International Workshop on Advanced Epilepsy Treatment
March 28-30, 2009, Kitakyushu, Japan
(Invited Talk #2)

# What's the difference between EEG and MEG in practice?

**Nobukazu Nakasato, MD, PhD**

Department of Neurosurgery,
Kohnan Hospital & Tohoku University, Sendai, Japan

# What's the difference between EEG and MEG in practice?

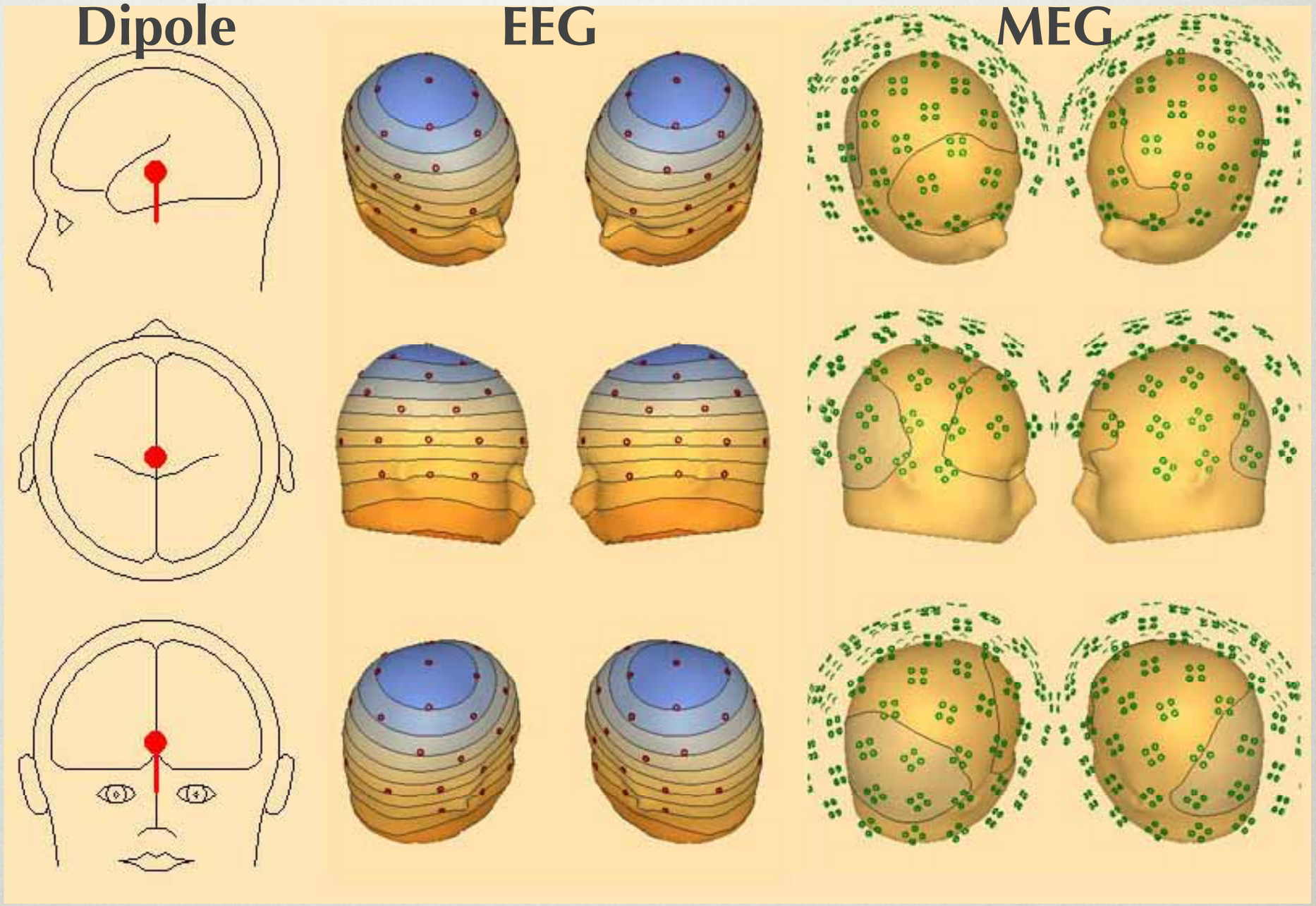
- Introduction
  - Theory & Practice
- Evoked Responses
  - Single Source
  - Dual Source
- Epileptic Spikes
  - Detectability
  - Localization
  - Orientation
- Summary

# Dipole Simulator (BESA)

Number:
**Single**

Position:
**Center**

Orientation:
**Radial**

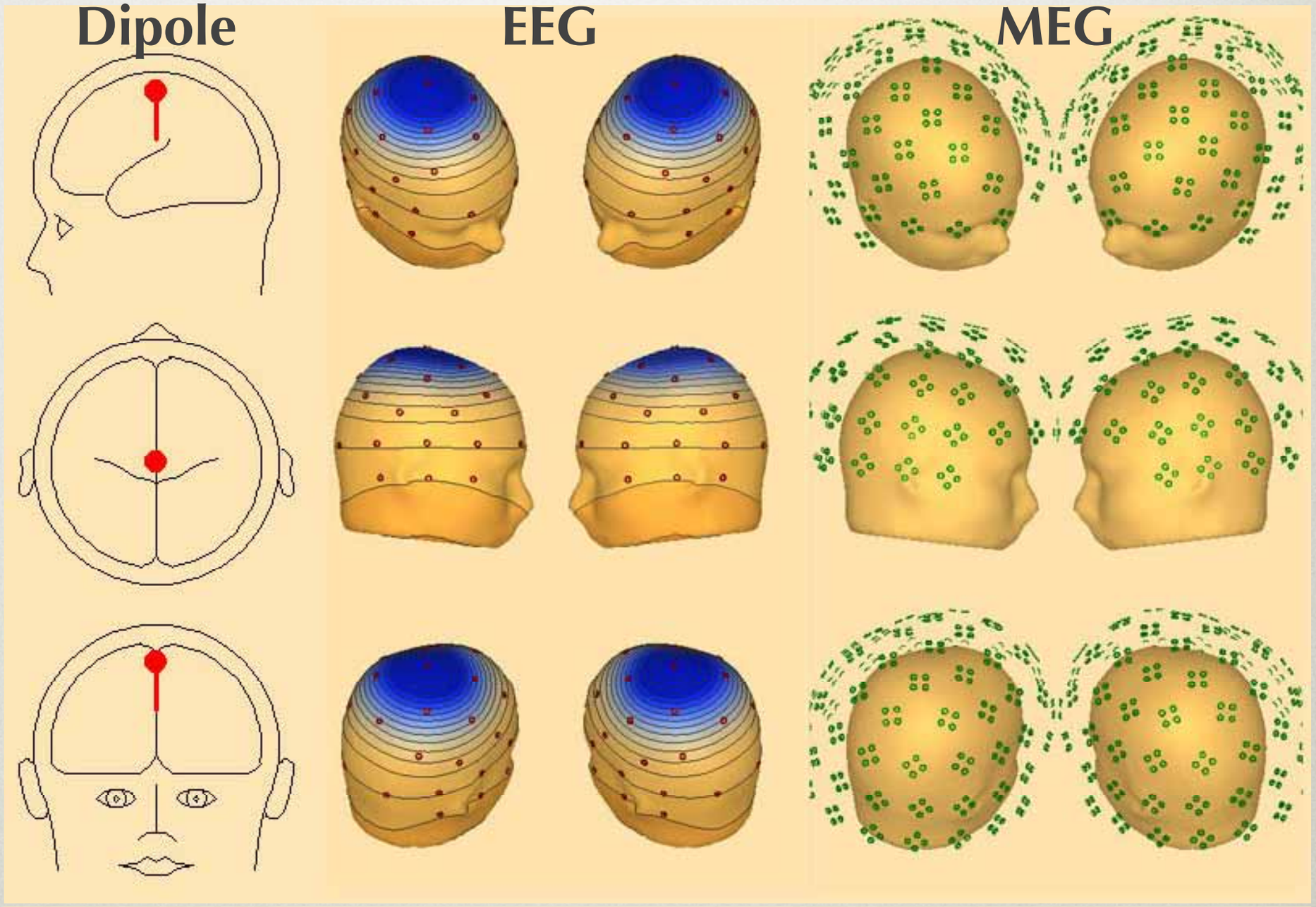


# Dipole Simulator (BESA)

Number:
**Single**

Position:
**Vertex**

Orientation:
**Radial**

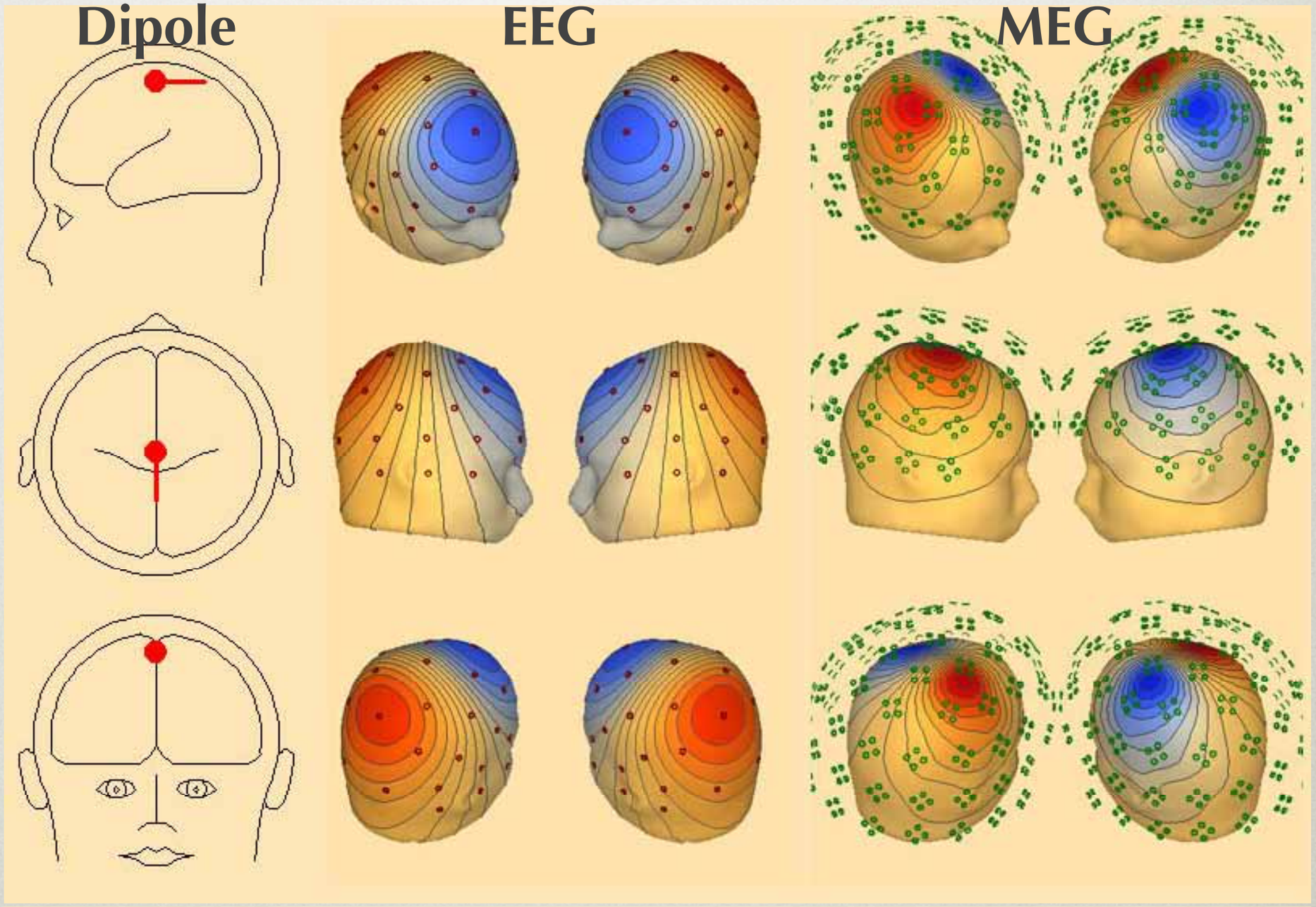


# Dipole Simulator (BESA)

Number:
**Single**

Position:
**Vertex**

Orientation:
**Tangential**

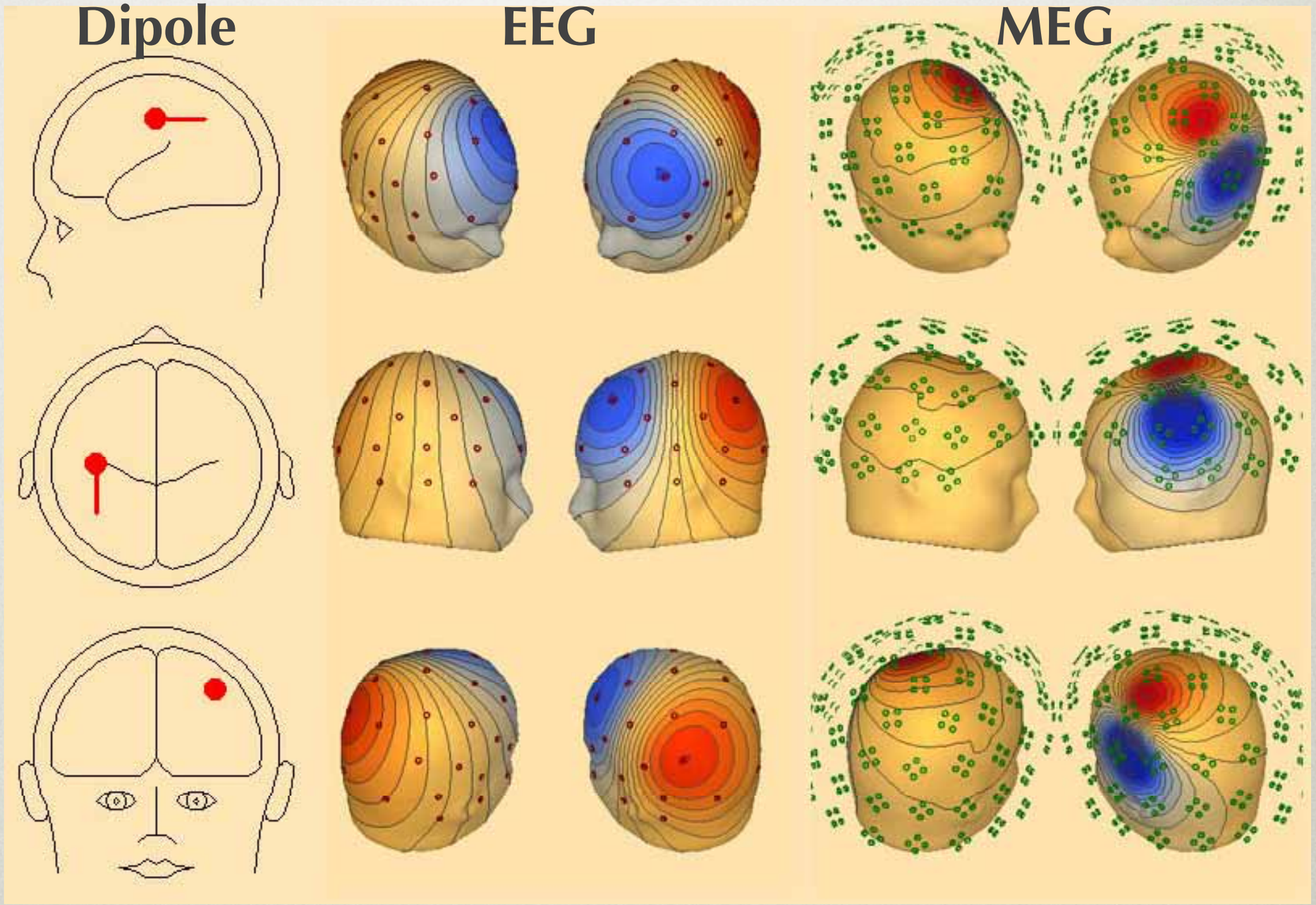


# Dipole Simulator (BESA)

Number:
**Single**

Position:
**Central**

Orientation:
**Tangential**

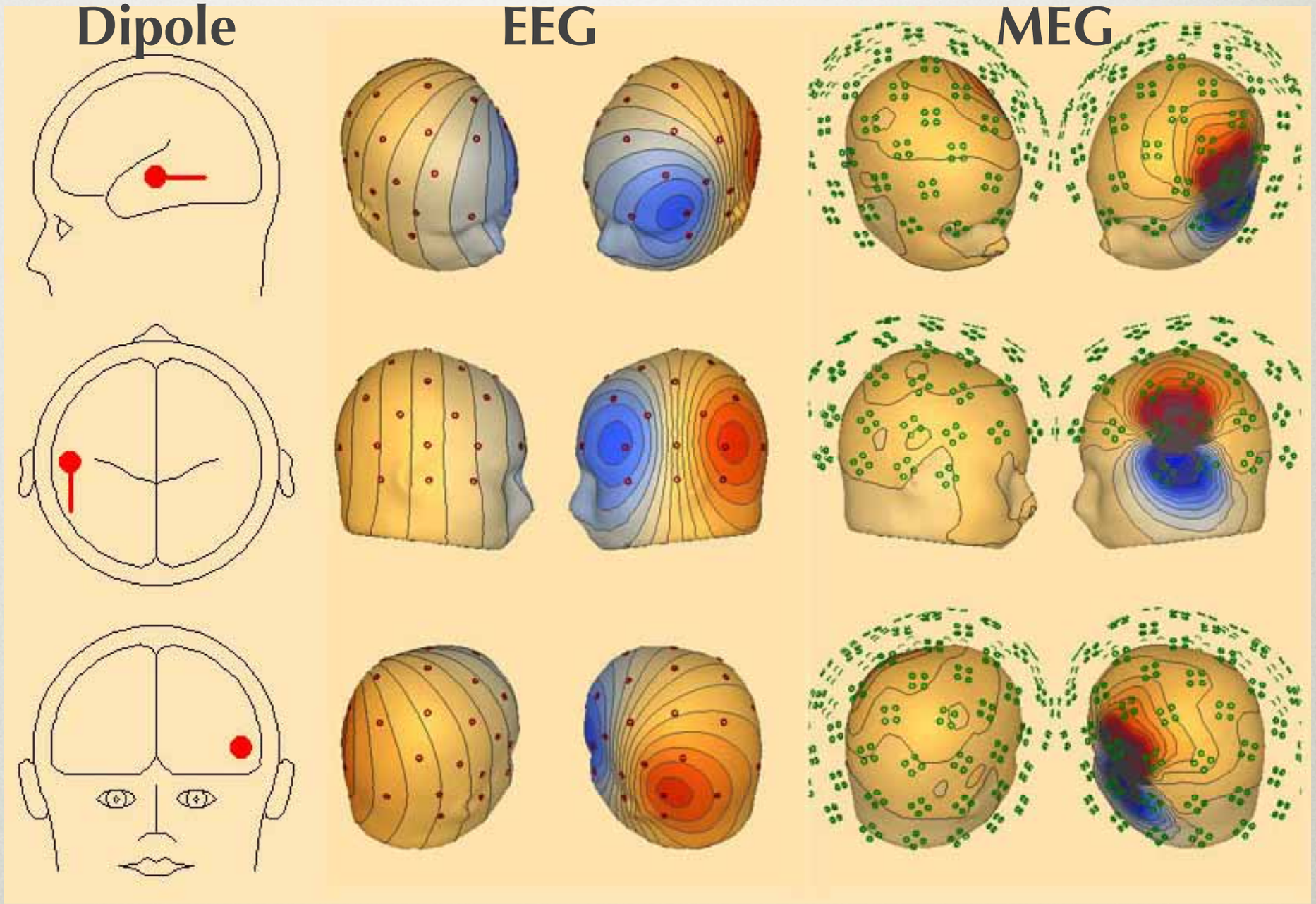


# Dipole Simulator (BESA)

Number:
**Single**

Position:
**Temporal**

Orientation:
**Tangential**

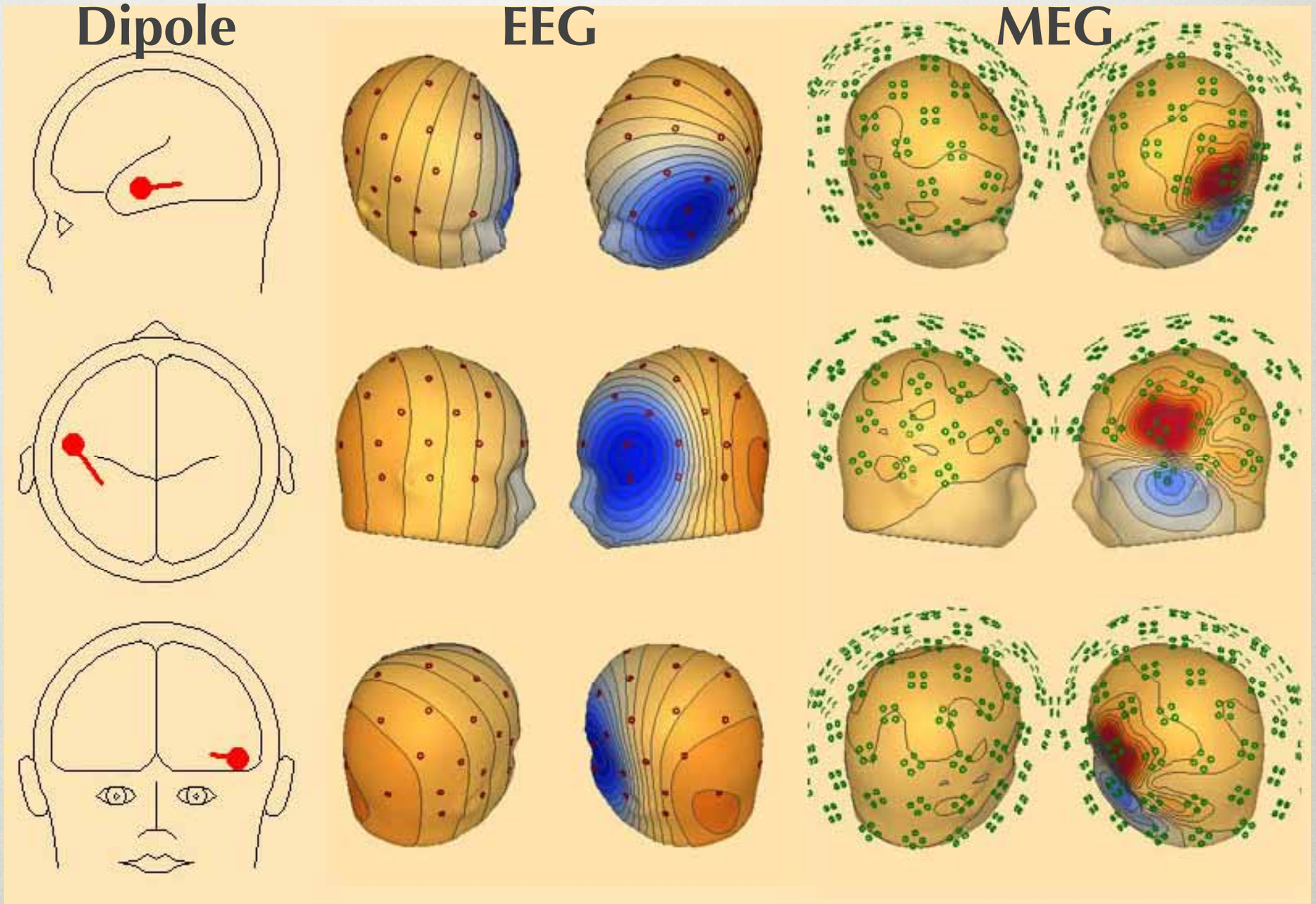


# Dipole Simulator (BESA)

Number:
**Single**

Position:
**Temporal**

Orientation:
**Oblique**

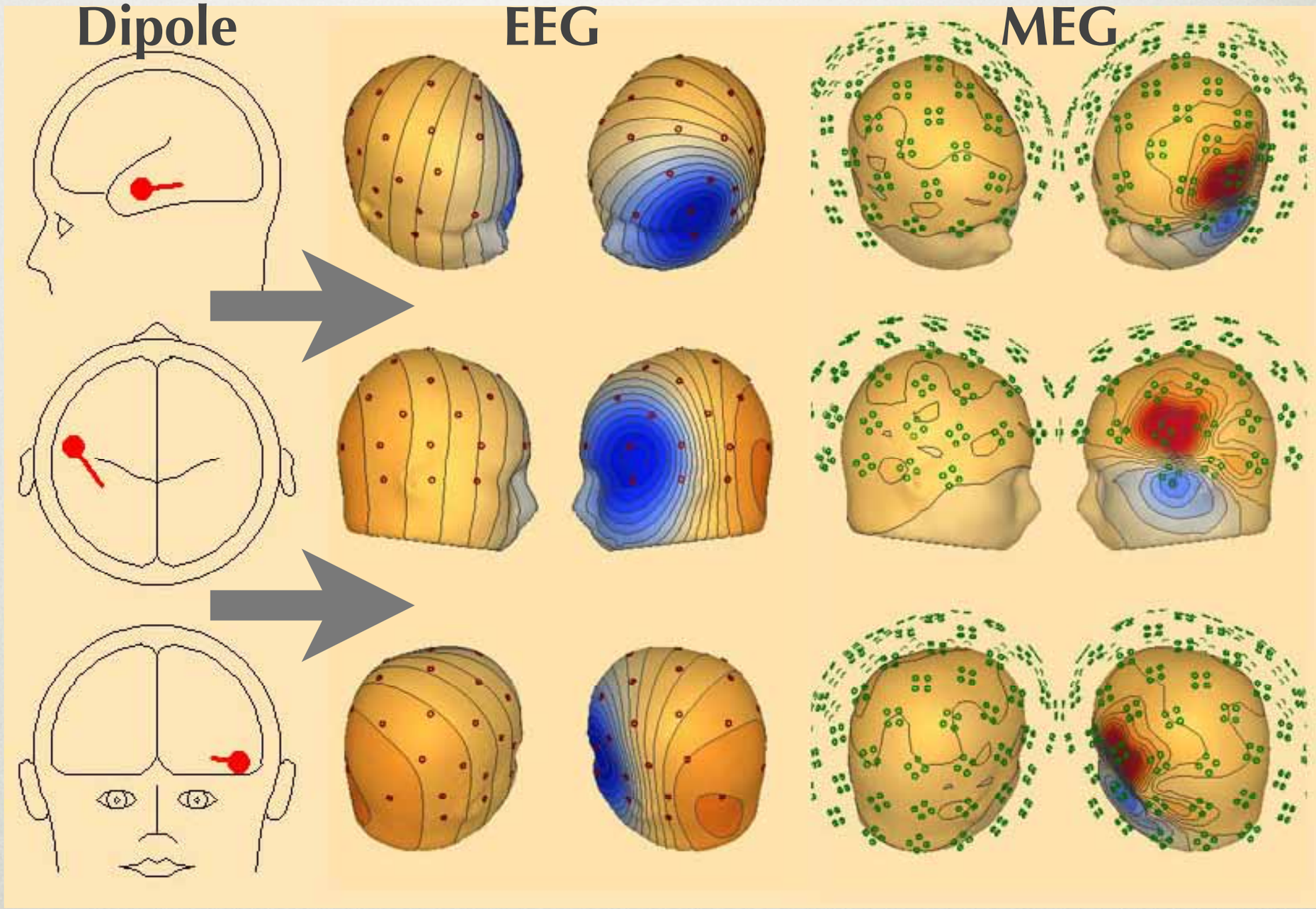


# Forward Calculation

Number:
**Single**

Position:
**Temporal**

Orientation:
**Oblique**



# MEG System “Model-2020”

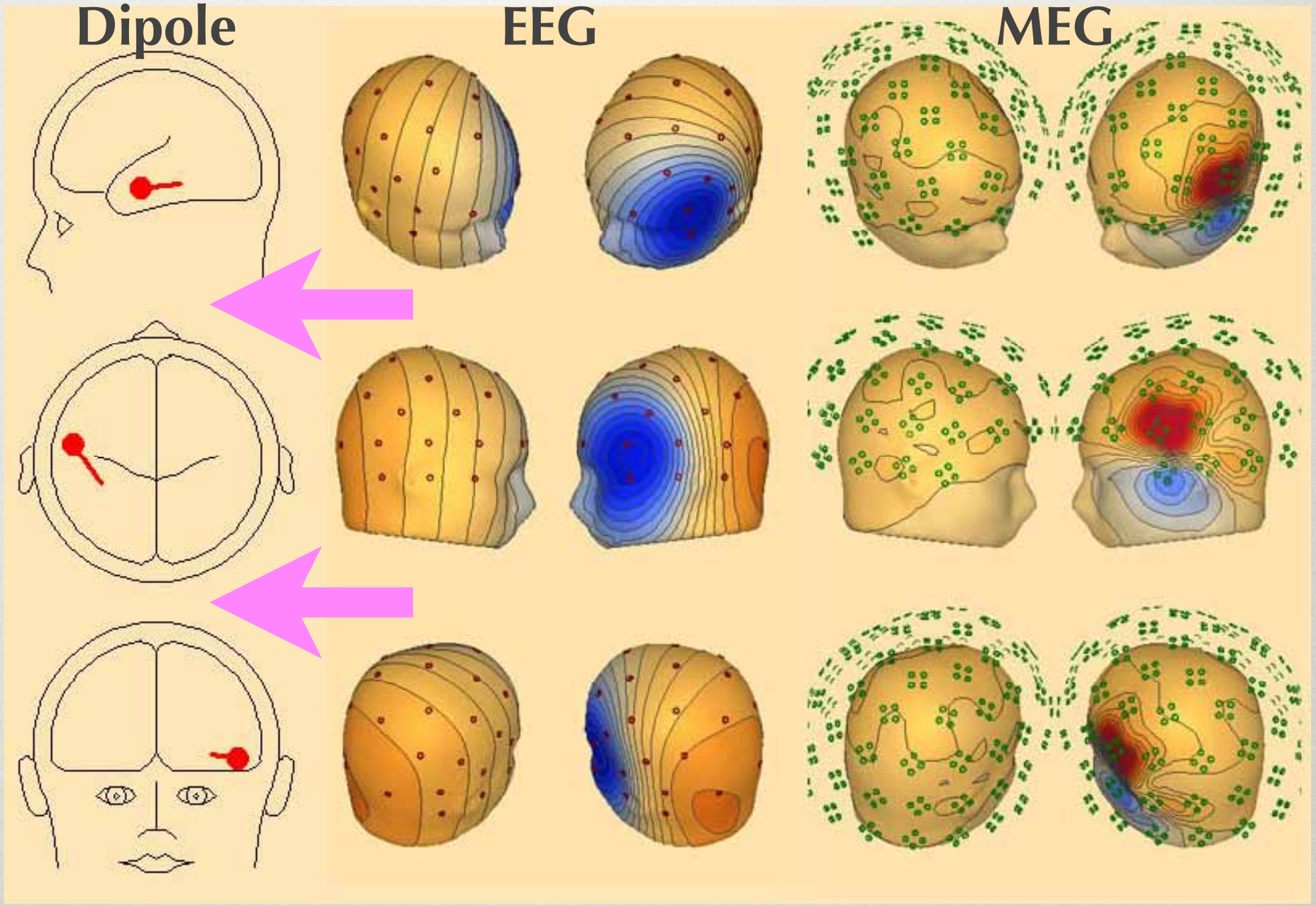
✓ More-channels and higher density
✓ Wider coverage including face and neck
✓ Shorter distance between sensor and scalp

# Inverse Problem

Number:
**Single**

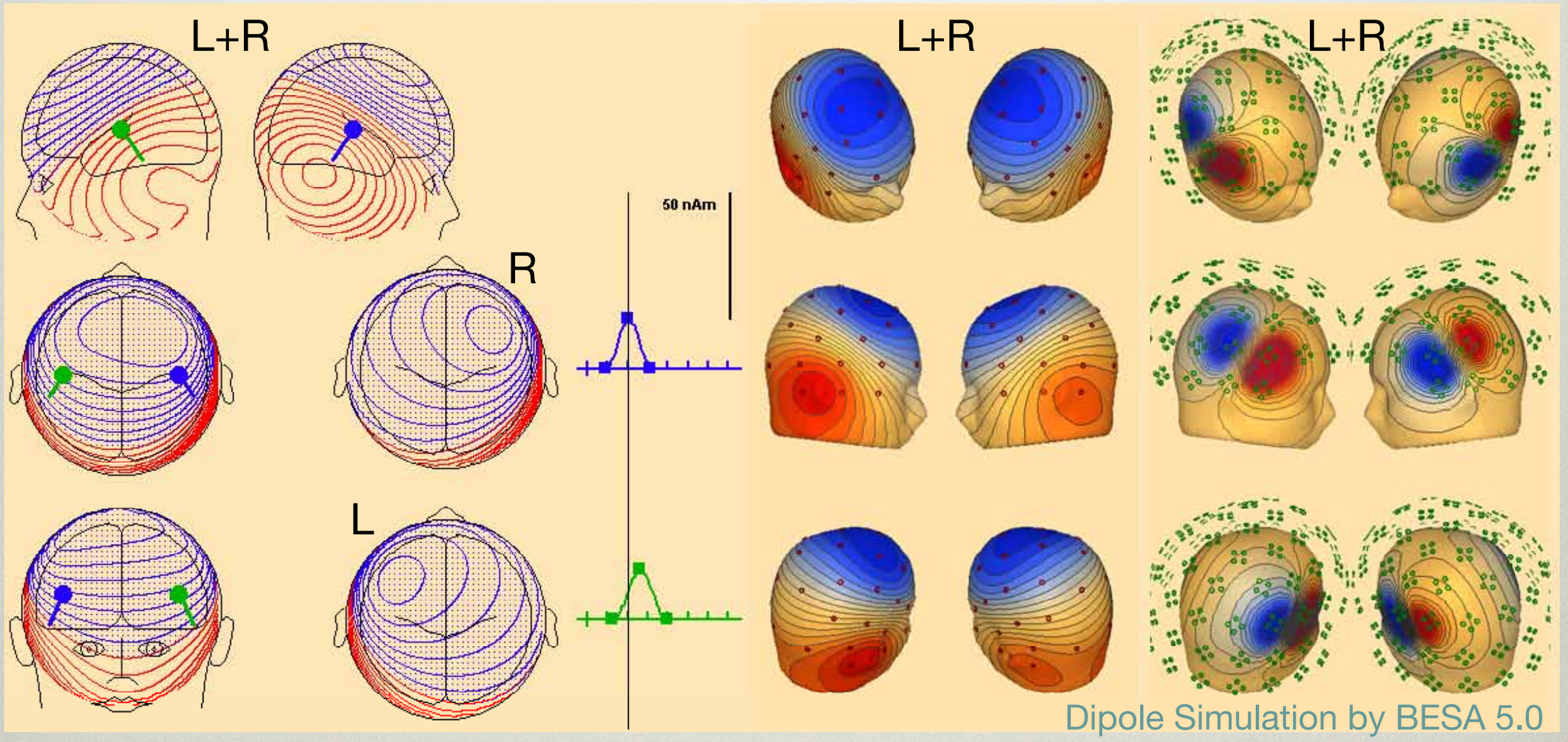
Position:
**Temporal**

Orientation:
**Oblique**



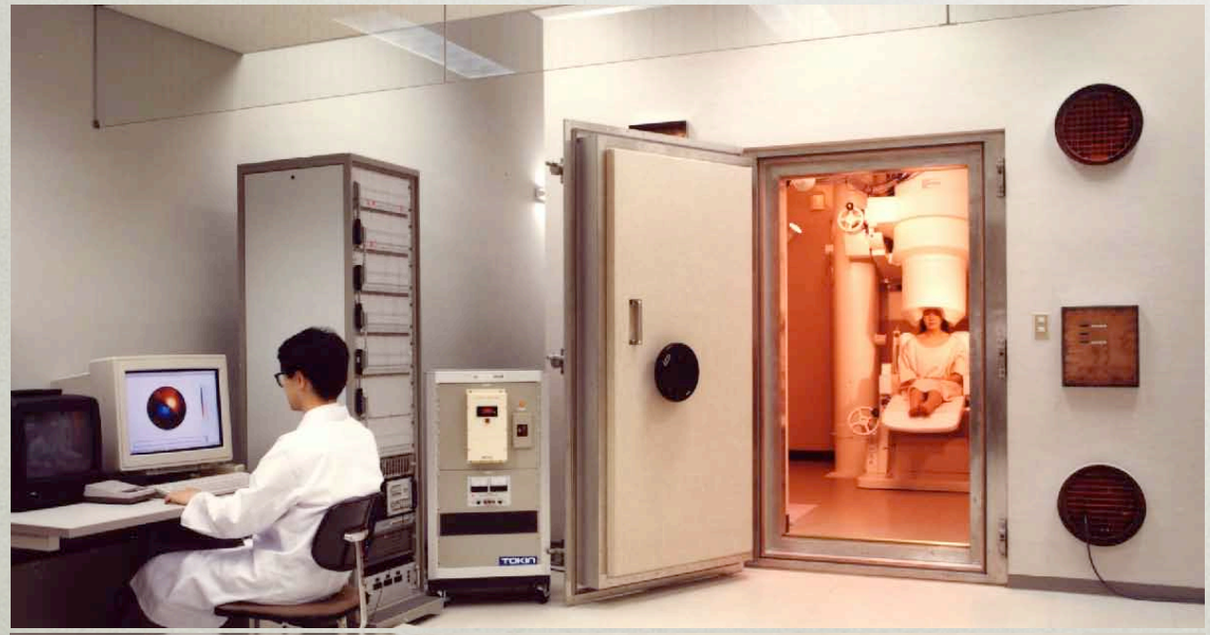

**No unique solution in inverse problem ... (Helmholtz)**

# Separation of Two Signals



# MEG in Sendai, since 1988

**1988**



**1993**

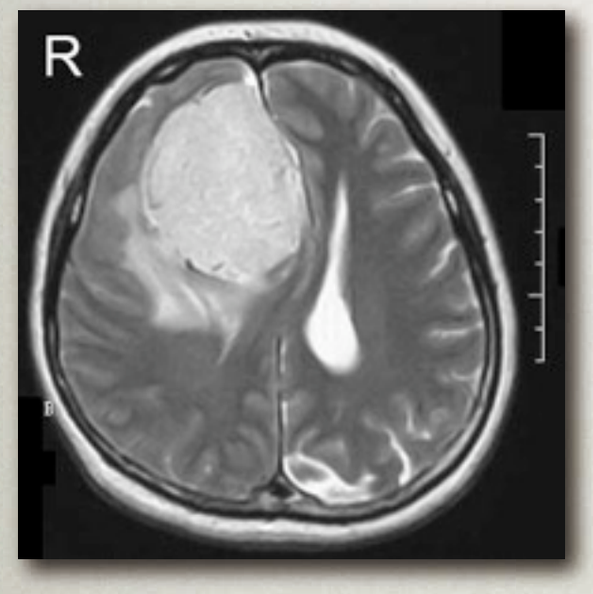

**1999**

# EEG-MEG powered by ... (2008)

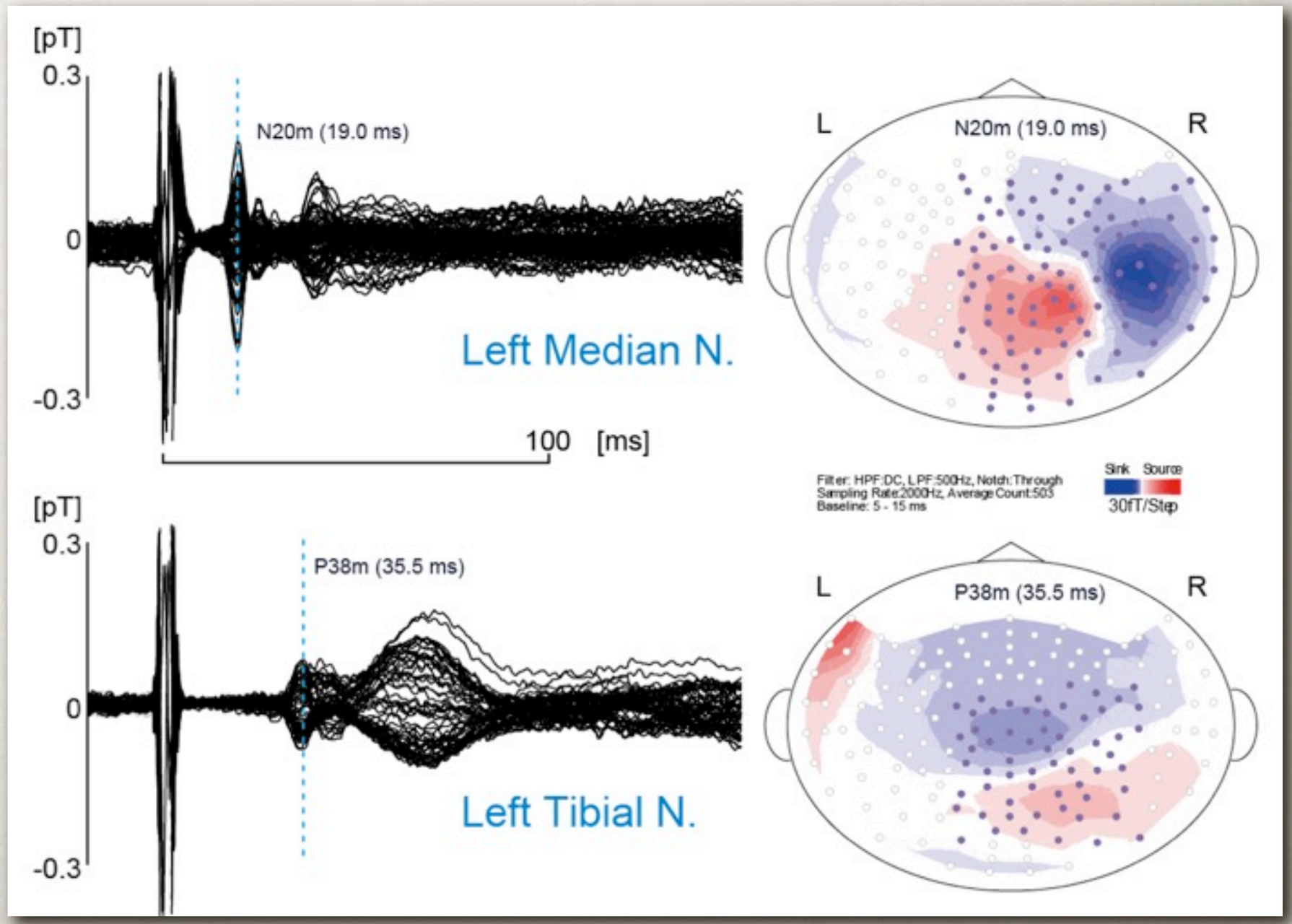

# What's the difference between EEG and MEG in practice?

- Introduction
  - Theory & Practice
- Evoked Responses
  - Single Source
  - Dual Source
- Epileptic Spikes
  - Detectability
  - Localization
  - Orientation
- Summary

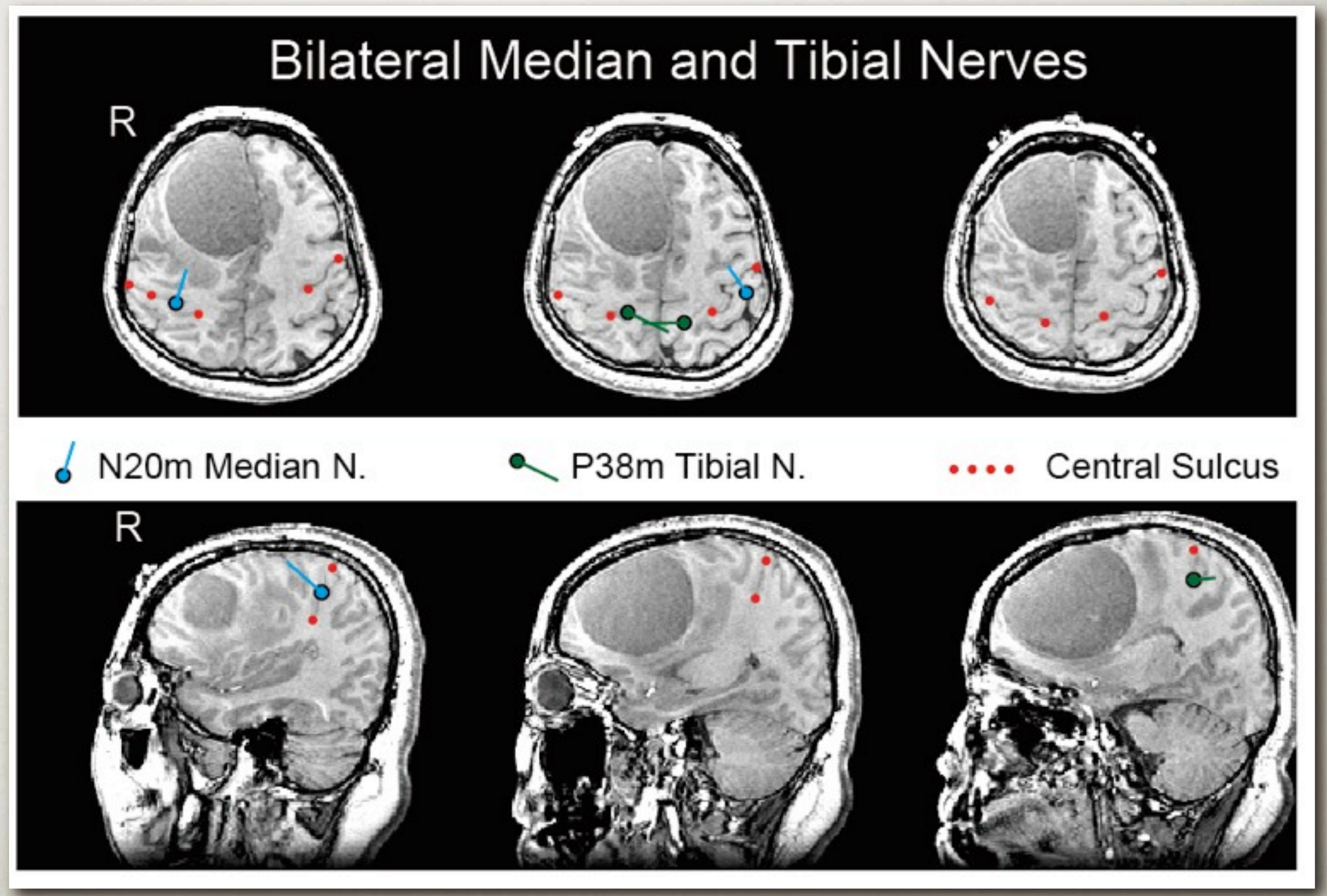
# Somatosensory Evoked Fields




F/48
Meningioma



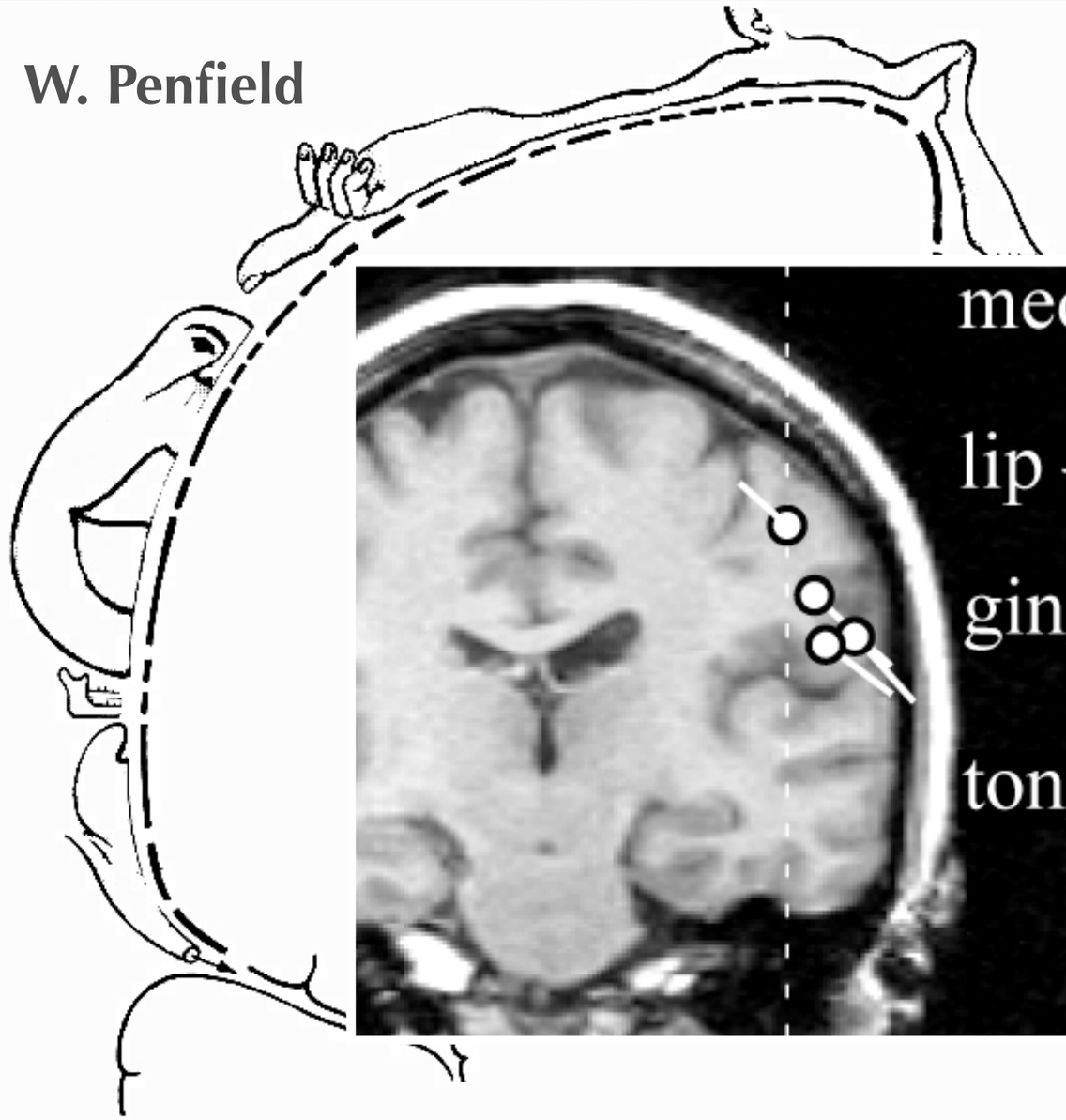
# Somatosensory Evoked Fields

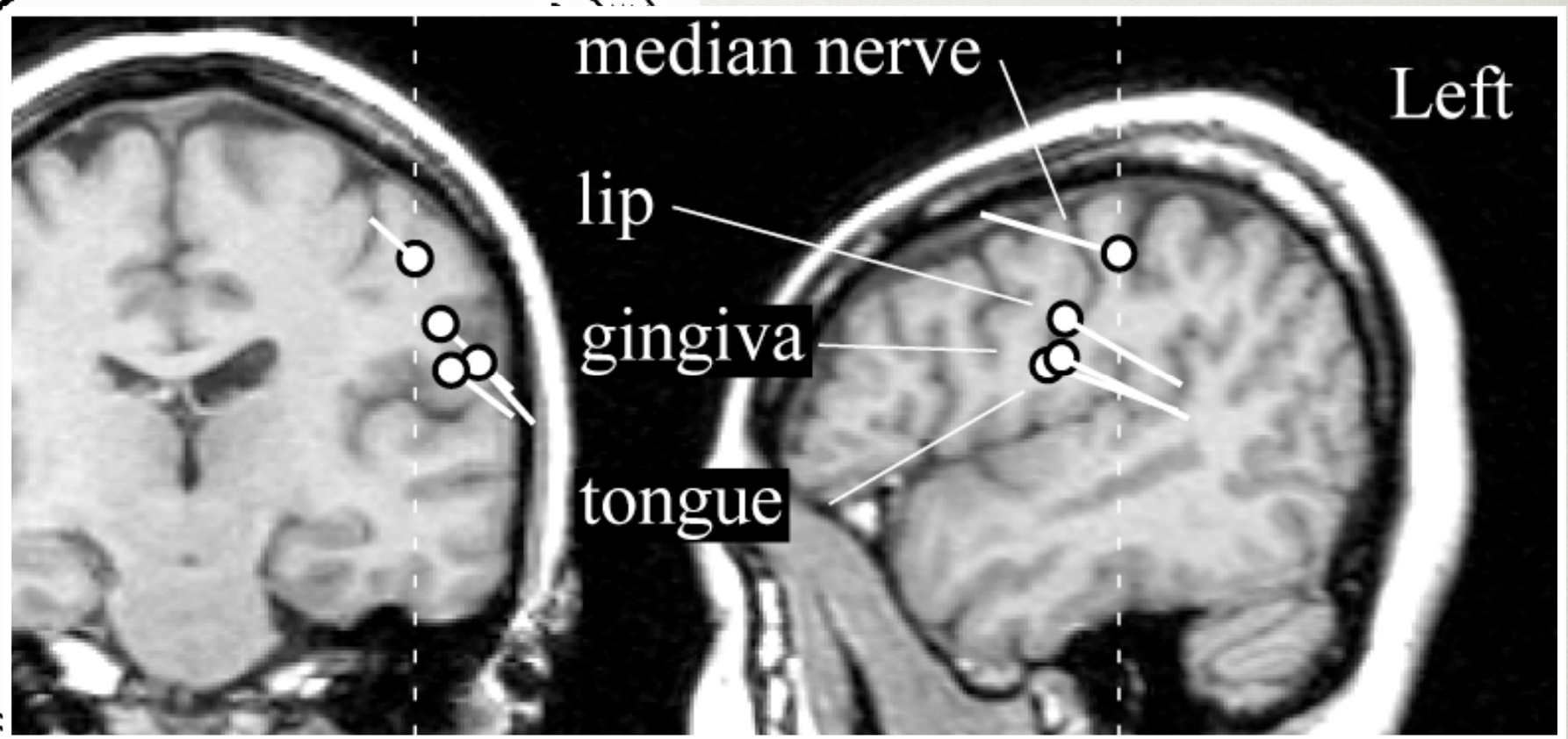



F/48
Meningioma

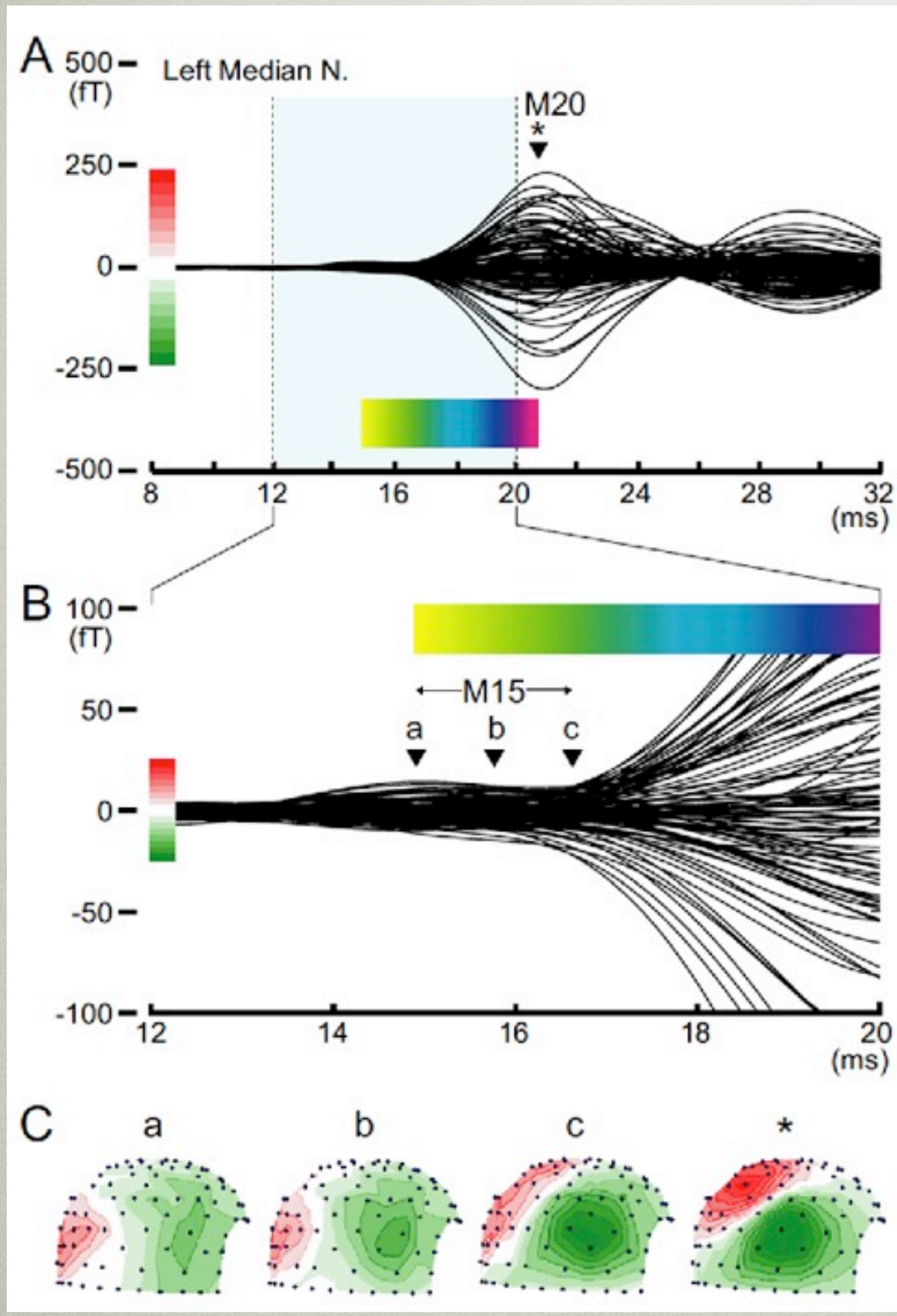
# Somatosensory Evoked Fields

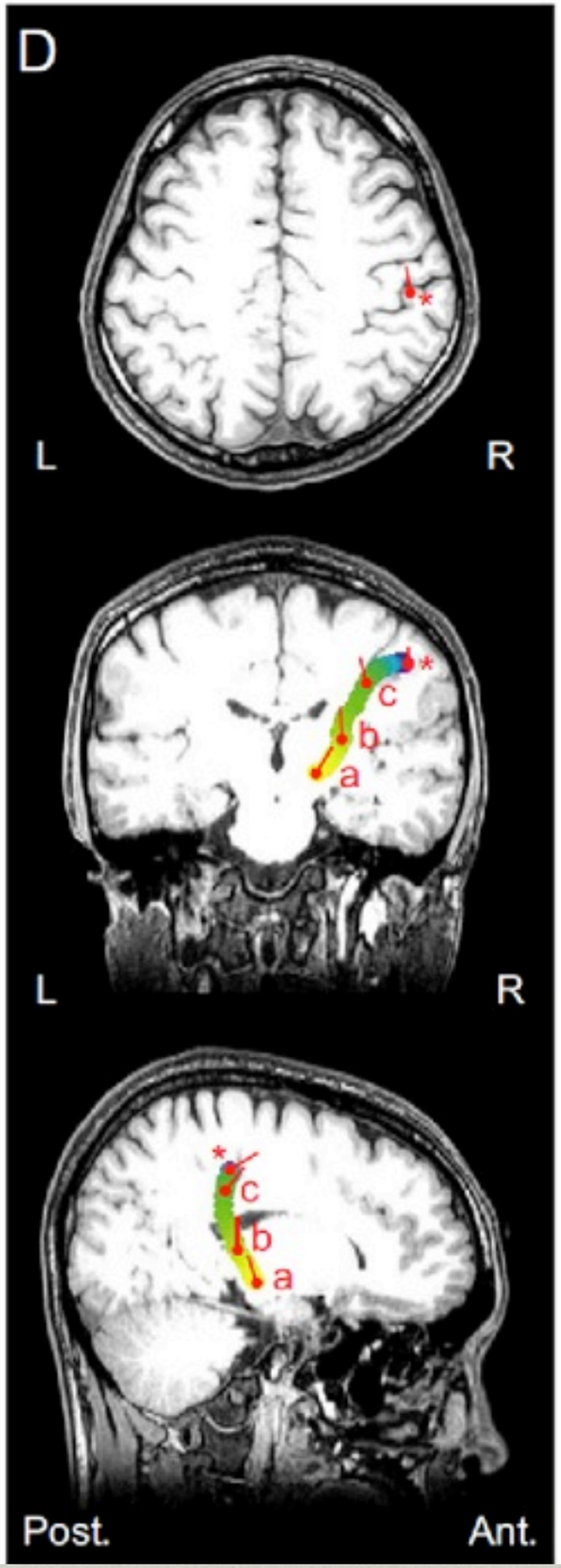
W. Penfield






Nakahara et al. 2004




**Kimura T, Ozaki I, Hashimoto I:**

**Impulse propagation along <u>thalamocortical fibers</u> can be detected magnetically outside the human brain.**

**J Neurosci 28: 12535-8, 2008**

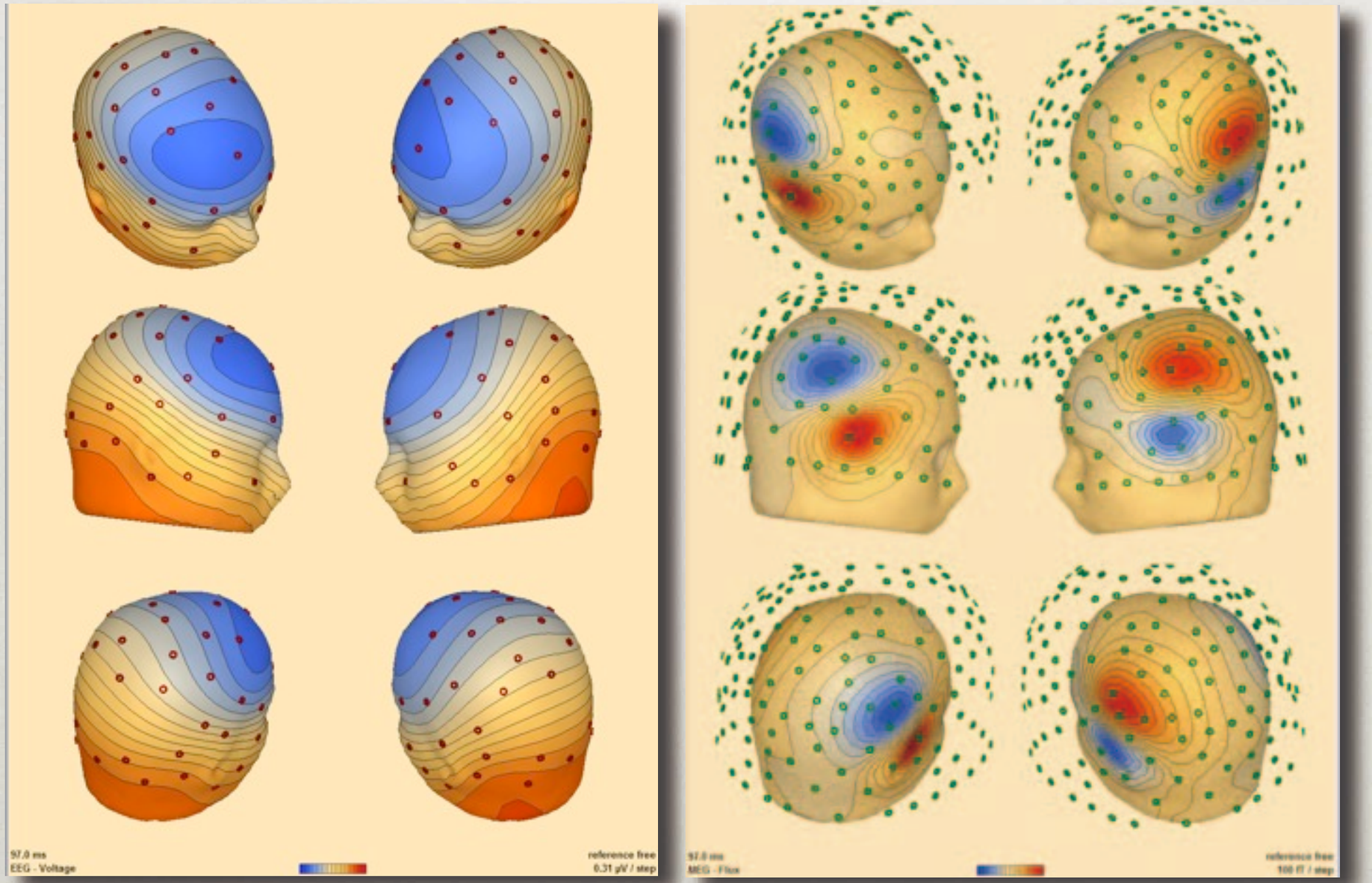
# What's the difference between EEG and MEG in practice?

- Introduction
  - Theory & Practice
- **Evoked Responses**
  - Single Source
  - **Dual Source**
- Epileptic Spikes
  - Detectability
  - Localization
  - Orientation
- Summary

# Auditory Evoked Response (N100)

EEG

MEG



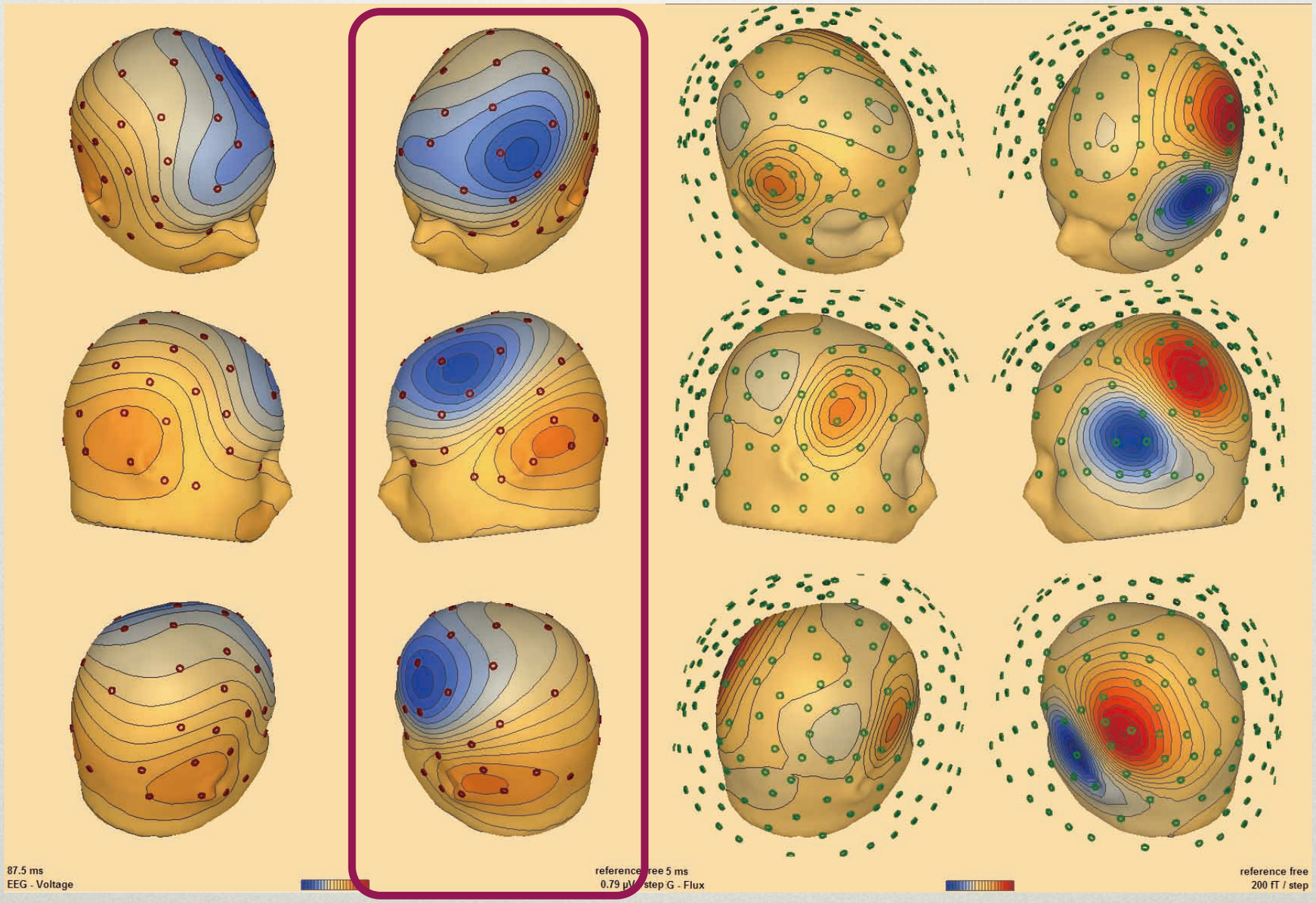

Normal Subject

# Auditory Evoked Response (N100)

EEG

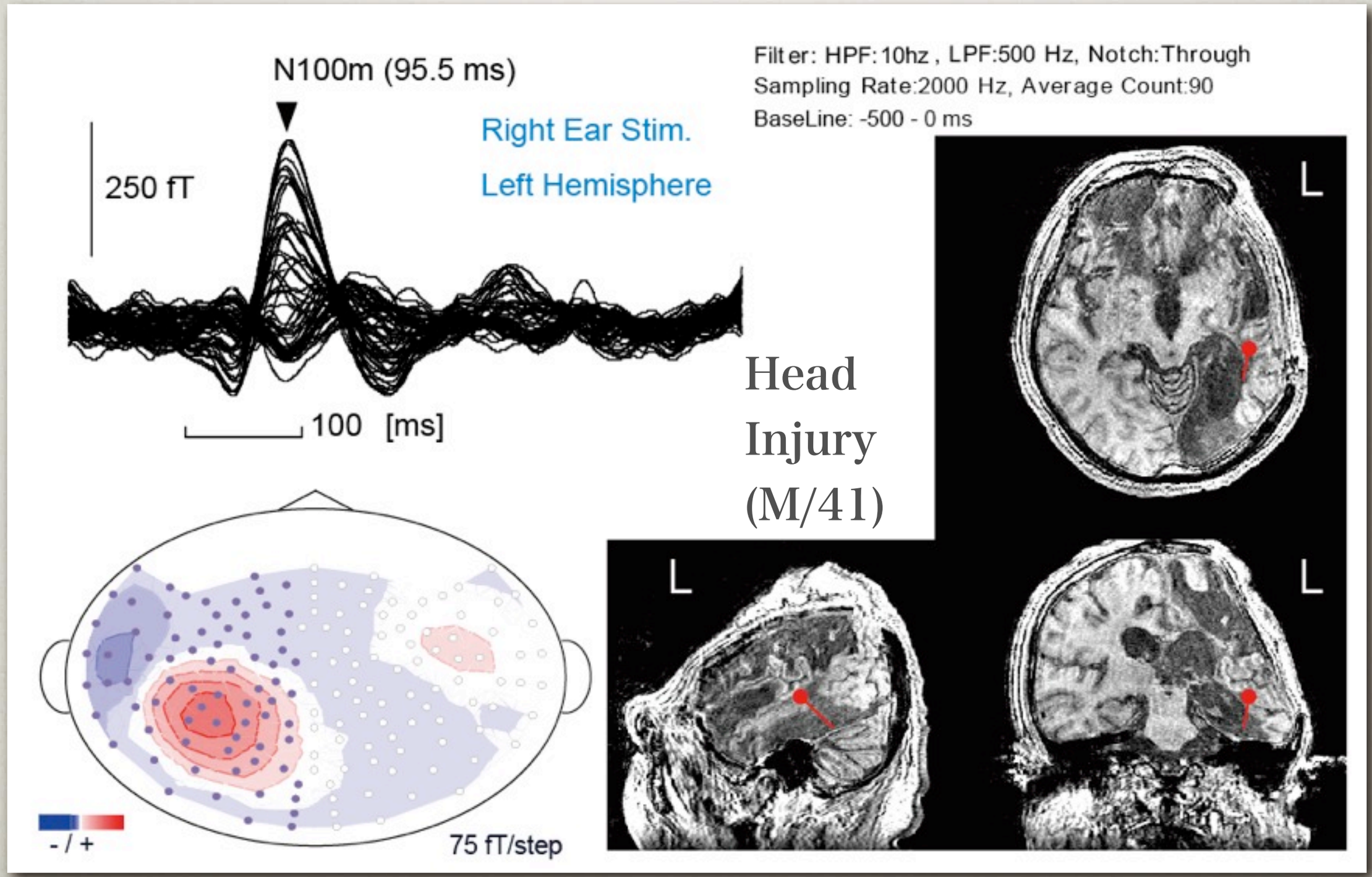
MEG

Head Injury (M/41)




Skull Defect

# Auditory Evoked Response (N100)



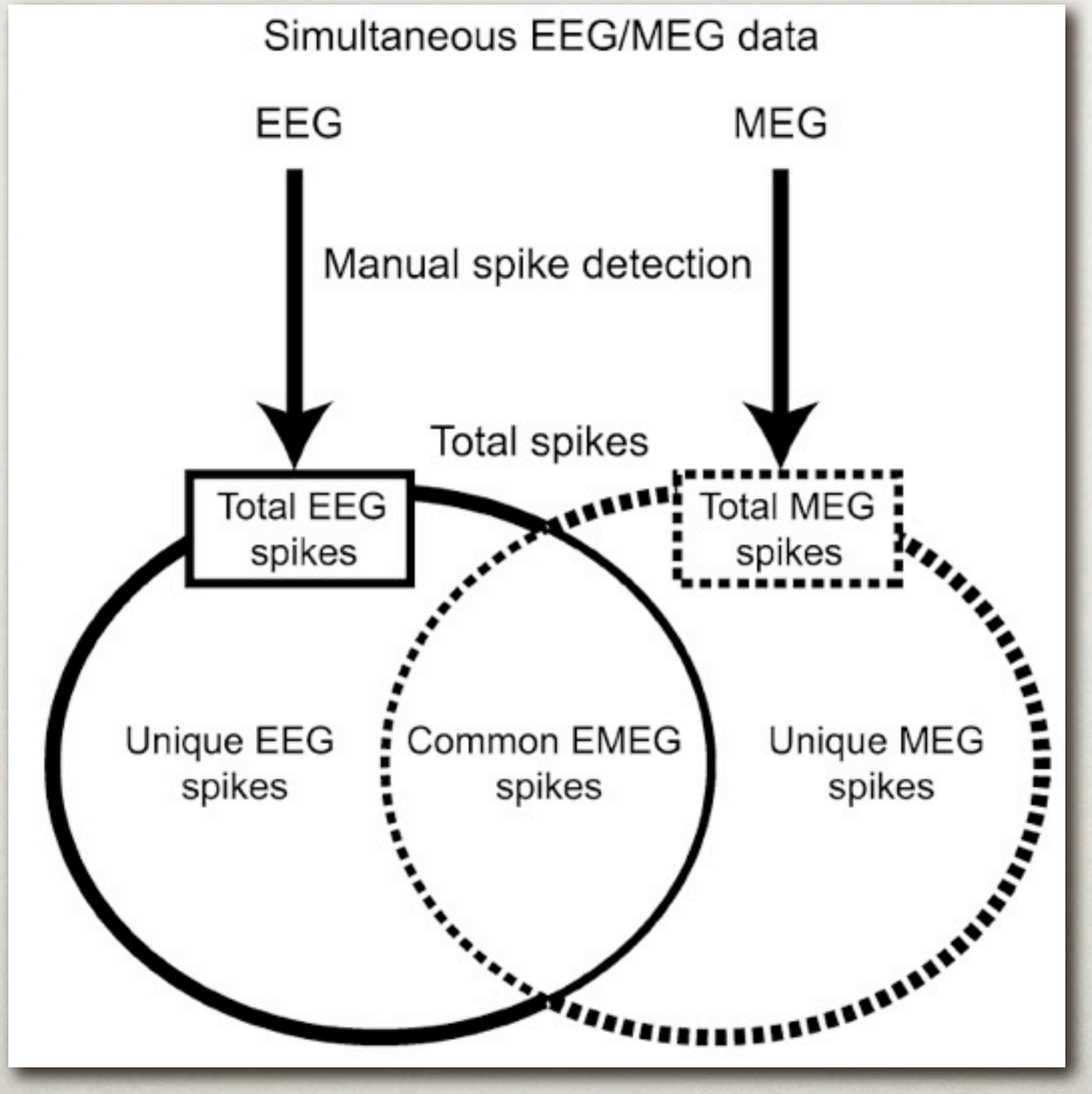
# Practical Problems in Spontaneous EEG and MEG Activity

| | | |
|---|---|---|
| Signal | Source Number | Unknown, usually multiple |
| | Source Extent | Unknown, usually wide |
| | Source Configuration | Unknown, usually complicated |
| | Source Stability | Unknown, usually moving, expanding, and propagating |
| Noise | Environmental Noise | Yes, but may be reduced technically |
| | Brain Noise | Yes, and hardly eliminated |

# What's the difference between EEG and MEG in practice?

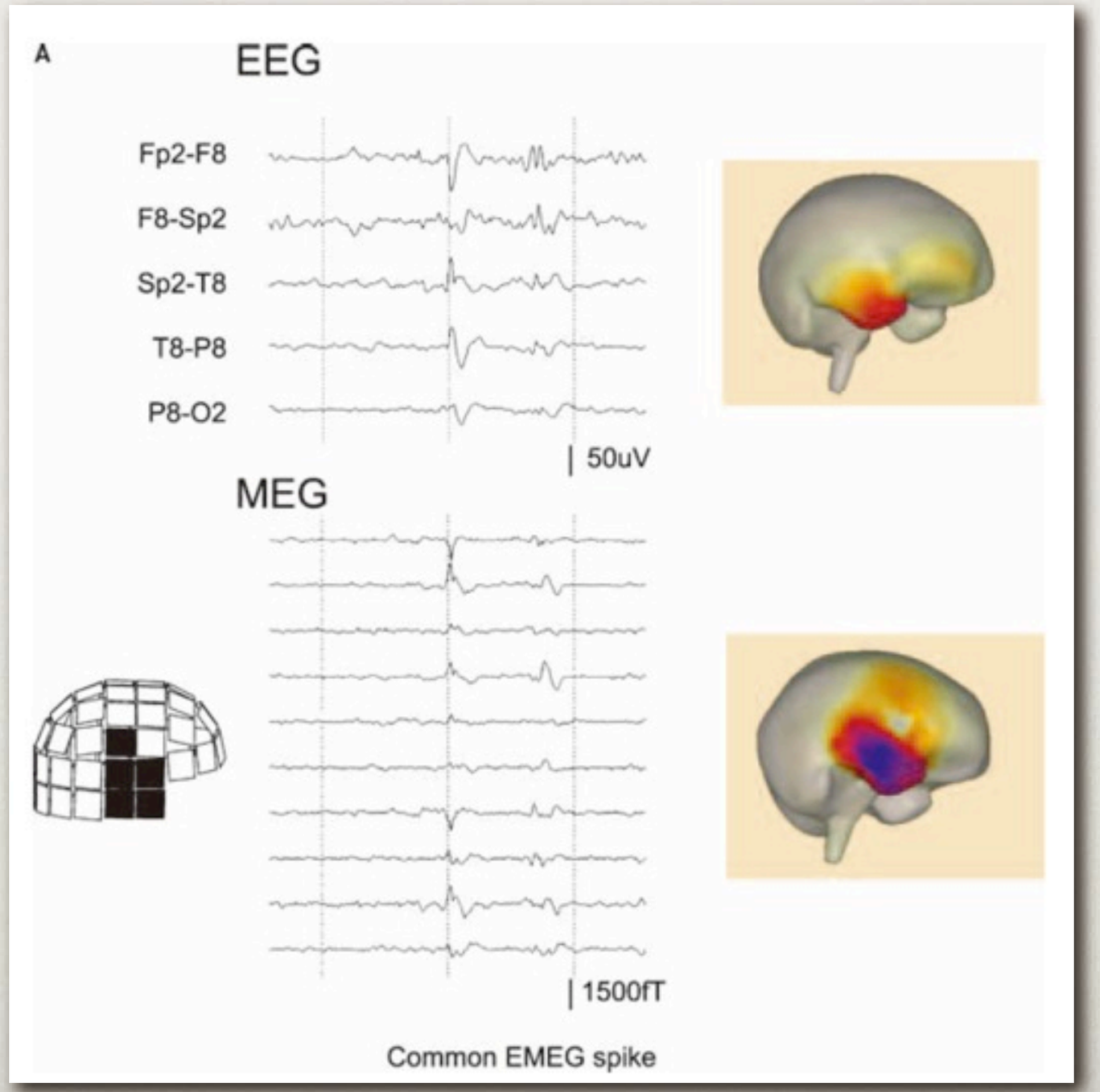
- Introduction
  - Theory & Practice
- Evoked Responses
  - Single Source
  - Dual Source
- Spontaneous Activity
  - Detectability
  - Localization
  - Orientation
- Summary

# Blinded Comparison of EEG and MEG



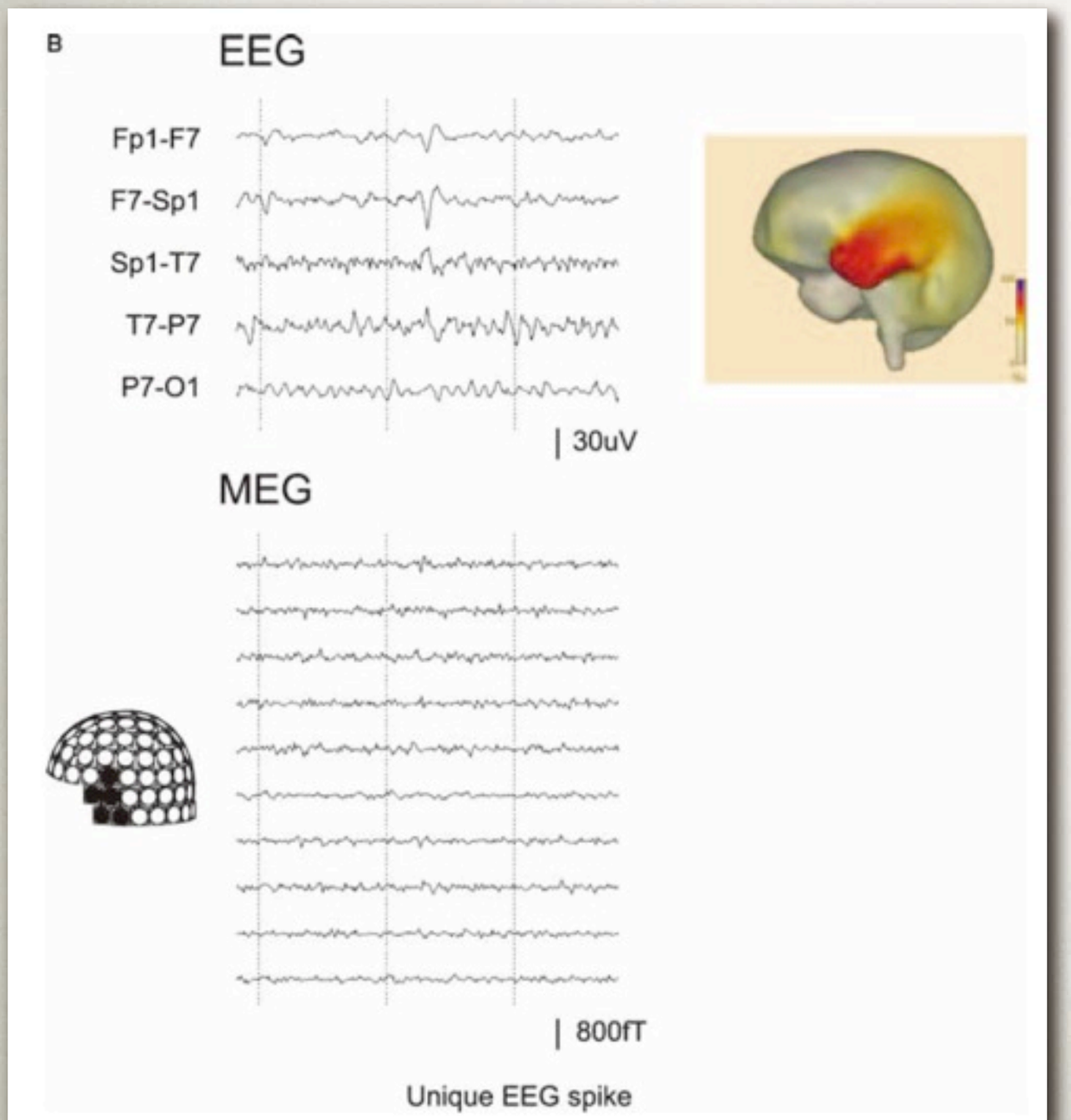

Iwasaki M, et al. 2003

# Blinded Comparison of EEG and MEG



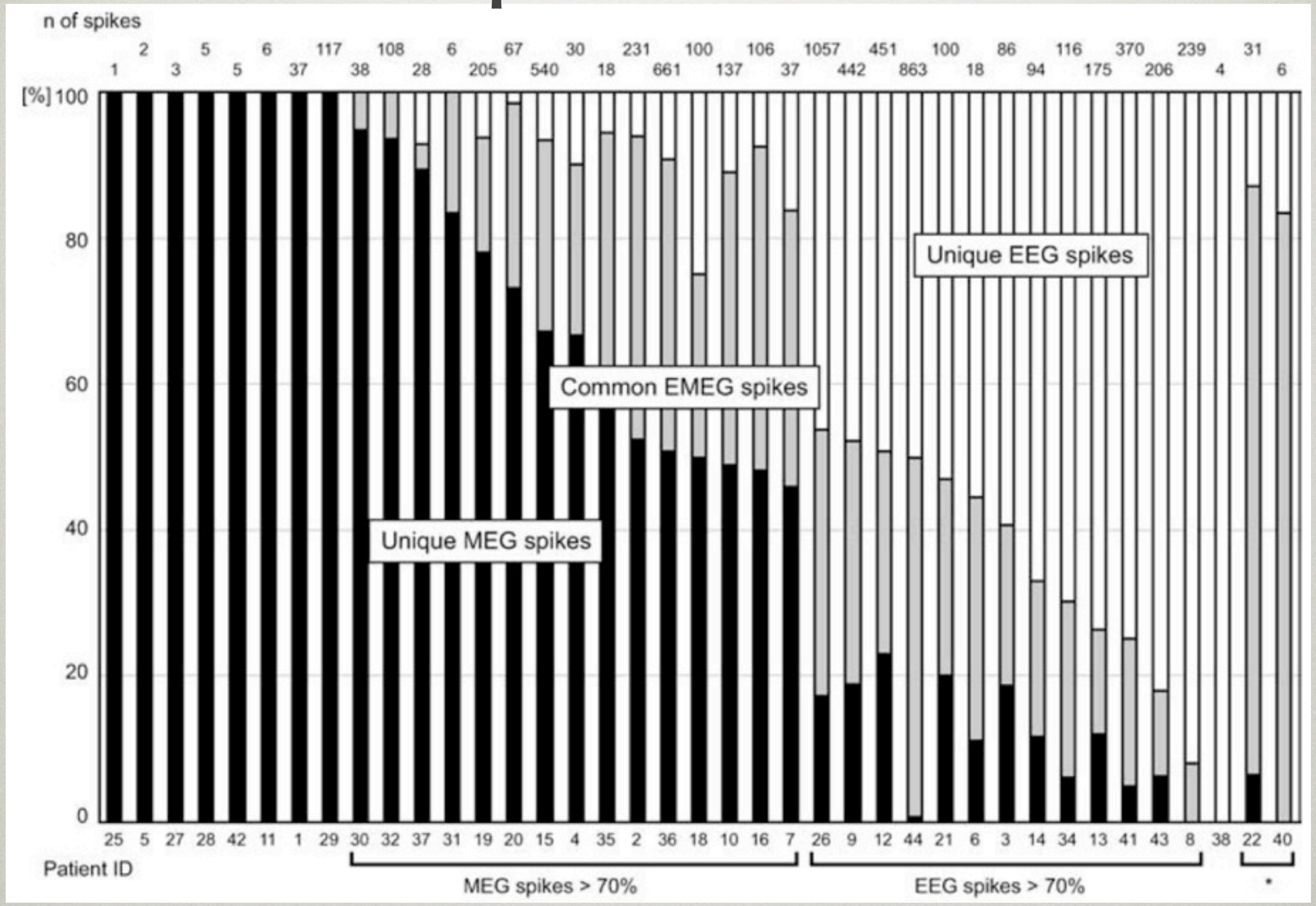

Iwasaki M, et al. 2003

# Blinded Comparison of EEG and MEG

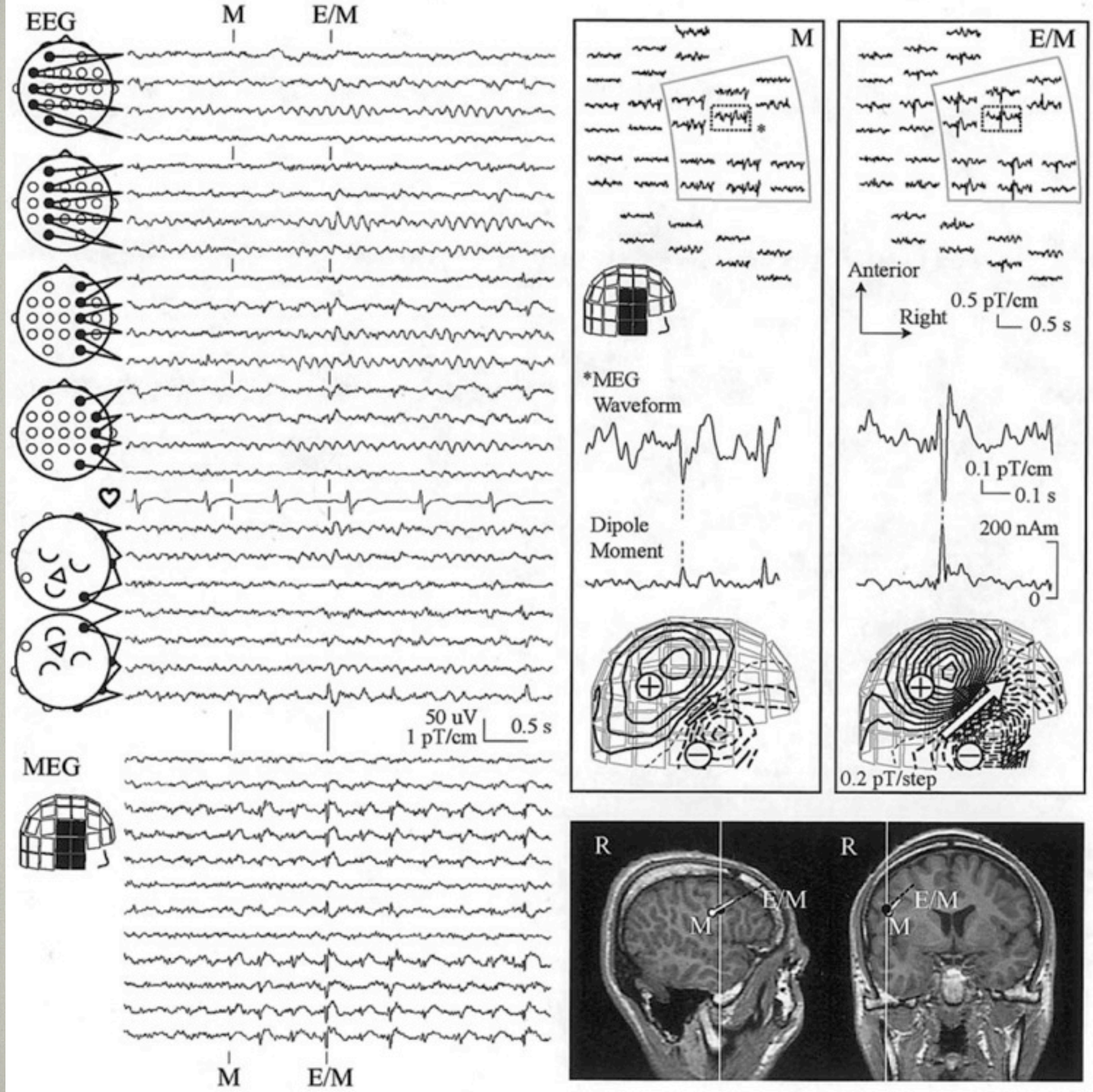



Iwasaki M, et al. 2003

# Blinded Comparison of EEG and MEG



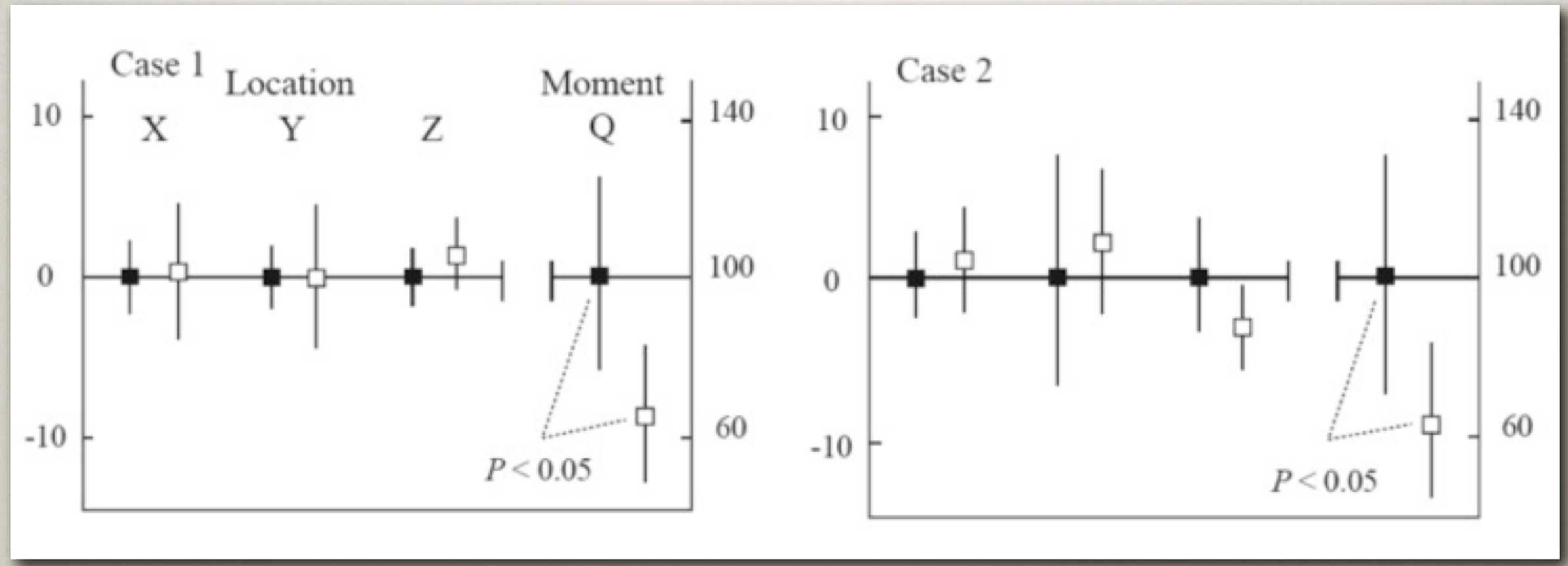

Iwasaki M, et al. 2003




Park HM, et al. 2003

# Scalp EEG may overlook small tangential spikes?

## Relative ECD Location (mm) and Moment (%)

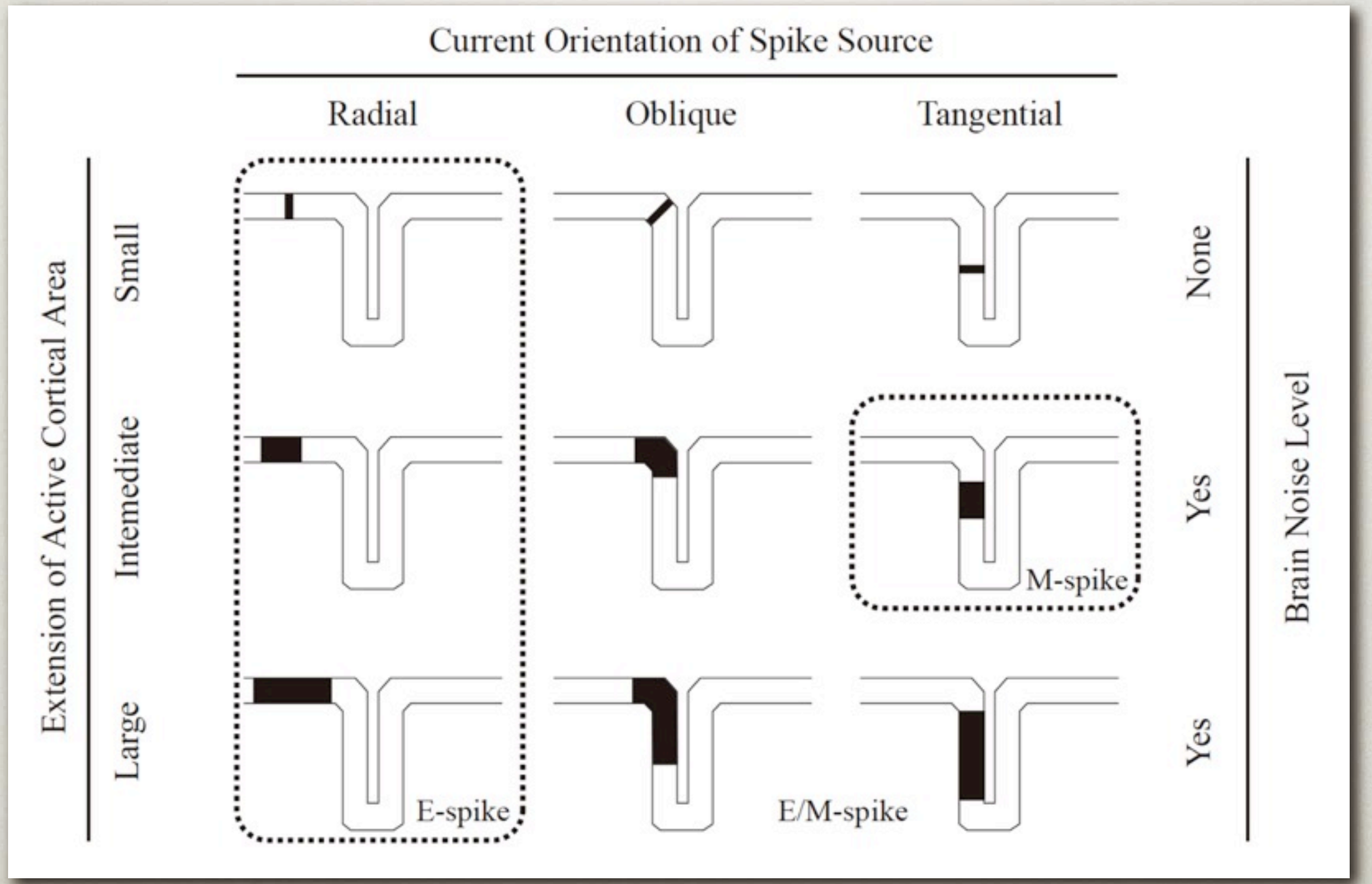



■ E/M spikes

□ M spikes

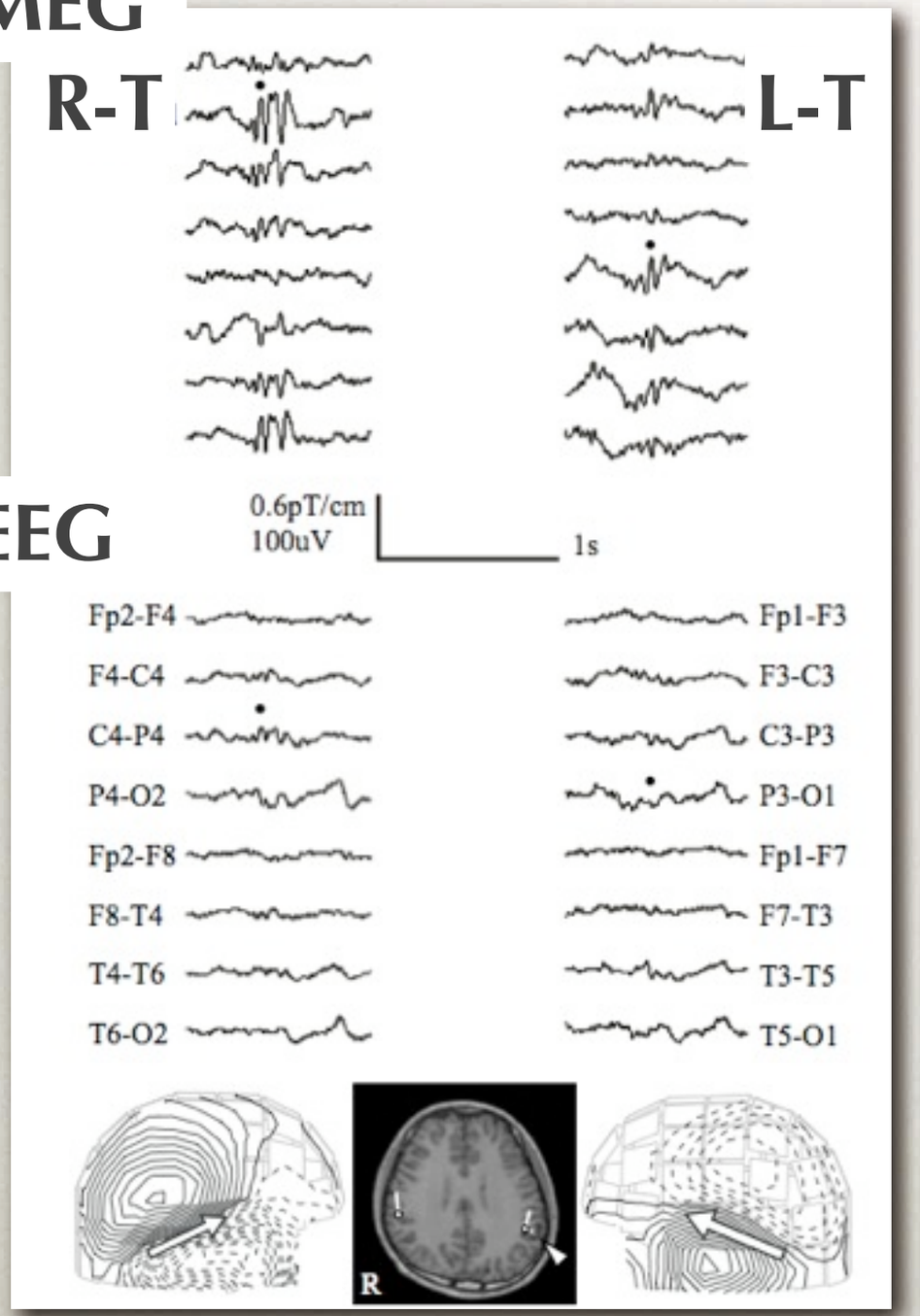
Park HM, et al. 2003

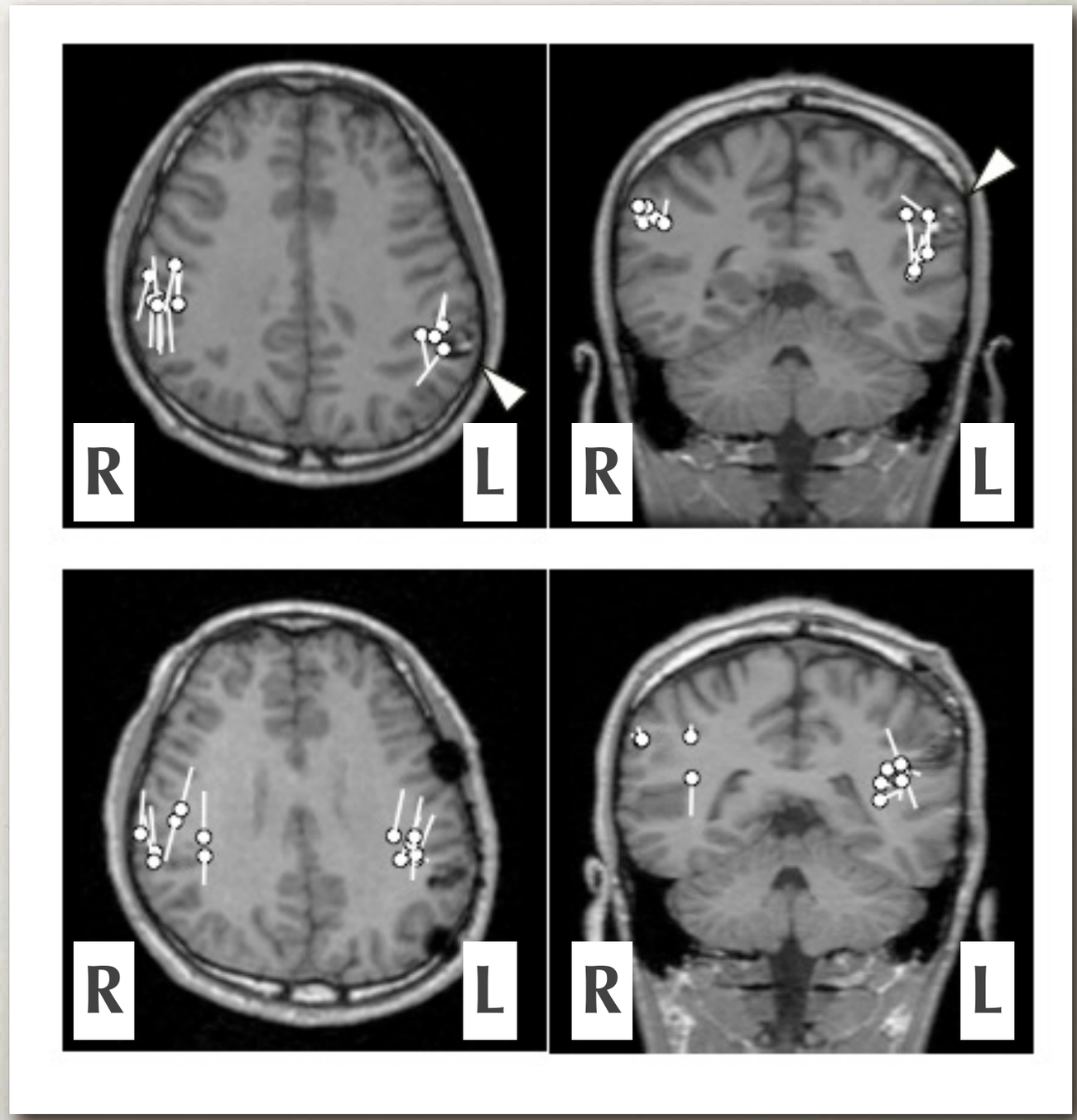
# Scalp EEG may overlook small tangential spikes?




Park HM, et al. 2003

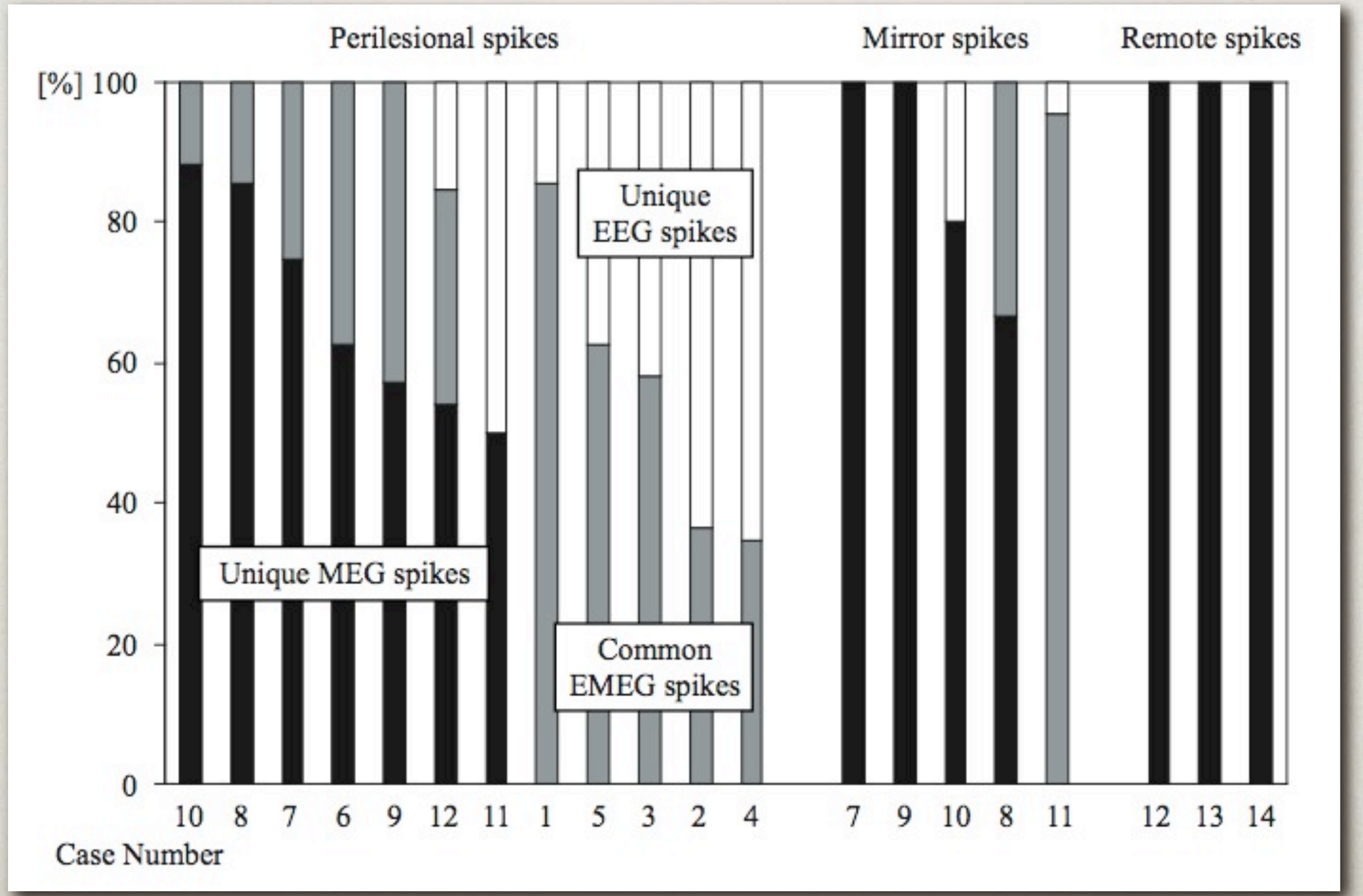
# Perilesional, Mirror and Remote Spikes in Single Cavernoma




Jin K, et al. 2007

# Perilesional, Mirror and Remote Spikes in Single Cavernoma

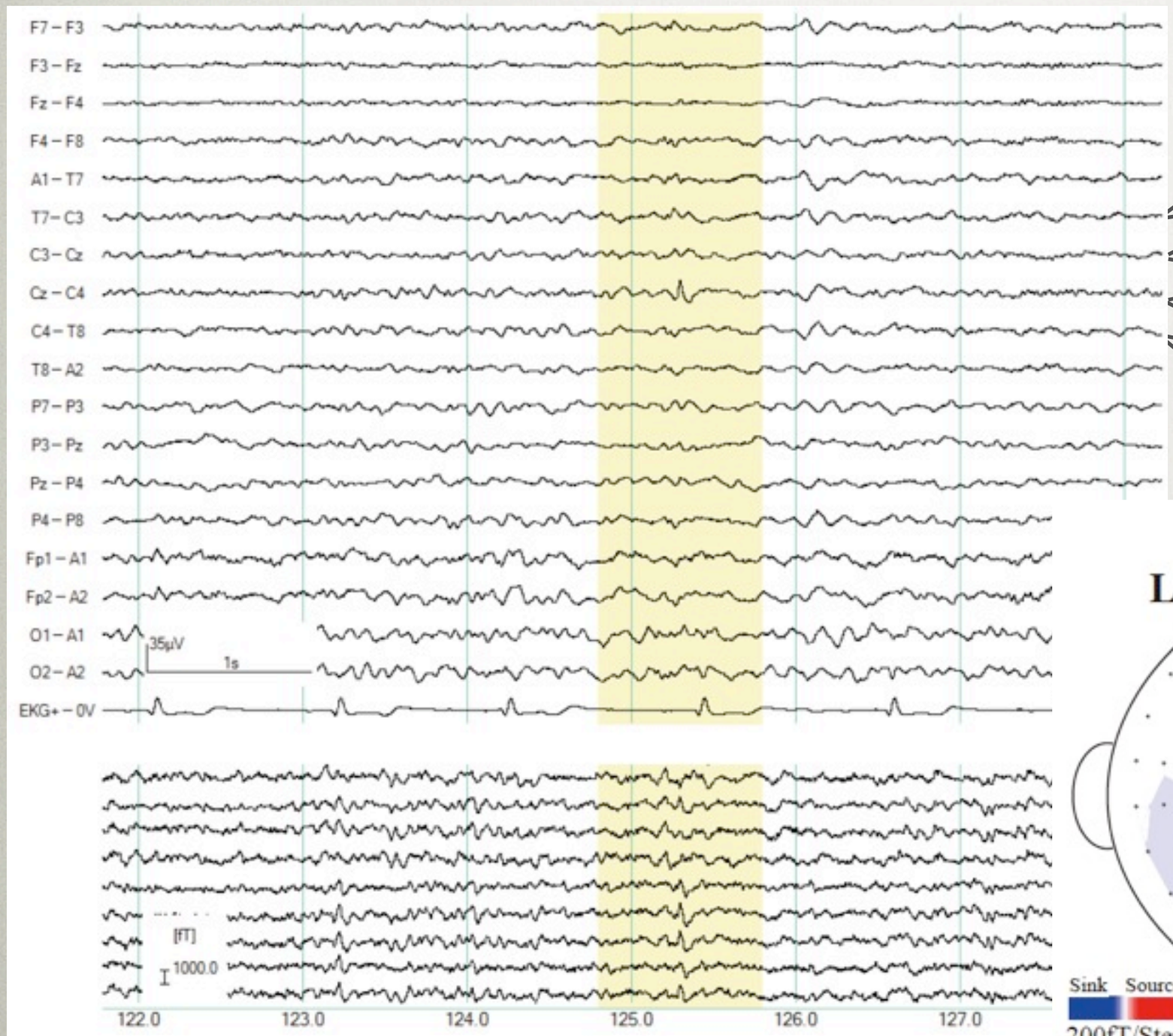



Jin K, et al. 2007

# What's the difference between EEG and MEG in practice?

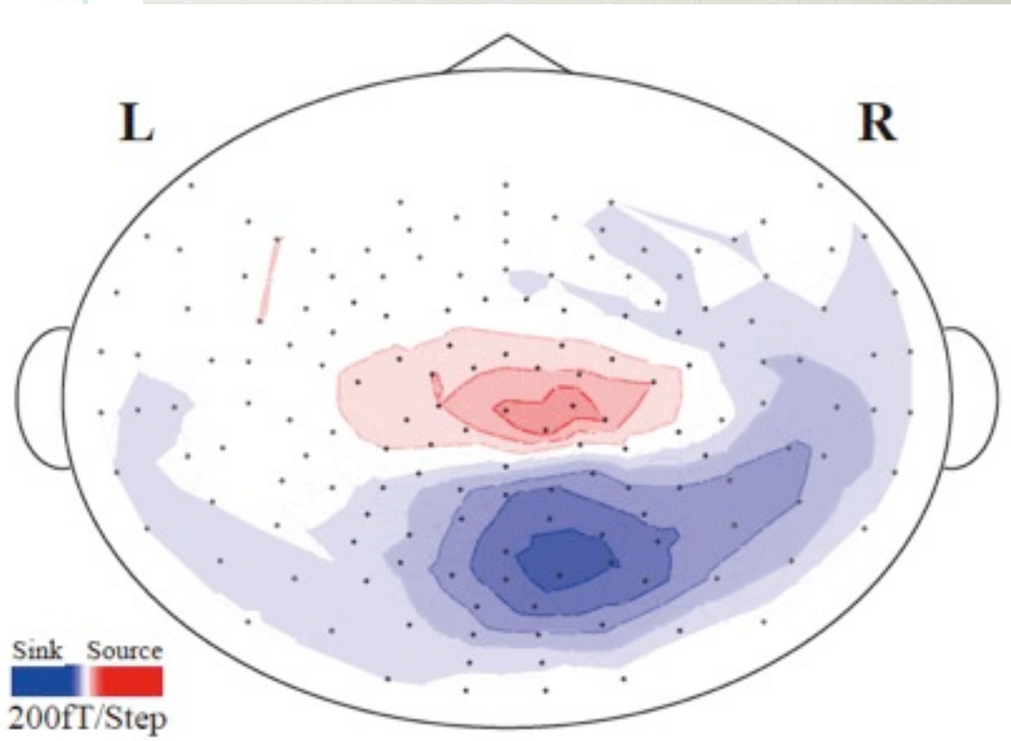
- Introduction
  - Theory & Practice
- Evoked Responses
  - Single Source
  - Dual Source
- Epileptic Spikes
  - Detectability
  - Localization
  - Orientation
- Summary

# Localization: Simple & Excellent

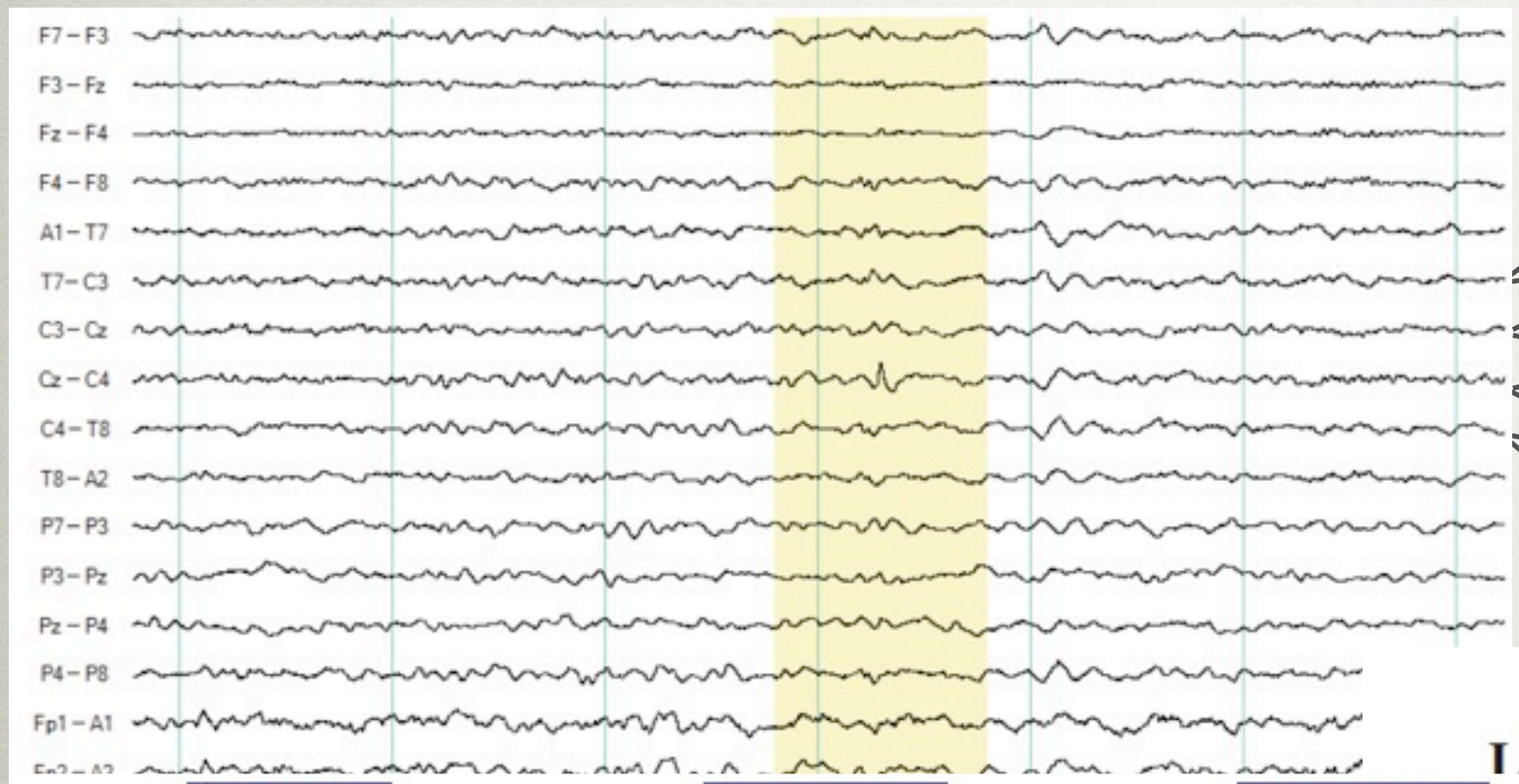



T7
C3
Cz
C4
T8

Left leg twitch followed by 2nd-GTC (M/20)

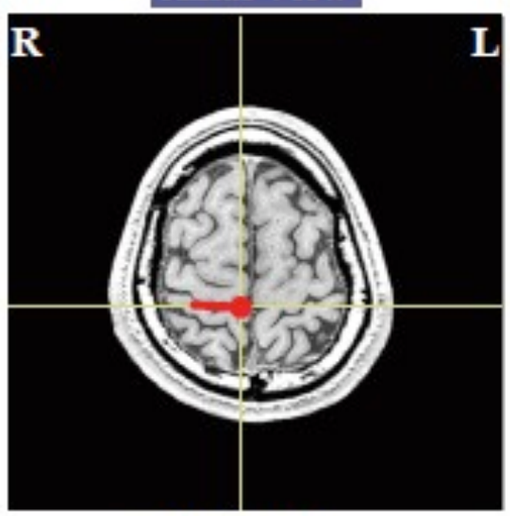


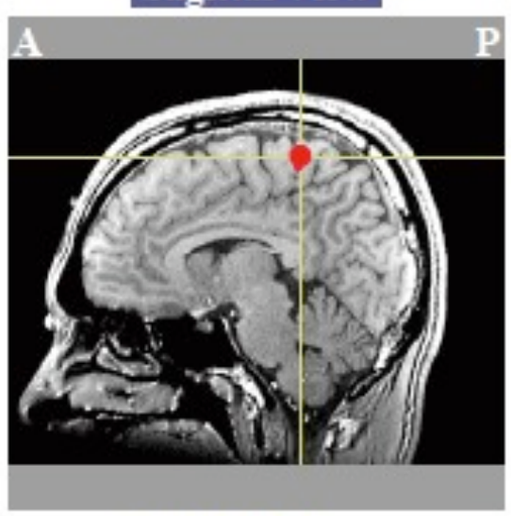
# Localization: Simple & Excellent

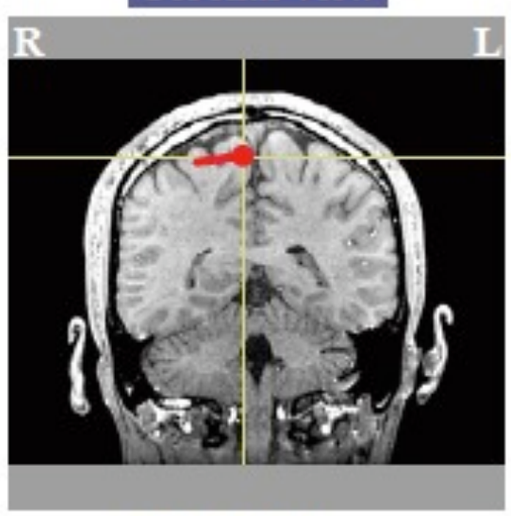


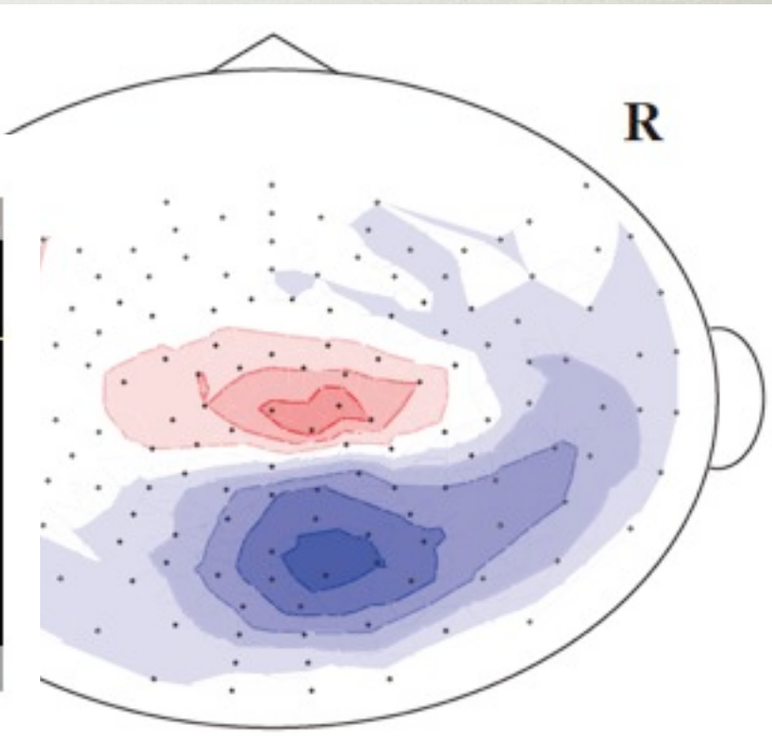

T7
C3
Cz
C4
T8

Left leg twitch followed by 2nd-GTC (M/20)

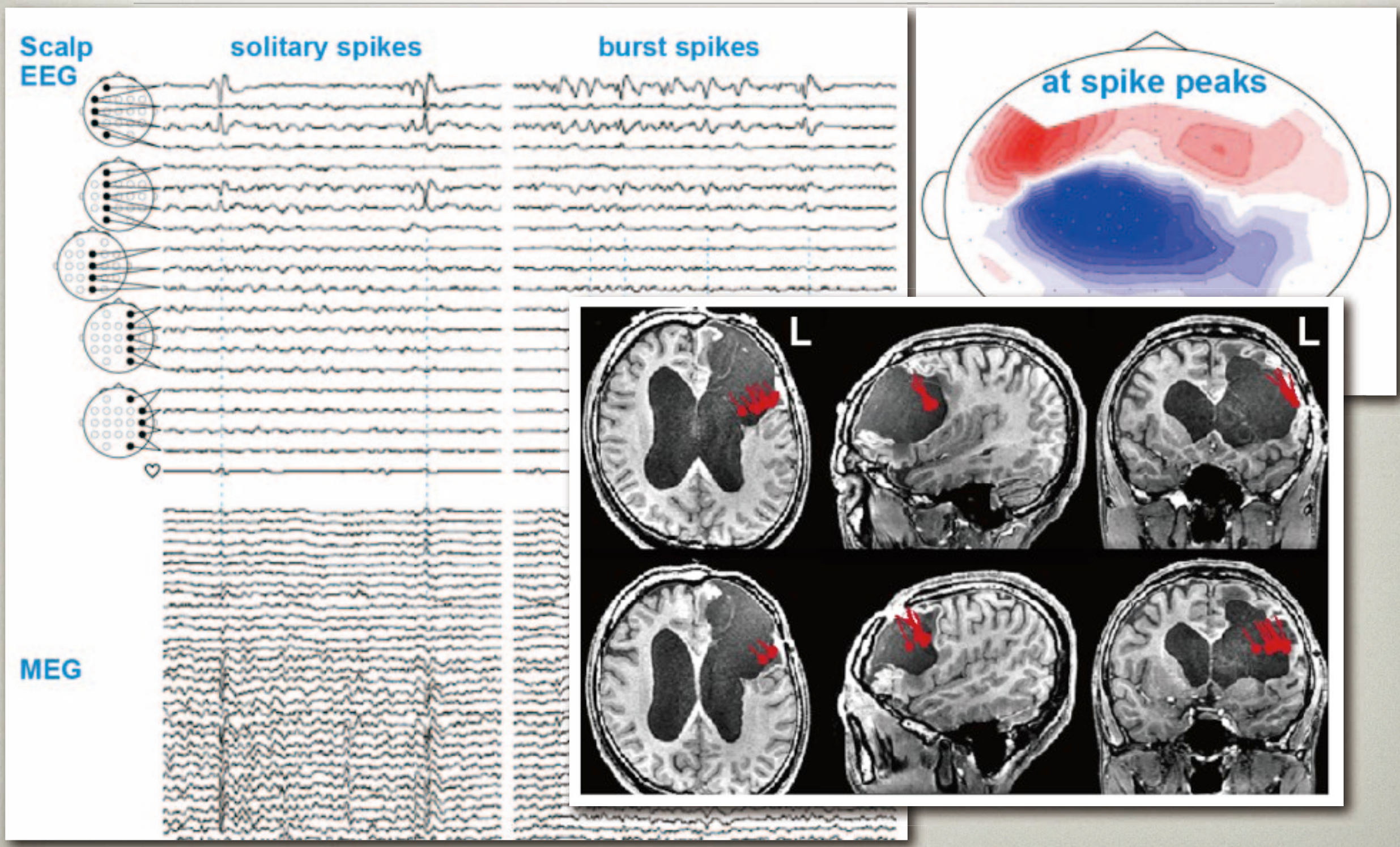


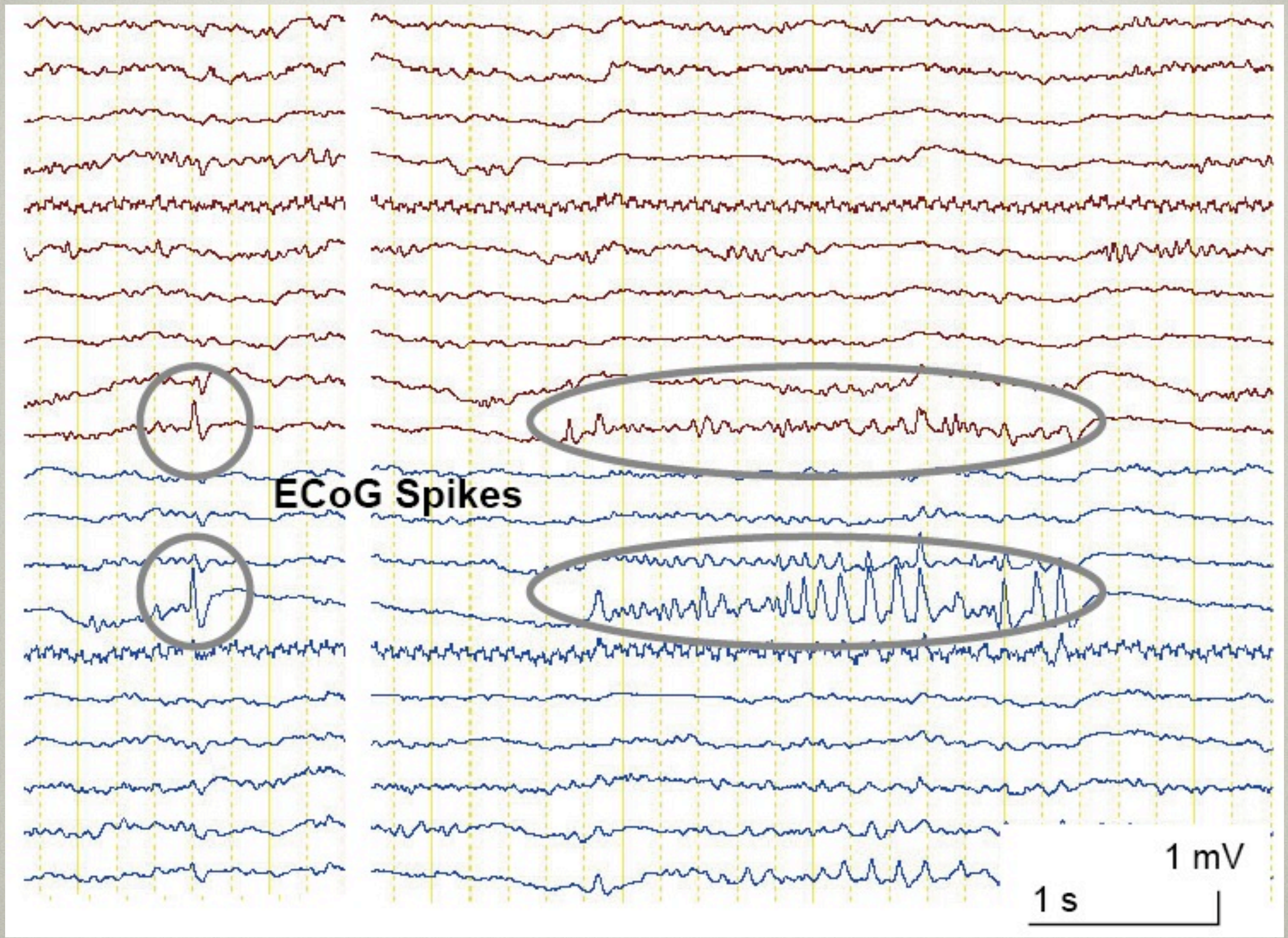



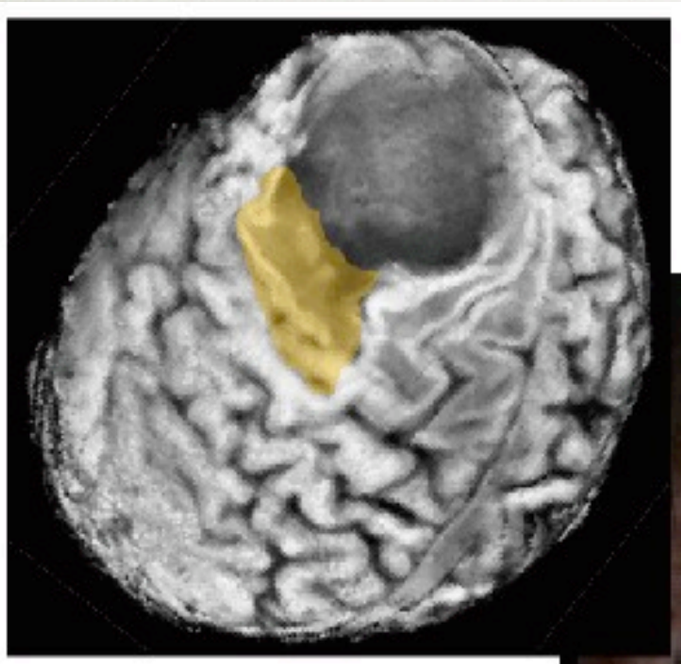



# Localization: Simple & Excellent



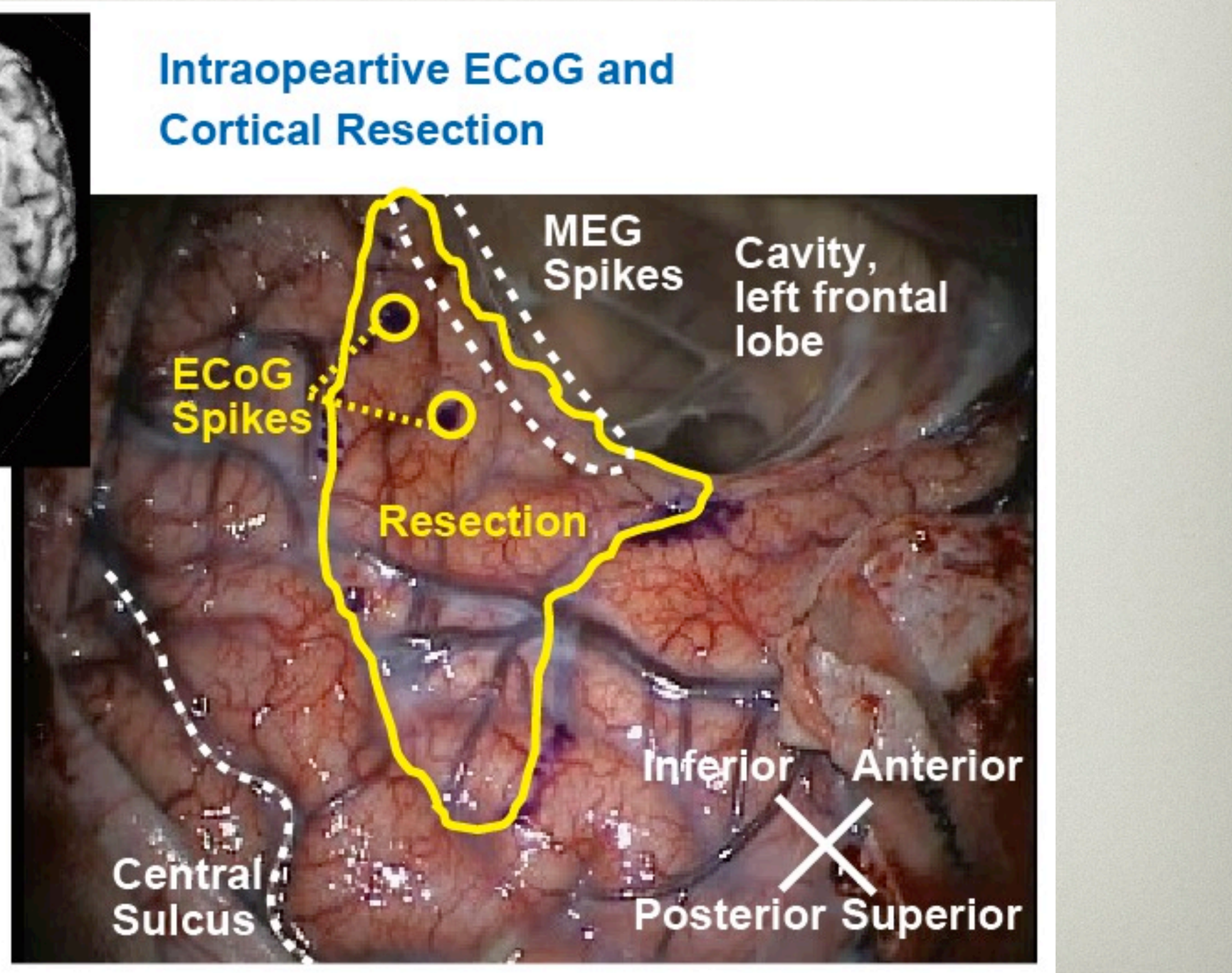

ECoG Spikes
1 mV
1 s

# Localization: Simple & Excellent



- ECoG spike zone adjacent to MEG spike zone on the edge of resection cavity in previous surgery.

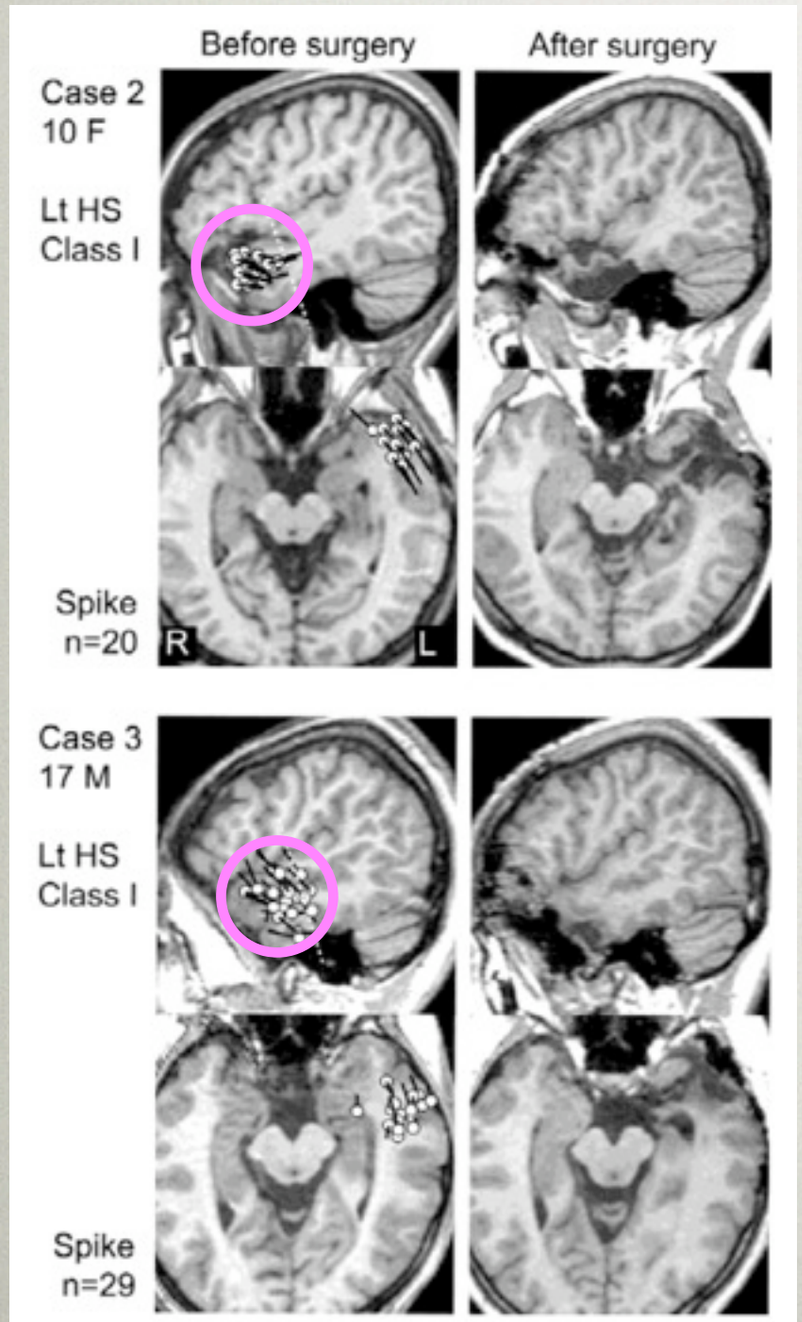
- Seizure free with no neurological deficit after cortical resection.



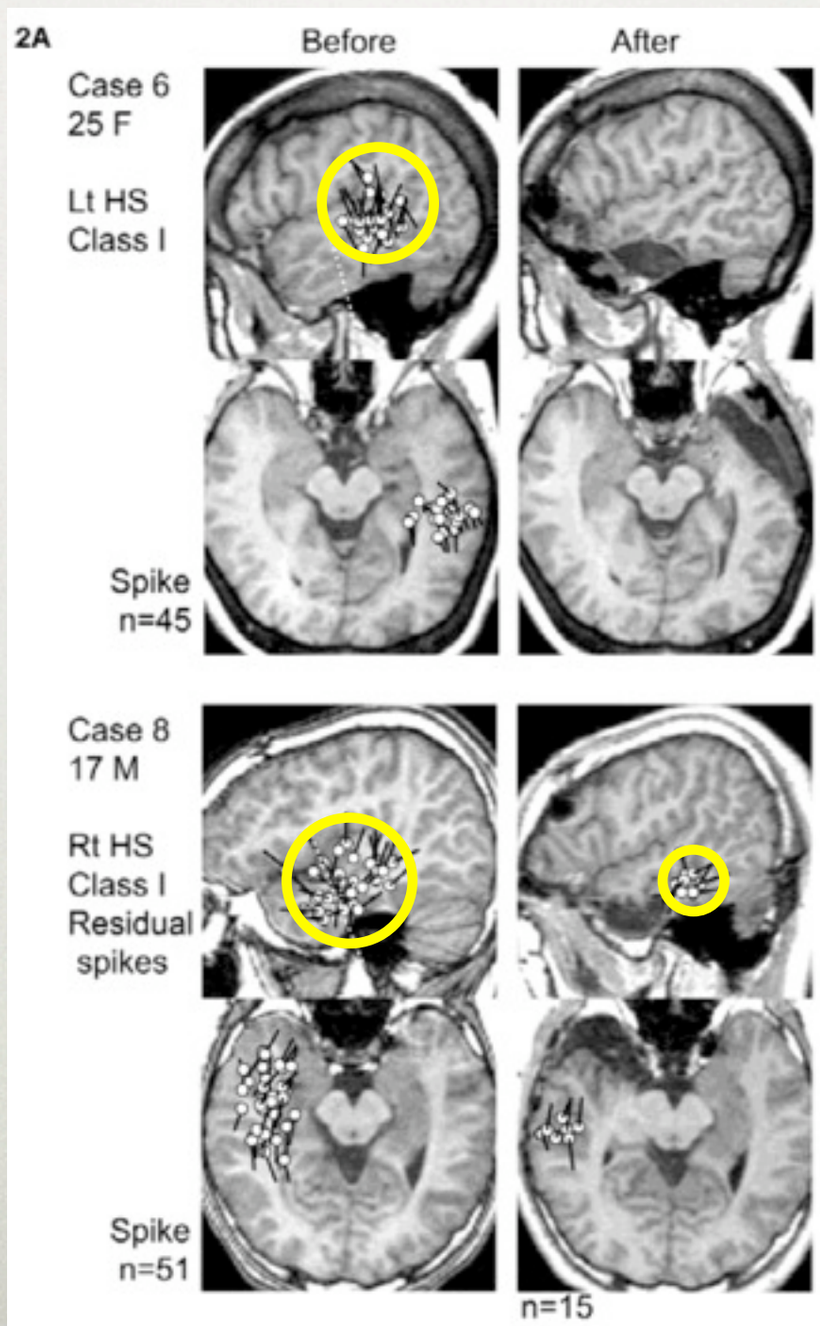
Iwasaki et al. 2002

# Localization: Propagation

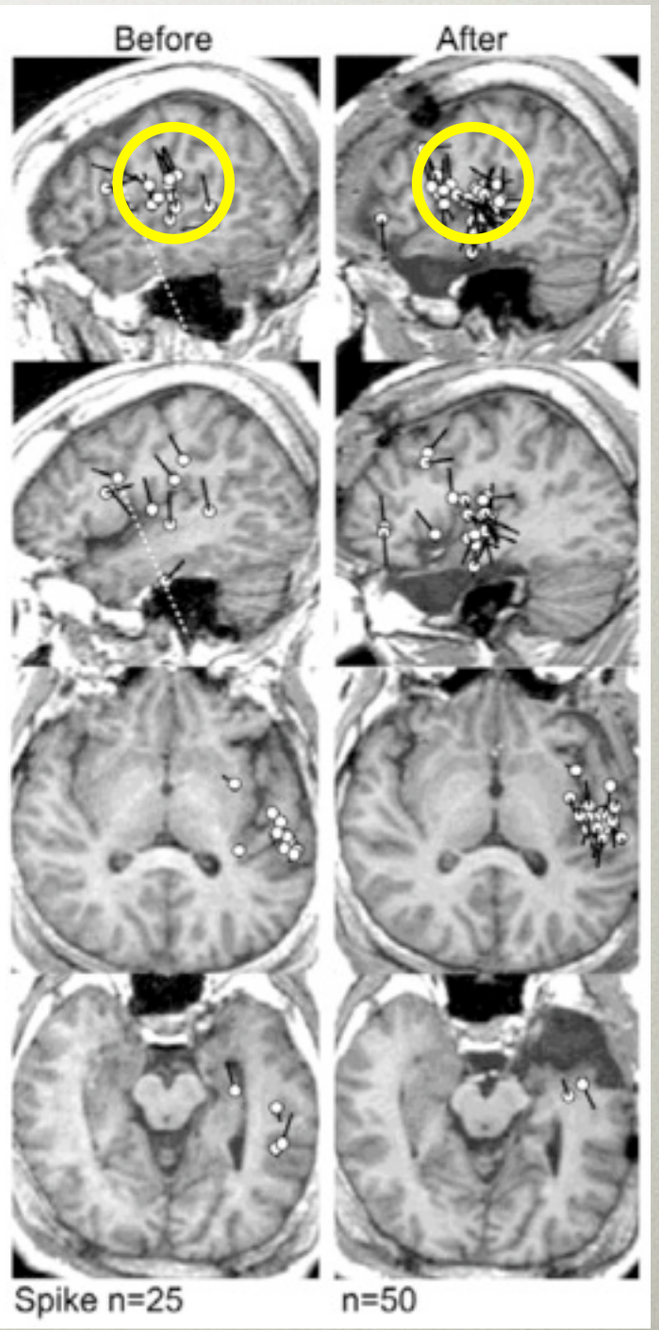
**AT, Class-I**



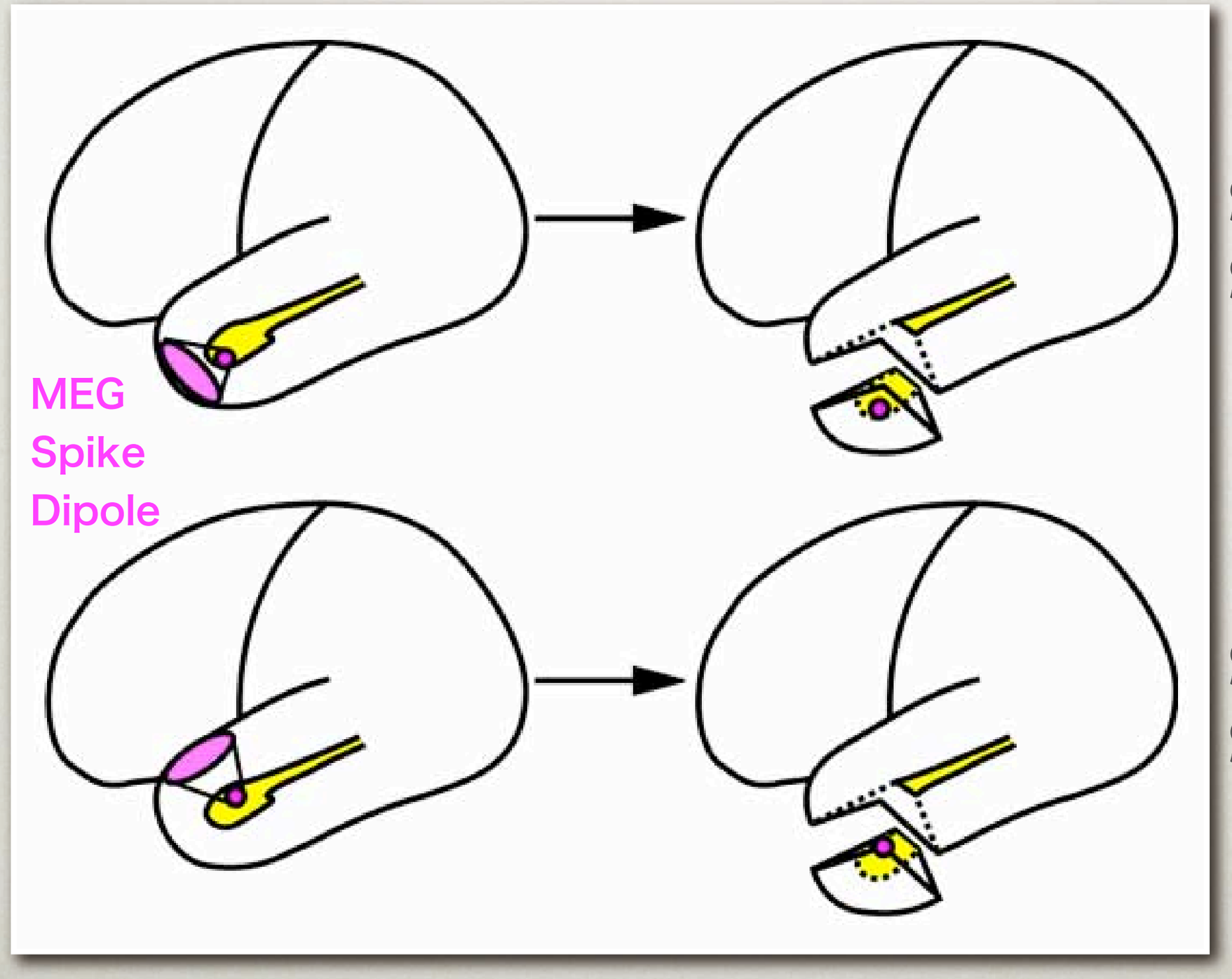

**Non-AT, Class-I**




**Non-AT, Class-III**



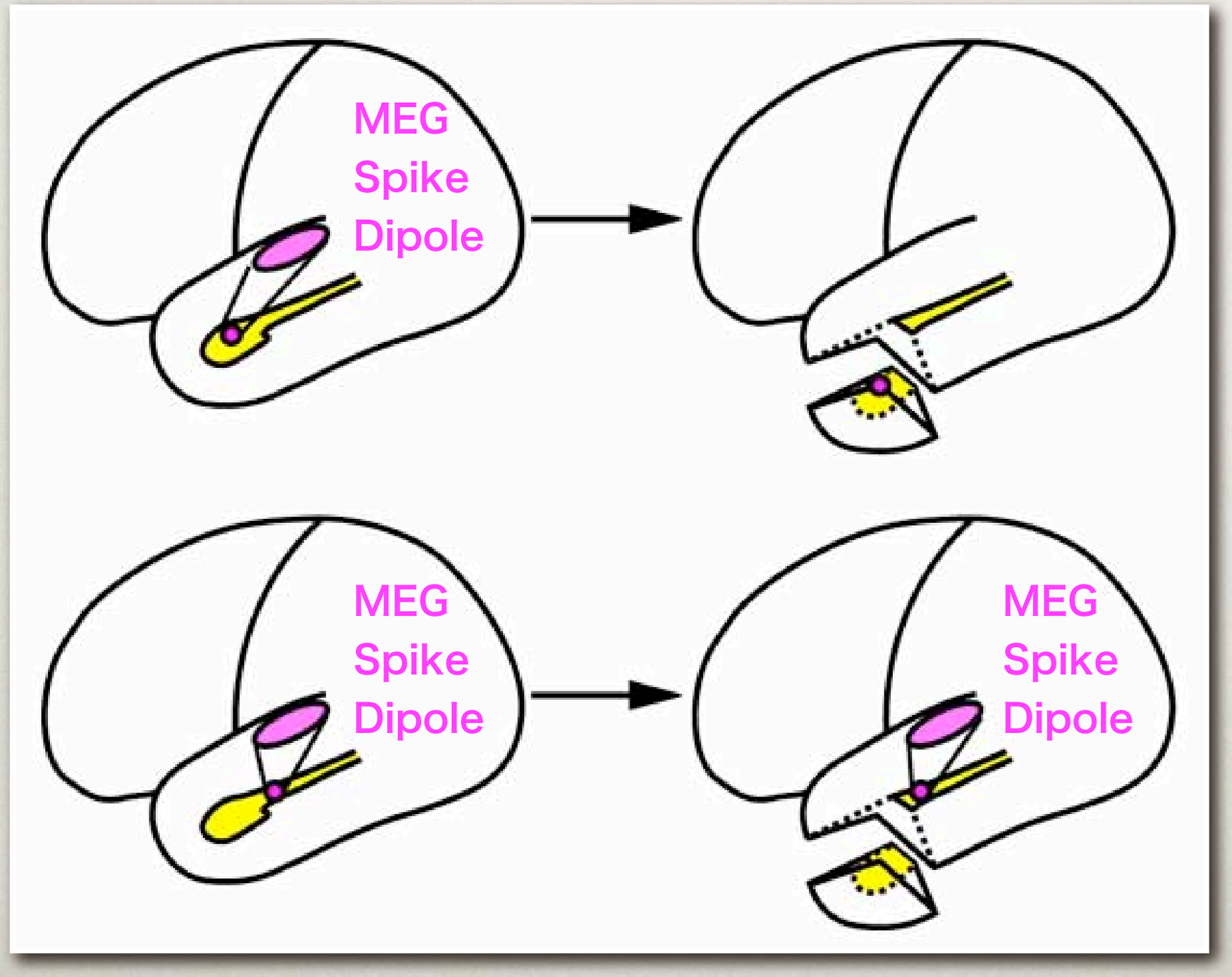
# Propagation Hypothesis: Anterior T.




Spike (-)
Seizure (-)

Spike (-)
Seizure (-)

# Propagation Hypothesis: Non-Ant. T.




Spike (-)
Seizure (-)

Spike (+)
Seizure (+)

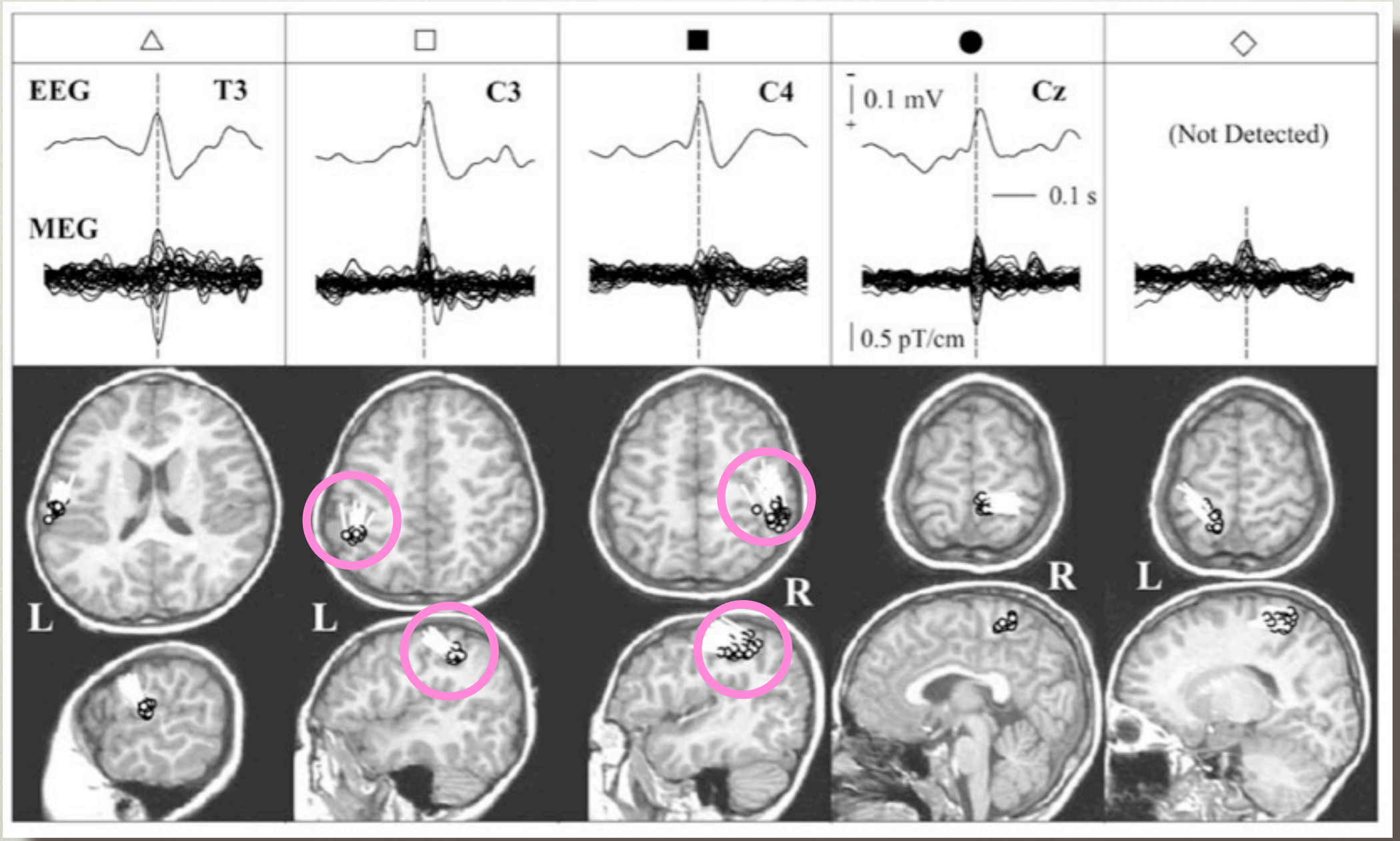
# What's the difference between EEG and MEG in practice?

- Introduction
  - Theory & Practice
- Evoked Responses
  - Single Source
  - Dual Source
- Epileptic Spikes
  - Detectability
  - Localization
  - Orientation
- Summary

# Benign Childhood Epilepsy with Centro-Temporal Spikes (BECCT)

- Idiopathic localization-related epilepsy
- Childhood-onset
- Motor and/or sensory symptom of orofacial, unilateral upper and/or lower limbs
- Rare seizure attacks
- Frequent spontaneous remission

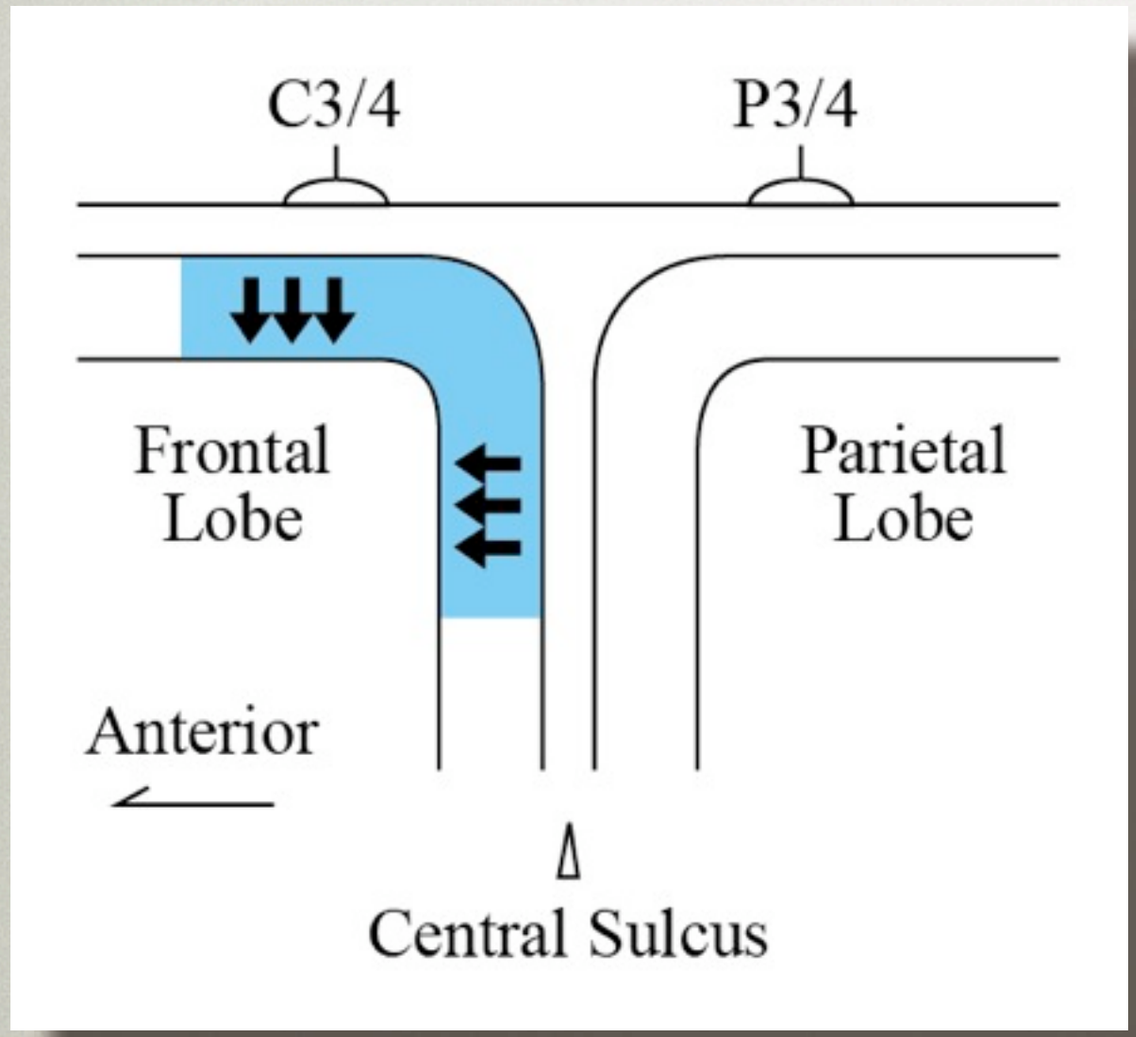
# Benign Rolandic Spikes



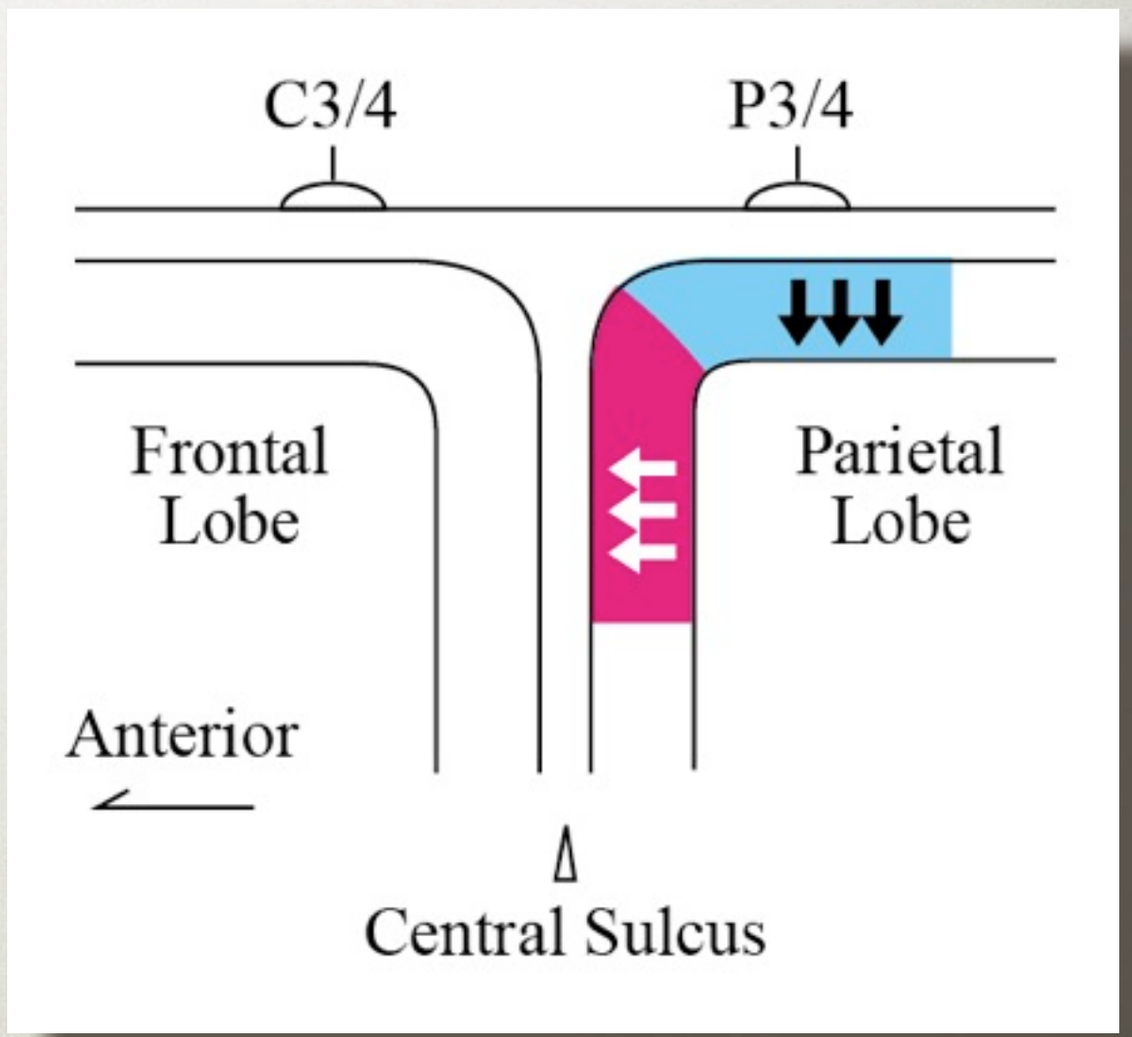

Ishitobi M et al. 2005

# Benign Rolandic Spikes

## Frontal Lobe Theory (Ishitobi et al. 2005)




## Parietal Lobe Theory (previous articles)

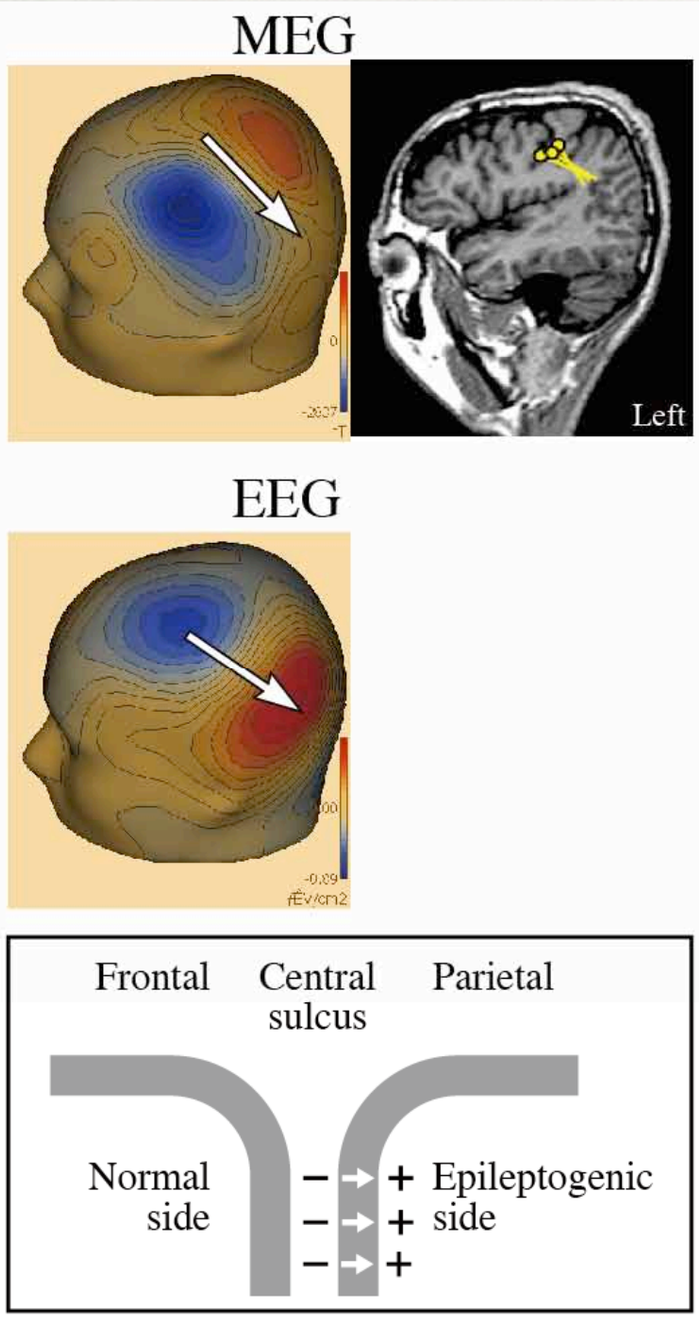


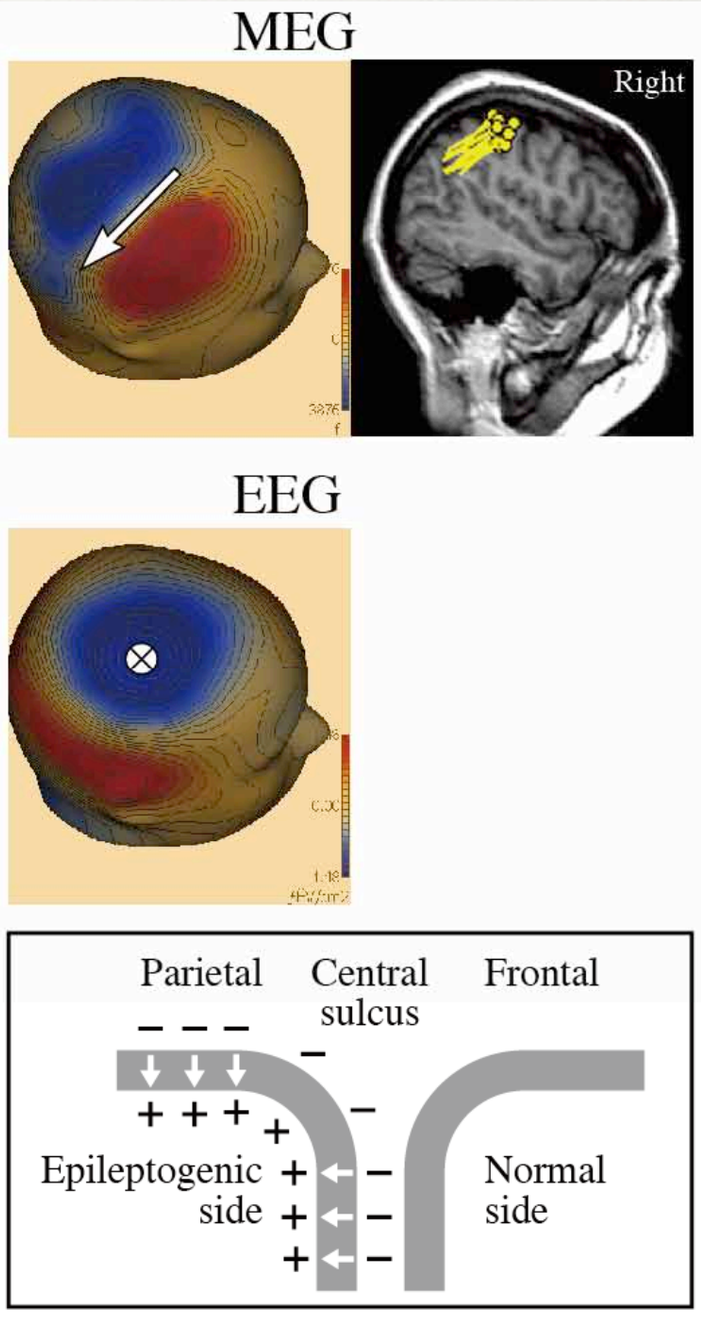

Ishitobi M et al. 2005

# Spike Orientation Predicts ...

**Case 1: Lt PLE**

**Central Spike, Posterior**




**Case 2: Rt PLE**

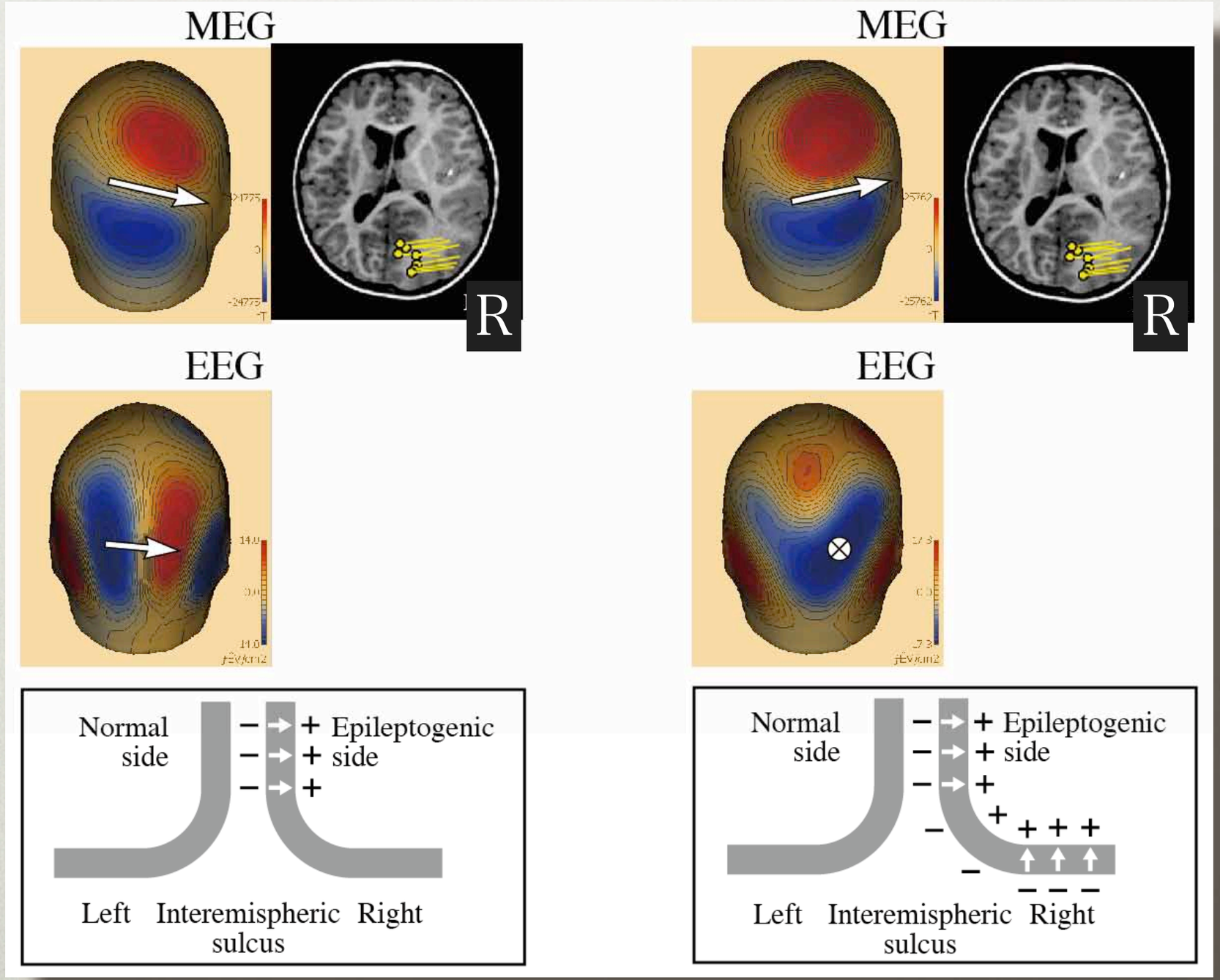
**Central Spike, Posterior**

Salayev KA et al. 2006

# Spike Orientation Predicts …

**Case 3: OLE**

**Medial Spike, towards Right**

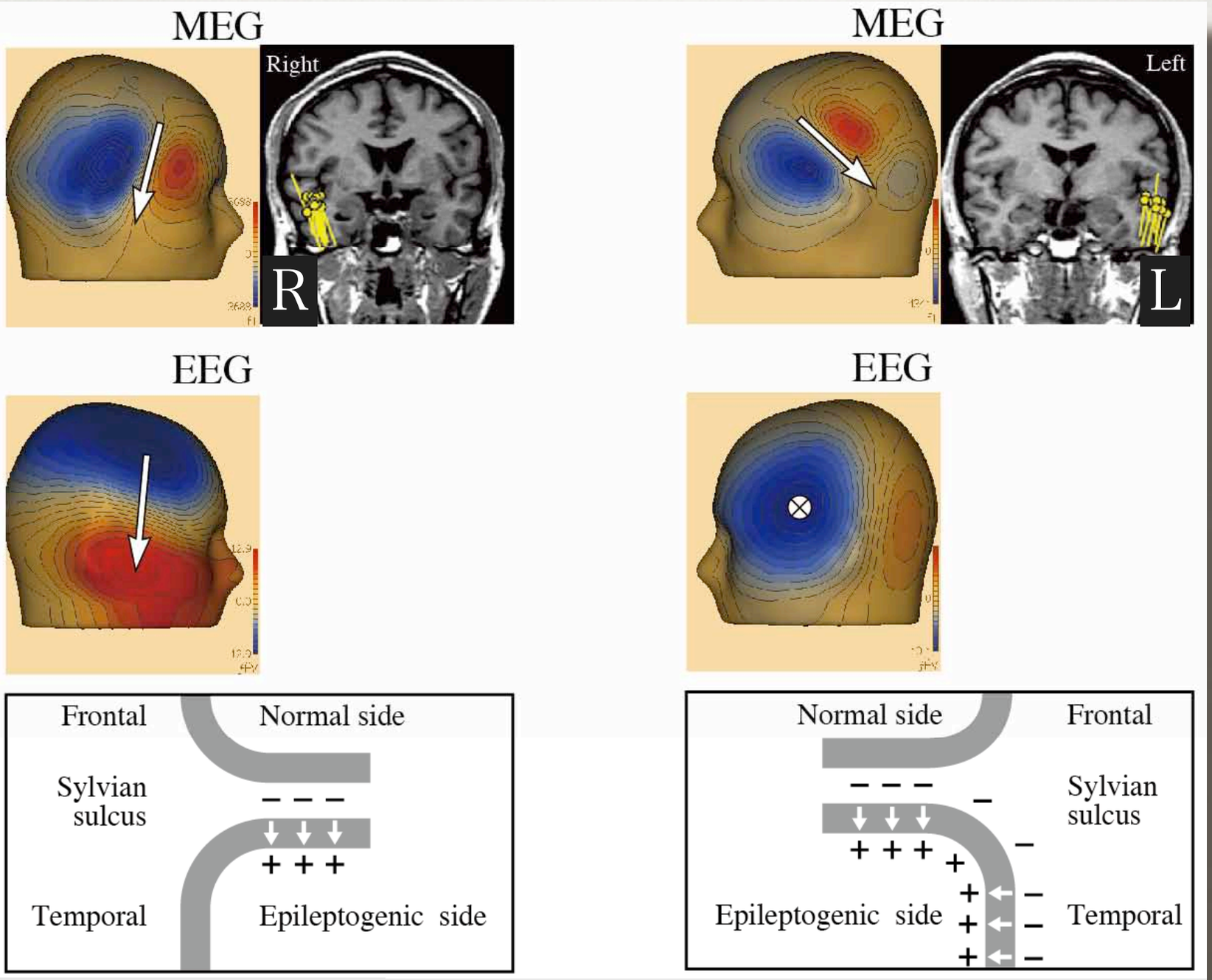



Salayev KA et al. 2006

# Spike Orientation Predicts ...

**Case 4: Rt TLE**

**Sylvian Spike, Downward**




**Case 5: Lt TLE**

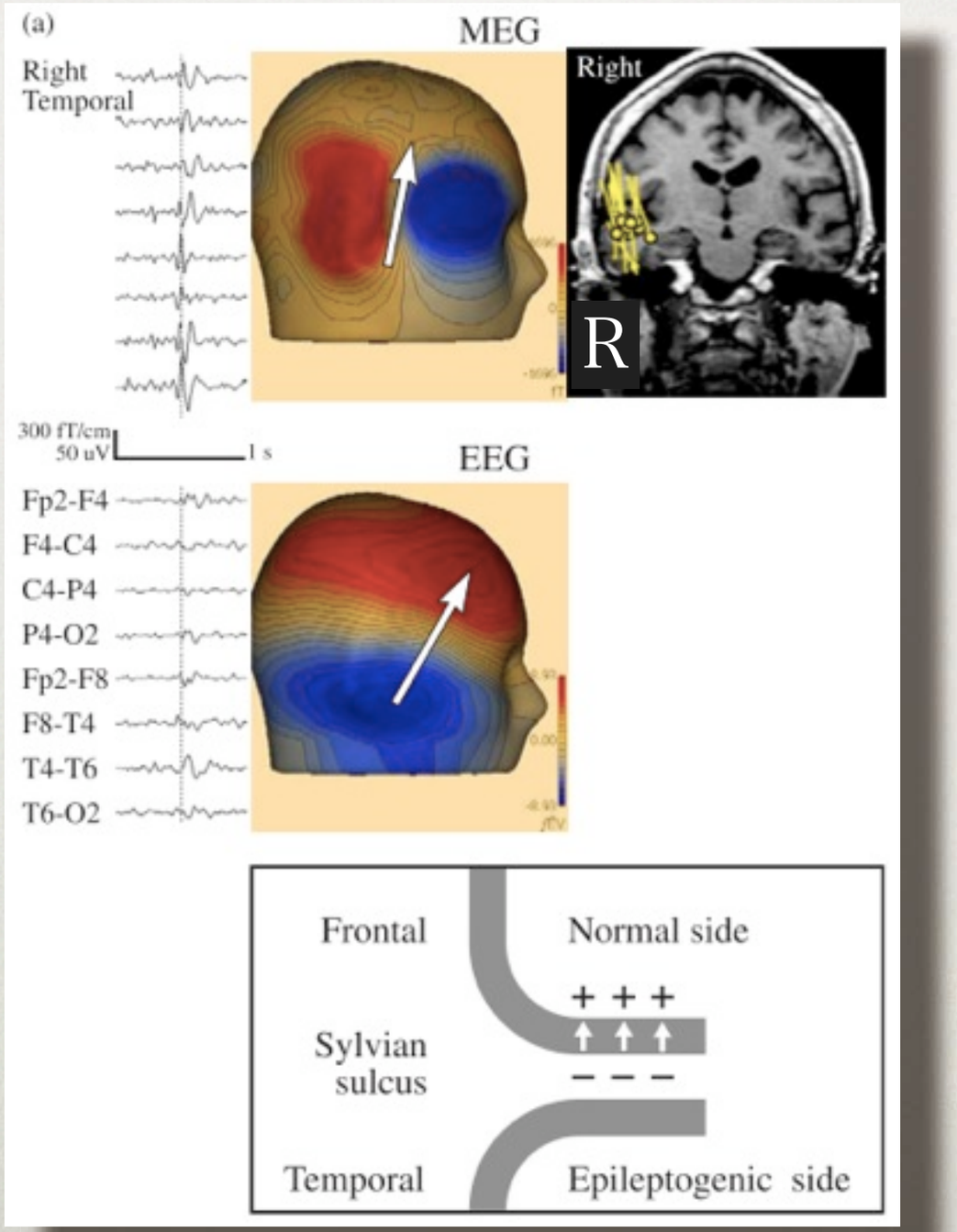
**Sylvian Spike, Downward**

Salayev KA et al. 2006

# Spike Orientation *Did Not* Predict ...

**Case 6: Rt TLE**

**Sylvian Spike, Upward**




Salayev KA et al. 2006

# Spike Orientation Predicts ...

- **Central (Rolandic) Spike**
  - Anterior Orientation: Frontal Side (100%)
  - Posterior Orientation: Parietal Side (100%)
- **Interhemispheric Spike**
  - Right Orientation: Right Hemisphere (100%)
  - Left Orientation: Left Hemisphere (100%)
- **Sylvian Spike in Temporal Lobe Epilepsy**
  - Downward Orientation: 73% of Sylvian spikes
  - Upward Orientation: 27% of Sylvian spikes

Exceptional !

Salayev KA et al. 2006

# Sensorimotor Seizures of Pediatric Onset with Unusual Posteriorly Oriented Rolandic Spikes

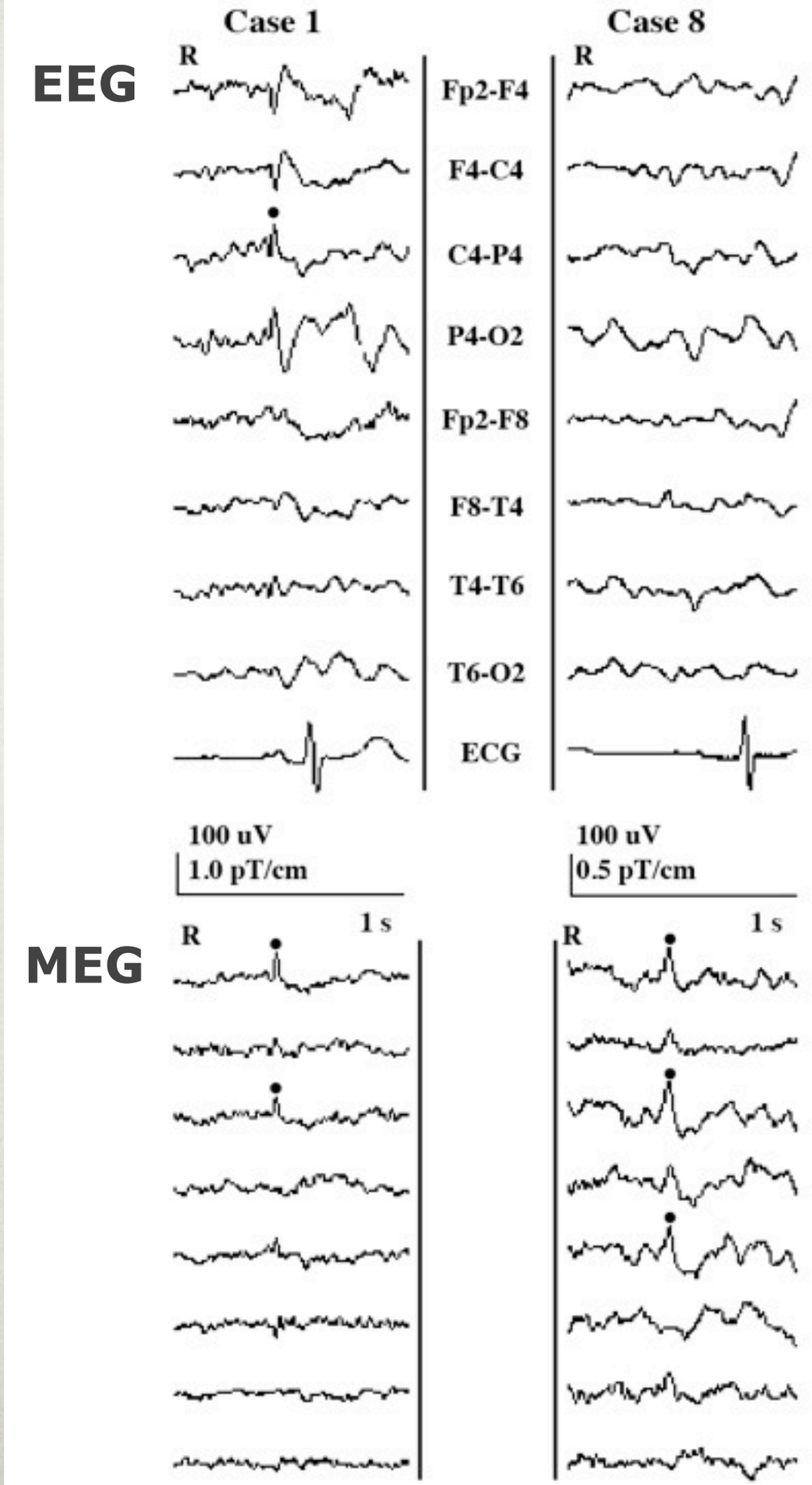
| | Sex/Onset, MEG | Atypical Seizures as BECCT | Seizure Frequency (Max./Latest) | Others |
|---|---|---|---|---|
| 1 | F/2, 22 | falling | weekly/weekly | PLE confirmed by ECoG |
| 2 | M/2, 29 | consciousness loss with automatism | daily/daily | |
| 3 | F/2, 3 | falling and head dropping | daily/ (-) | Mental retardation and behavioral problems |
| 4 | F/3, 12 | posturing | daily/daily | |
| 5 | F/3, 5 | head dropping | daily/ (-) | Transient graphomotor impairment |
| 6 | F/11, 23 | auditory hallucinations | monthly/monthly | |
| 7 | F/12, 23 | auditory hallucinations | daily/daily | |

Kakisaka Y. et al. 2009

Kakisaka Y. et al. 2009

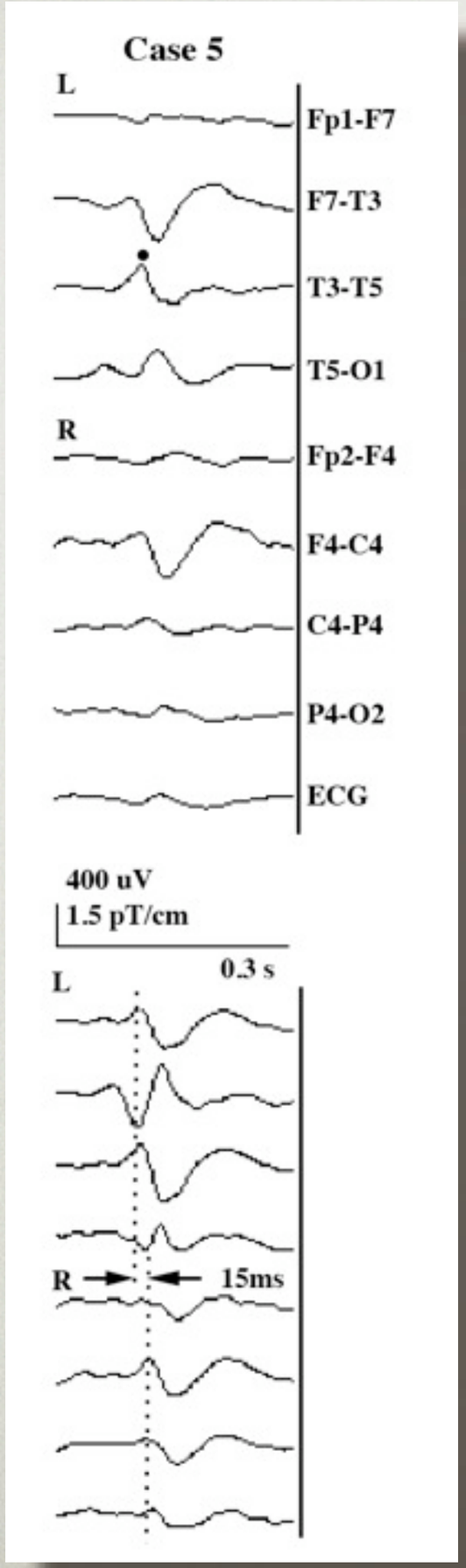
## Case 1

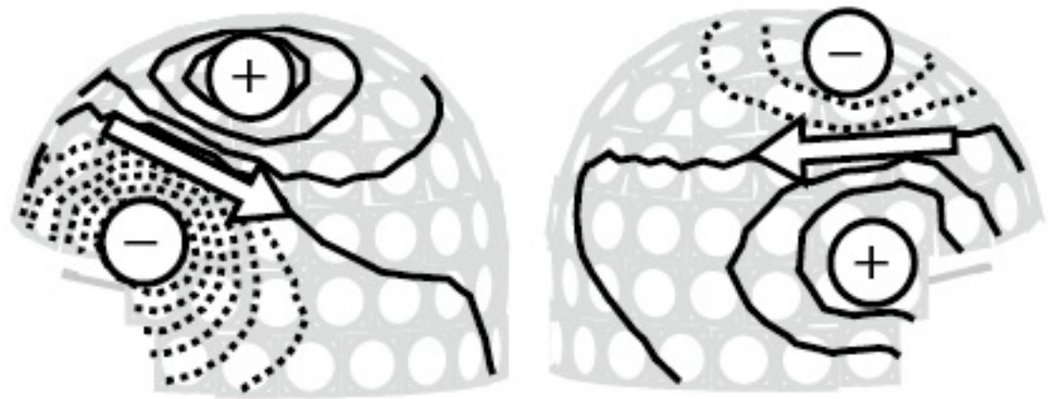
Step=200 fT

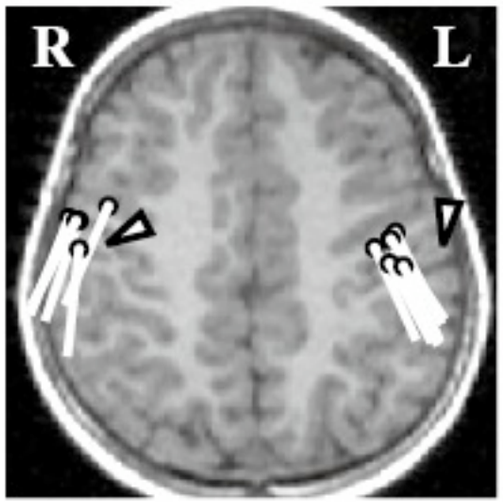

## Case 8

Step=300 fT



Step=600 fT *




Case 5

Kakisaka Y. et al. 2009

# What's the difference between EEG and MEG in practice?

- Introduction
  - Theory & Practice
- Evoked Responses
  - Single Source
  - Dual Source
- Epileptic Spikes
  - Detectability
  - Localization
  - Orientation
- Summary

# What's the difference between EEG and MEG in practice?

- Spike Detectability
  - Theory: EEG detects radial and tangential currents, while MEG detects Tangential current only.
  - Practice: Some are found in EEG only, MEG only, or both.
- Spike Localization
  - Theory: No unique solution in inverse problem (Helmholtz).
  - Practice: Assumption is simpler in MEG than in EEG.
- Spike Orientation
  - Theory: Both EEG and MEG can be used to define orientation of tangential current (= sulcal activity).
  - Practice: MEG is more useful, neglecting radial current.