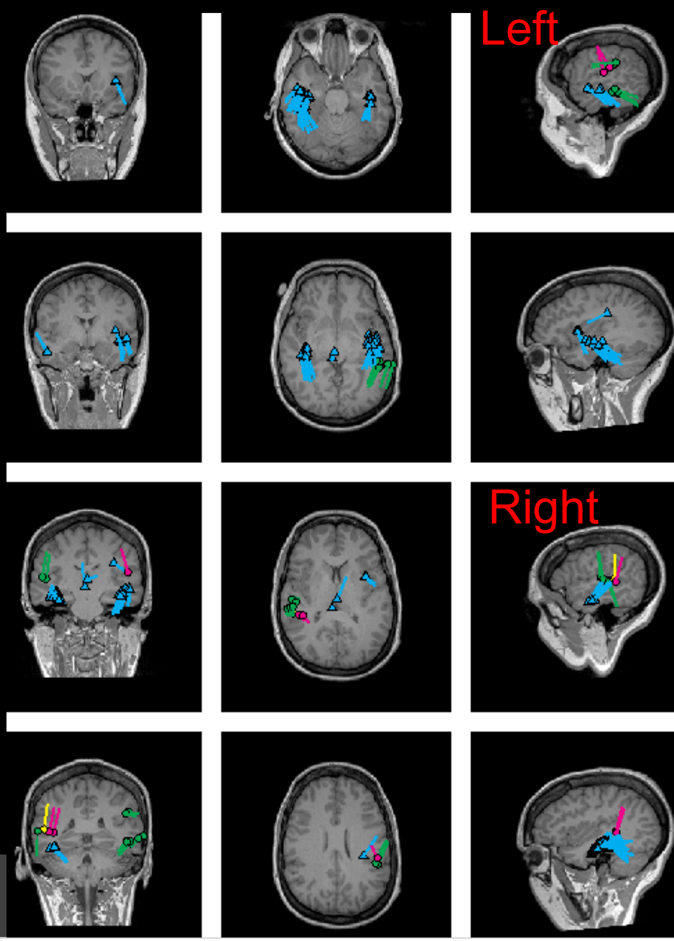
Pa Laterality Index (R-L)/(R+L)

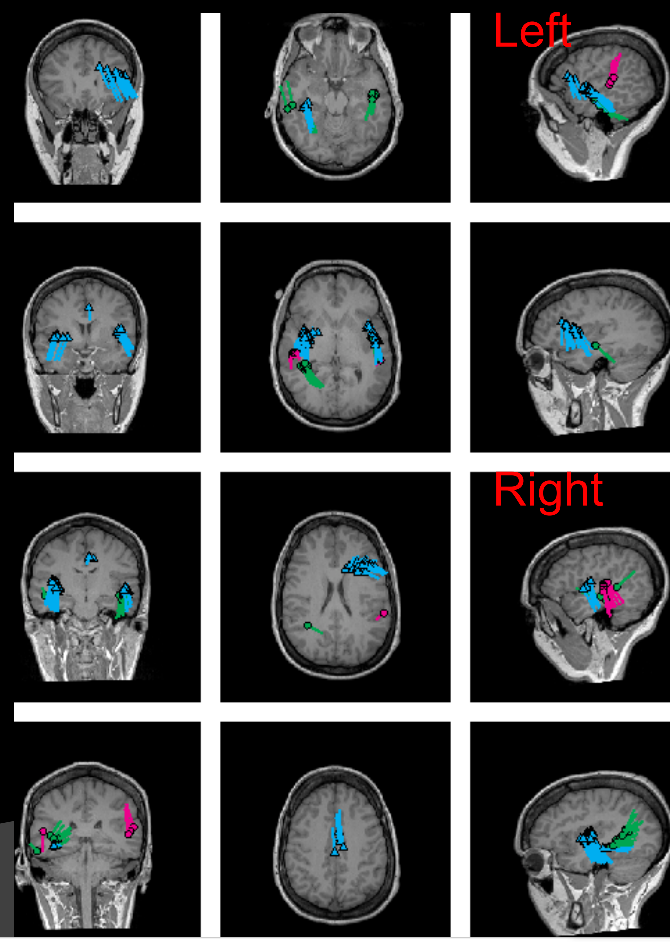
80-150: - (none)

160-250: 0.63

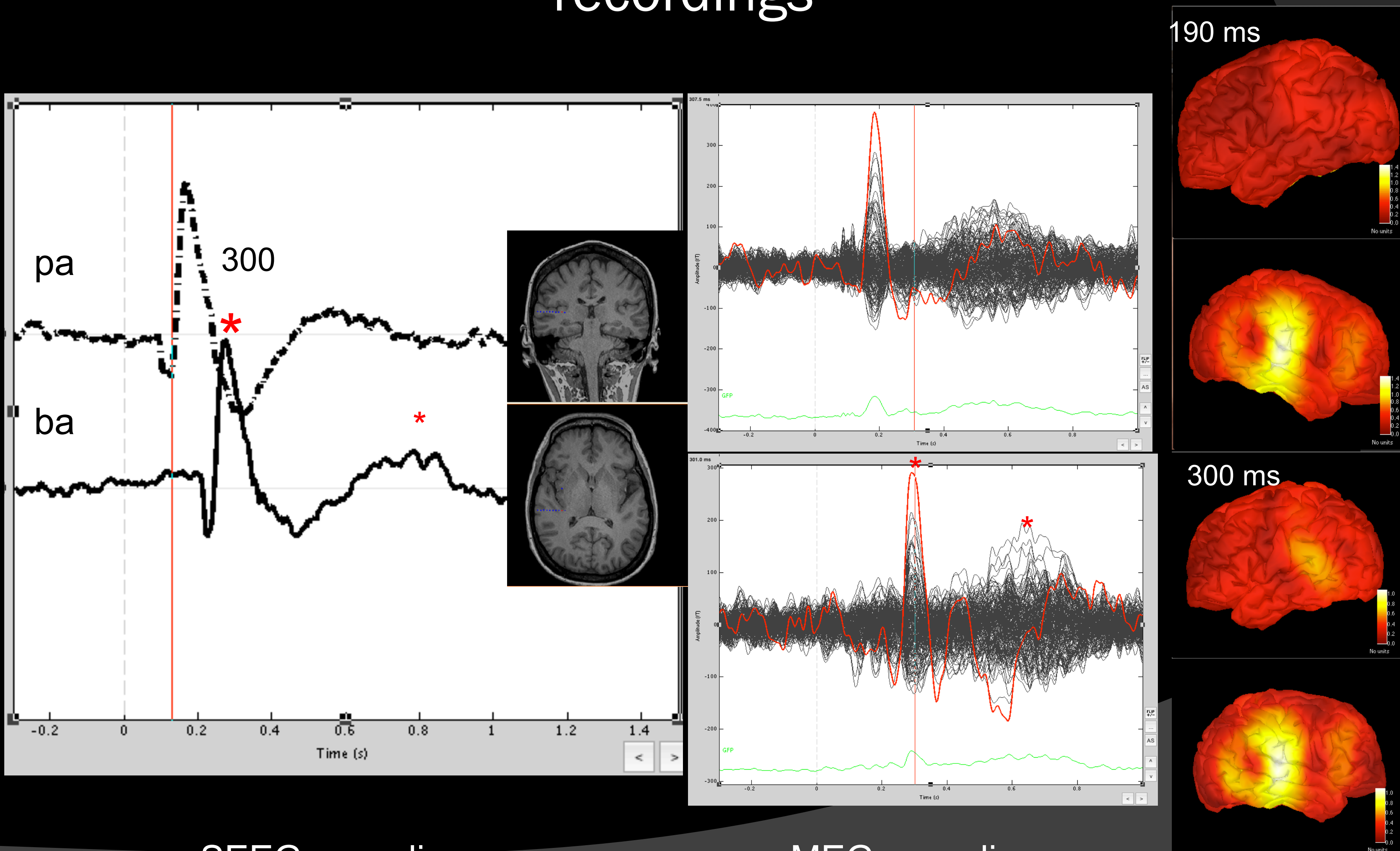
300-500: 0.05

500-800: 0.01





AUDITORY EVOKED RESPONSES
to syllables: comparison Intracerebral and MEG recordings

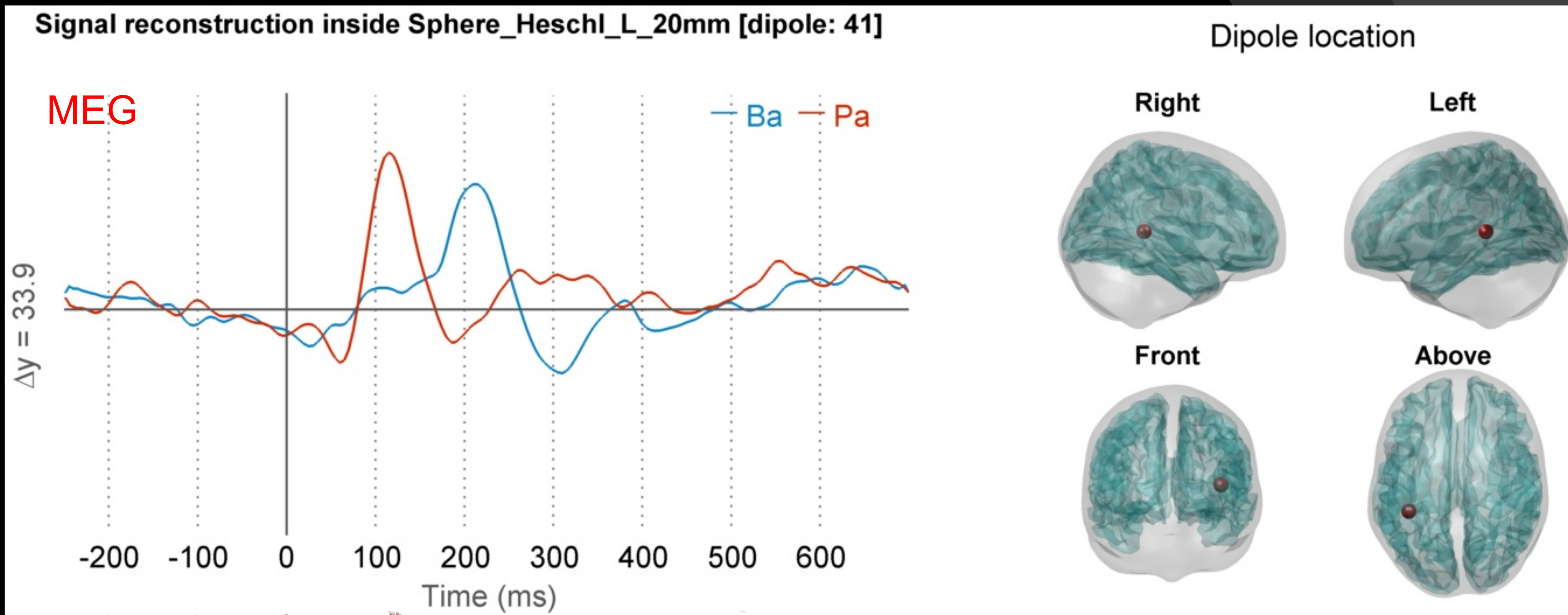


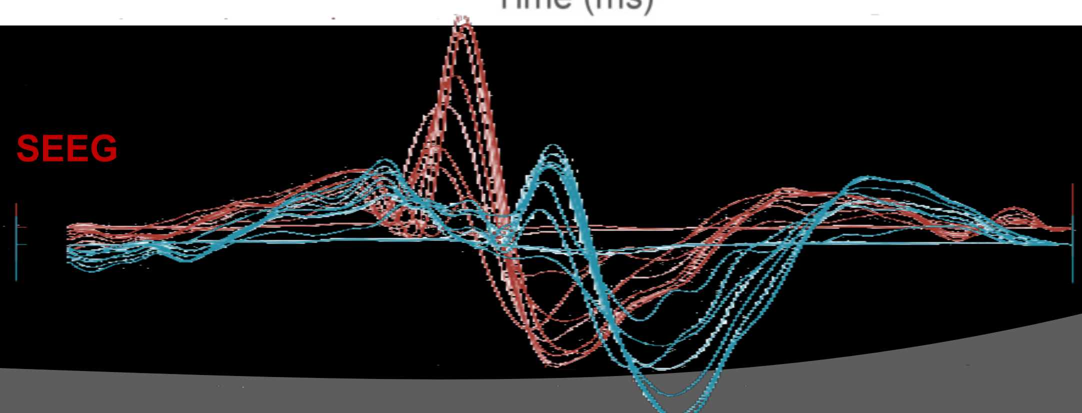
SEEG recordings

MEG recordings

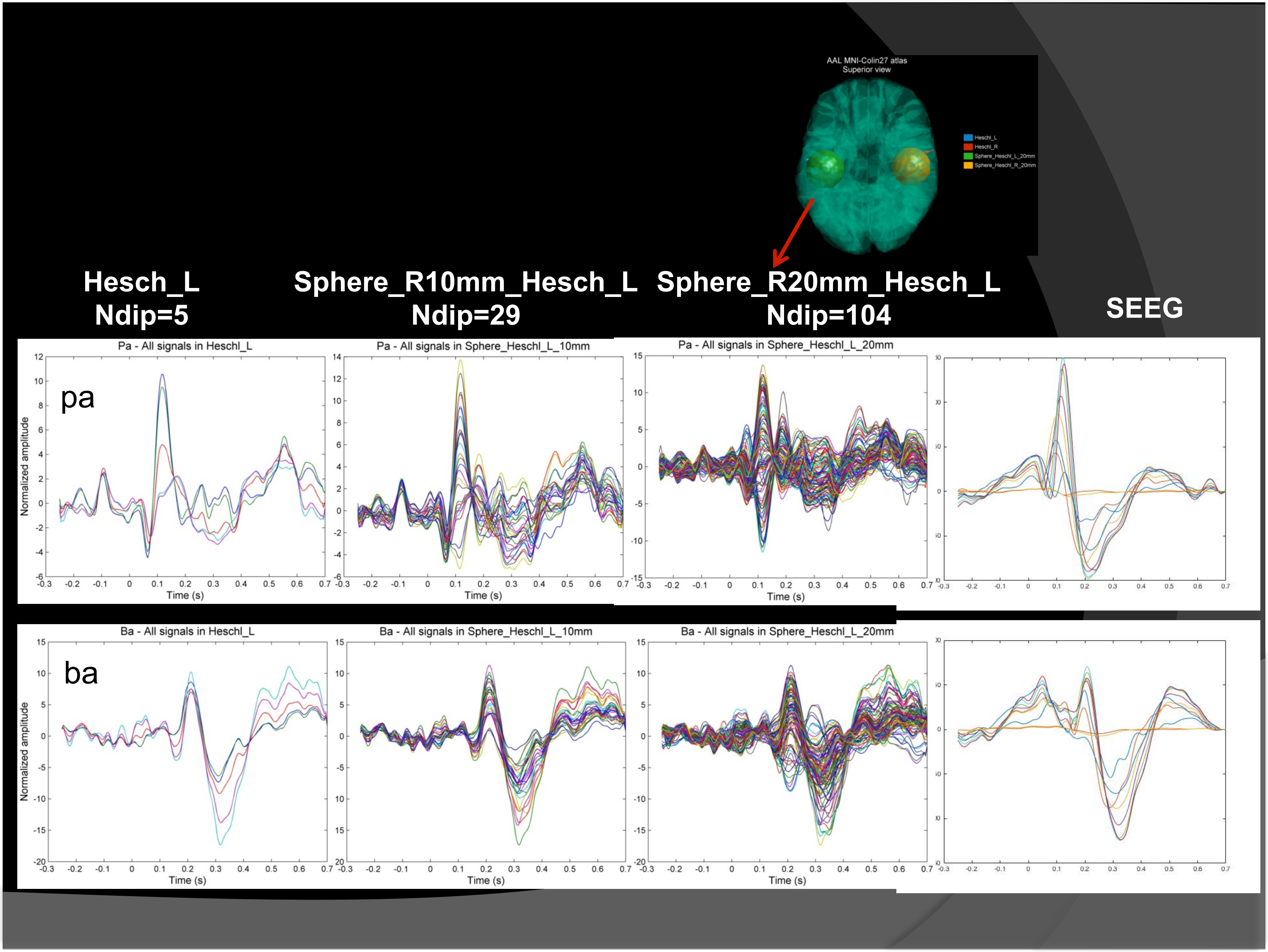
Simultaneous Recordings SEEG - MEG

Source signal reconstruction example *(from MEG beamforming, at some dipole location)*





SEEG data recording within the auditory cortex during the BaPa task where available for this subject


AAL MNI-Colin27 atlas
Superior view
Heschl_L
Heschl_R
Sphere_Heschl_L_20mm
Sphere_Heschl_R_20mm
Hesch_L
Ndip=5
Sphere_R10mm_Hesch_L
Ndip=29
Sphere_R20mm_Hesch_L
Ndip=104
SEEG
Pa - All signals in Heschl_L
Pa - All signals in Sphere_Heschl_L_10mm
Pa - All signals in Sphere_Heschl_L_20mm
pa
Normalized amplitude
Time (s)
Ba - All signals in Heschl_L
Ba - All signals in Sphere_Heschl_L_10mm
Ba - All signals in Sphere_Heschl_L_20mm
ba

Conclusion

- MEG can capture the physiological mechanisms underlying language perception
  - More than one task should be used to reveal language function
  - A number of different methods should be used to assess the language network (dSPM, MNE, beamforming etc…)
  - Passive listening demonstrates that language lateralization starts at the level of auditory cortex and may provide adequate information to accurately determine language dominance.

ACMEGS

AMERICAN CLINICAL MEG SOCIETY

The State of MEG Fellowships
Update and Announcements on MEG/EEG-Technologist Activities

Richard C. Burgess, Cleveland

What's on the Horizon: Vendor Innovations and Plans

ANT Neuro North America – Frank Zanow
Compumedics, USA – Curtis Ponton, Vice President, Chief Science Officer
Elekta Neuroscience – Miikka Putaala, Director, Business Line MEG
York Instruments – Gary Green, Director

American Clinical Magnetoencephalography Society (ACMEGS)
Annual Business Meeting
Agenda

February 11, 2016
5:00 p.m.
Camilla/Dogwood Room · Mezzanine Level
Hilton Orlando Lake Buena Vista · Orlando, Florida

I. Call to Order (Dr. Burgess)

II. Minutes of Previous Business Meetings (Dr. Burgess)

III. President's Report (Dr. Burgess)

IV. Financial and Membership Report (Dr. Bowyer)

V. Public Relations Report (Dr. Bowyer)

VI. ACMEGS Website (Dr. Ferrari)

VII. New Business

  a. ACMEGS committees (Dr. Burgess)

  b. Joint Meeting with ACNS—hosting 31st ICCN in May 2018 (Dr. Burgess)

  c. Tales from the reimbursement front (Drs. Hernandez and Funke)

  d. Election of new Board of Directors members (Dr. Burgess)

VIII. Announcements

IX. Adjourn

ACMEGS
AMERICAN CLINICAL MEG SOCIETY

AMERICAN CLINICAL MAGNETOENCEPHALOGRAPHY SOCIETY
2016 Annual Conference ♦ February 11, 2016

Evaluation Form

Please identify yourself: ☐ Neurologist ☐ Neurosurgeon ☐ Radiologist

☐ MEG/EEG Technologist ☐ Other ______________________________

Please rate each speaker's effectiveness in conveying the material of his/her presentation using 5 as most effective and 1 as least effective:

Faculty	Most Effective				Least Effective	Comments
Dr. Jin	5	4	3	2	1	
Dr. Kirsch	5	4	3	2	1	
Dr. Chu	5	4	3	2	1	
Dr. Mosher	5	4	3	2	1	
Dr. Rampp	5	4	3	2	1	
Dr. Burgess	5	4	3	2	1	
Dr. Wang	5	4	3	2	1	
Dr. Liegeois-Chauvel	5	4	3	2	1	

Please rate using 5 as most effective and 1 as least effective:

Rate your overall satisfaction with the opportunity to network with colleagues.	5	4	3	2	1
Rate your overall satisfaction with the quality of this conference/workshop.	5	4	3	2	1
Please rate your satisfaction with the organization of the conference/workshop.	5	4	3	2	1
How would you rate the cost of registration versus what you personally got out of the conference?	5	4	3	2	1

What topics should be addressed at future meetings?

What features should be added to future meetings?

What features should be deleted from future meetings?

.

Did you perceive commercial bias in any of the presentations? ☐ Yes ☐ No
Explain:

YOUR TRIP TO:

Hyatt Regency Grand Cypress

38 MIN | 1.6 MI

Trip time based on traffic conditions as of 1:36 PM on January 29, 2016. Current Traffic: N/A

1. Start out going **north**.

Then 0.05 miles .... 0.05 total miles

2. Turn **slight right**.

Then 0.04 miles .... 0.09 total miles

3. Turn **right** onto Hotel Plaza Blvd.

Then 0.71 miles .... 0.80 total miles

4. Turn **left** onto State Road 535/FL-535.

Then 0.27 miles .... 1.08 total miles

5. Turn **left** onto State Road 535.

Then 0.13 miles .... 1.20 total miles

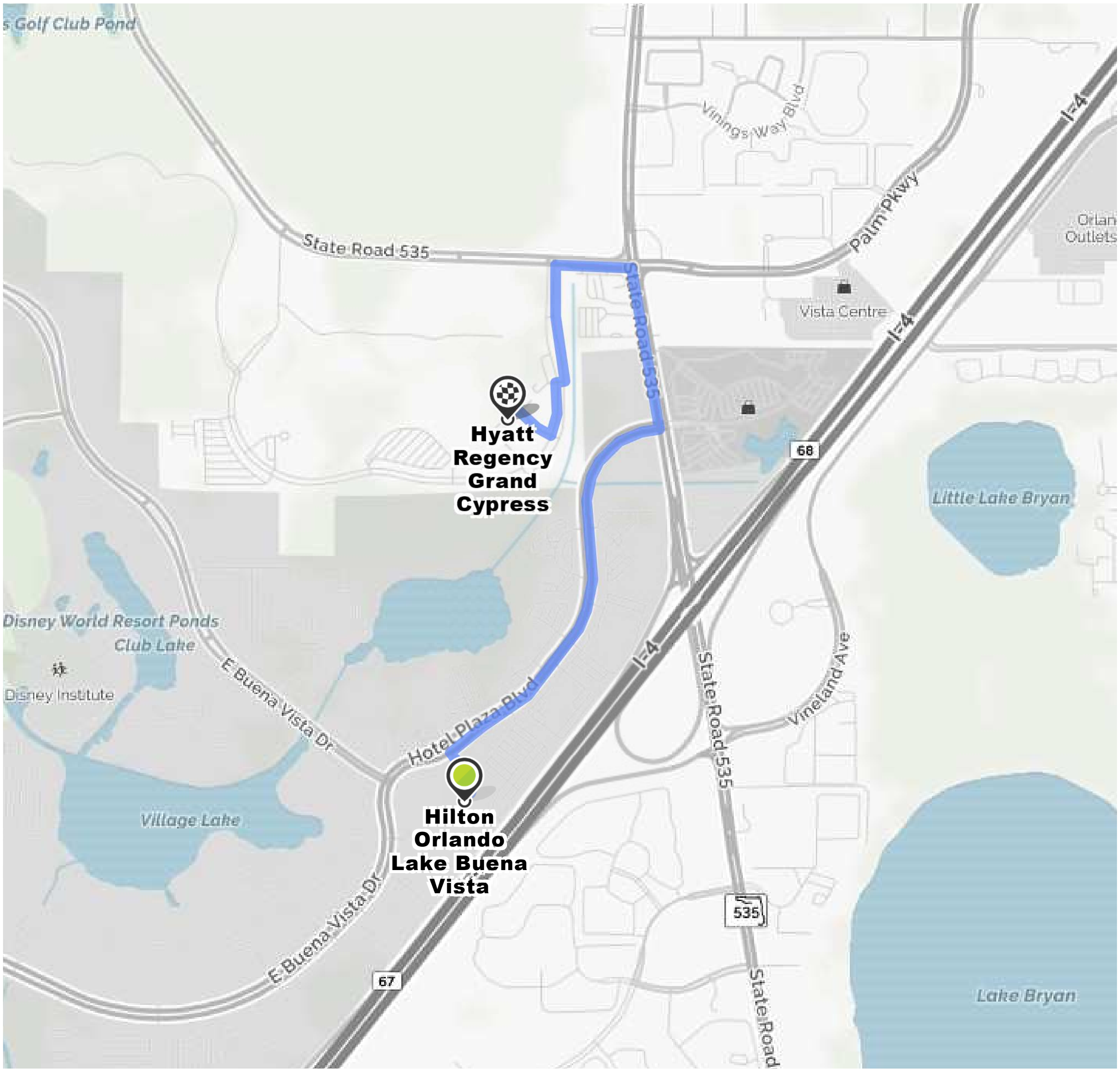
6. Turn **left** onto Grand Cypress Blvd.

Then 0.30 miles .... 1.51 total miles

7. Turn **right**.

Then 0.10 miles .... 1.60 total miles

8. Hyatt Regency Grand Cypress, ONE GRAND CYPRESS BOULEVARD.



Golf Club Pond
Vinings Way Blvd
State Road 535
Palm Pkwy
Orlando Outlets
Vista Centre
I-4
State Road 535
Hyatt Regency Grand Cypress
68
Little Lake Bryan
Disney World Resort Ponds
Club Lake
Disney Institute
E Buena Vista Dr
Vineland Ave
Hotel Plaza Blvd
Hilton Orlando Lake Buena Vista
Village Lake
535
E Buena Vista Dr
67
Lake Bryan
State Road