What’s the difference between EEG and MEG in practice?

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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 | EEG | MEG
Dipole Simulator (BESA)

Number: Single
Position: Temporal
Orientation: Oblique
Dipole Simulator (BESA)

Forward Calculation

Number: Single
Position: Temporal
Orientation: Oblique

Dipole  EEG  MEG
MEG System “Model-2020”

- More-channels and higher density
- Wider coverage including face and neck
- Shorter distance between sensor and scalp
No unique solution in inverse problem ... (Helmholtz)
Separation of Two Signals

DIPOLE

EEG MAP

MEG MAP

Dipole Simulation by BESA 5.0
MEG in Sendai, since 1988

1988

1993

1999
EEG-MEG powered by ... (2008)

Simultaneous Recording

Combined Analysis
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Somatosensory Evoked Fields

F/48
Meningioma
Somatosensory Evoked Fields

Bilateral Median and Tibial Nerves

N20m Median N.  P38m Tibial N.  Central Sulcus

F/48 Meningioma
Somatosensory Evoked Fields

W. Penfield

median nerve
lip
gingiva
tongue

Left

Nakahara et al. 2004
Kimura T, Ozaki I, Hashimoto I:

Impulse propagation along thalamocortical fibers can be detected magnetically outside the human brain.

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Auditory Evoked Response (N100)
Auditory Evoked Response (N100)

EEG

MEG

Head Injury (M/41)

Skull Defect
Auditory Evoked Response (N100)

N100m (95.5 ms)

Right Ear Stim.
Left Hemisphere

Head Injury (M/41)

Filter: HPF: 10hz, LPF: 500 Hz, Notch: Through
Sampling Rate: 2000 Hz, Average Count: 90
Baseline: -500 - 0 ms

75 fT/step
### Practical Problems in Spontaneous EEG and MEG Activity

<table>
<thead>
<tr>
<th>Signal</th>
<th>Source Number</th>
<th>Unknown, usually multiple</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Source Extent</td>
<td>Unknown, usually wide</td>
</tr>
<tr>
<td></td>
<td>Source Configuration</td>
<td>Unknown, usually complicated</td>
</tr>
<tr>
<td></td>
<td>Source Stability</td>
<td>Unknown, usually moving, expanding, and propagating</td>
</tr>
<tr>
<td>Noise</td>
<td>Environmental Noise</td>
<td>Yes, but may be reduced technically</td>
</tr>
<tr>
<td></td>
<td>Brain Noise</td>
<td>Yes, and hardly eliminated</td>
</tr>
</tbody>
</table>
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Blinded Comparison of EEG and MEG

Simultaneous EEG/MEG data

EEG

- Manual spike detection

- Total EEG spikes

- Unique EEG spikes

MEG

- Total MEG spikes

- Common EMEG spikes

- Unique MEG spikes

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 (%)

Case 1
Location X Y Z
Moment Q

Case 2

E/M spikes
M spikes

Park HM, et al. 2003
Scalp EEG may overlook small tangential spikes?

[Diagram showing the relationship between scalp EEG orientation and spike source.]

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
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Localization: Simple & Excellent

T7  Left leg
c3  twitch
Cz  followed by
C4  2nd-GTC
T8  (M/20)
Localization: Simple & Excellent

T7  Left leg twitch
C3  followed by
Cz  2nd-GTC
C4  (M/20)
T8
Localization: Simple & Excellent
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.
Localization: Propagation

Iwasaki et al. 2002
Propagation Hypothesis: Anterior T.

Spike (-)
Seizure (-)

MEG
Spike
Dipole

Spike (-)
Seizure (-)
Propagation Hypothesis: Non-Ant. T.

Spike (-)
Seizure (-)

Spike (+)
Seizure (+)
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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

Salayev KA et al. 2006
### Sensorimotor Seizures of Pediatric Onset with Unusual Posteriorly Oriented Rolandic Spikes

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

Kakisaka Y. et al. 2009
<table>
<thead>
<tr>
<th>EEG</th>
<th>Case 1</th>
<th>Case 8</th>
</tr>
</thead>
<tbody>
<tr>
<td>R</td>
<td>Fp2-F4</td>
<td>R</td>
</tr>
<tr>
<td></td>
<td>F4-C4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>C4-P4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>P4-O2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Fp2-F8</td>
<td></td>
</tr>
<tr>
<td></td>
<td>F8-T4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>T4-T6</td>
<td></td>
</tr>
<tr>
<td></td>
<td>T6-O2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>ECG</td>
<td></td>
</tr>
<tr>
<td>Step=200 fT</td>
<td>100 uV/1.0 pT/cm</td>
<td>100 uV/0.5 pT/cm</td>
</tr>
</tbody>
</table>

**Case 1**

**Case 8**

Kakisaka Y. et al. 2009
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- **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.