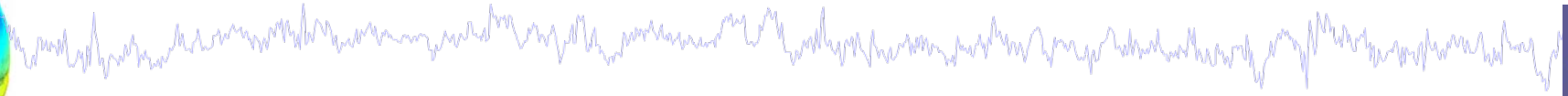
Simultaneous EEG/MEG analysis in EEGLAB

John Iversen

Close cousins



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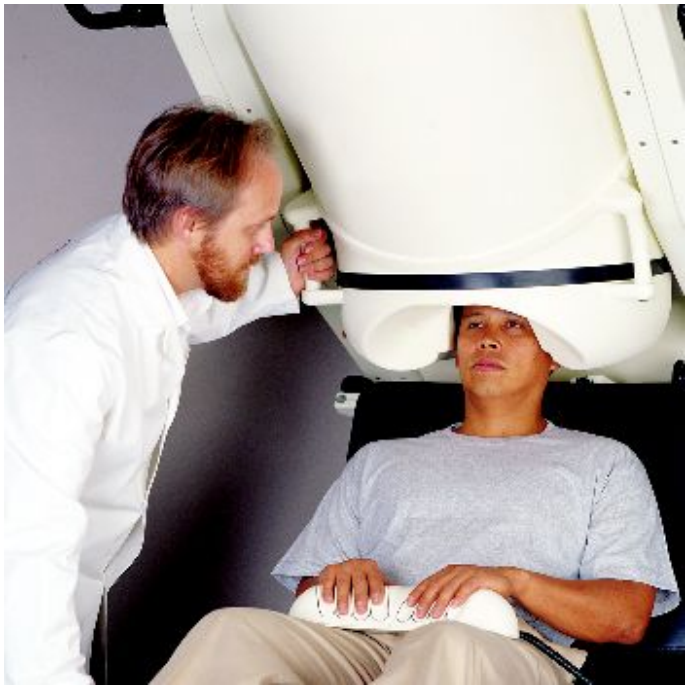
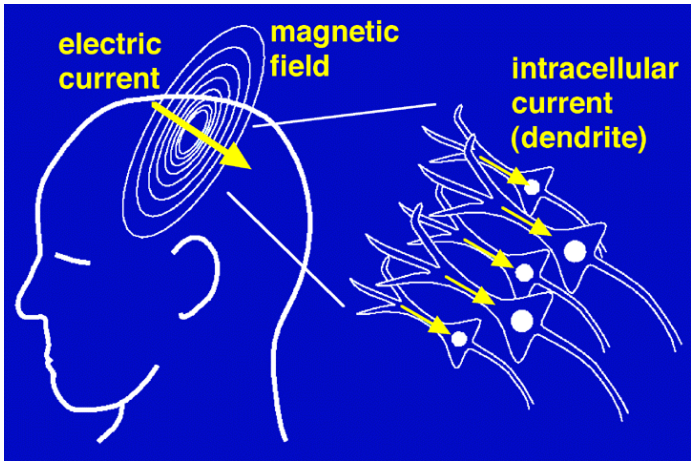
EEG

MEG



MEG Basics

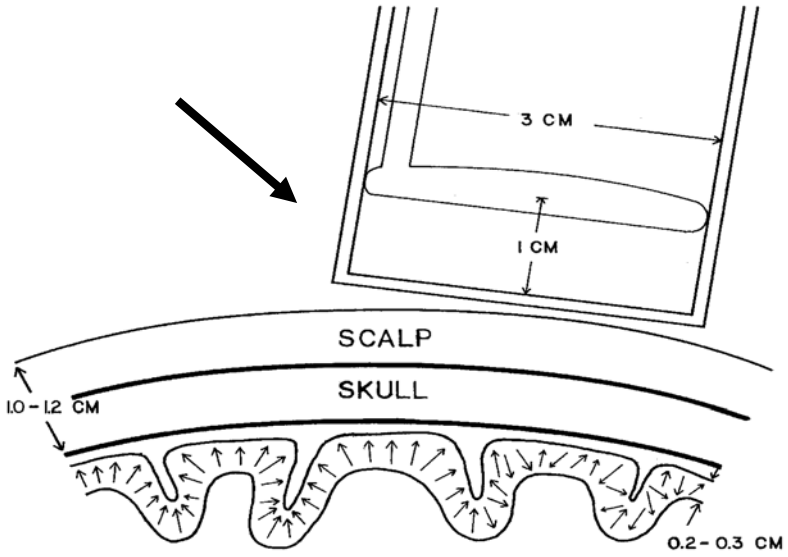
Measures magnetic fields induced by neural activity in cortex

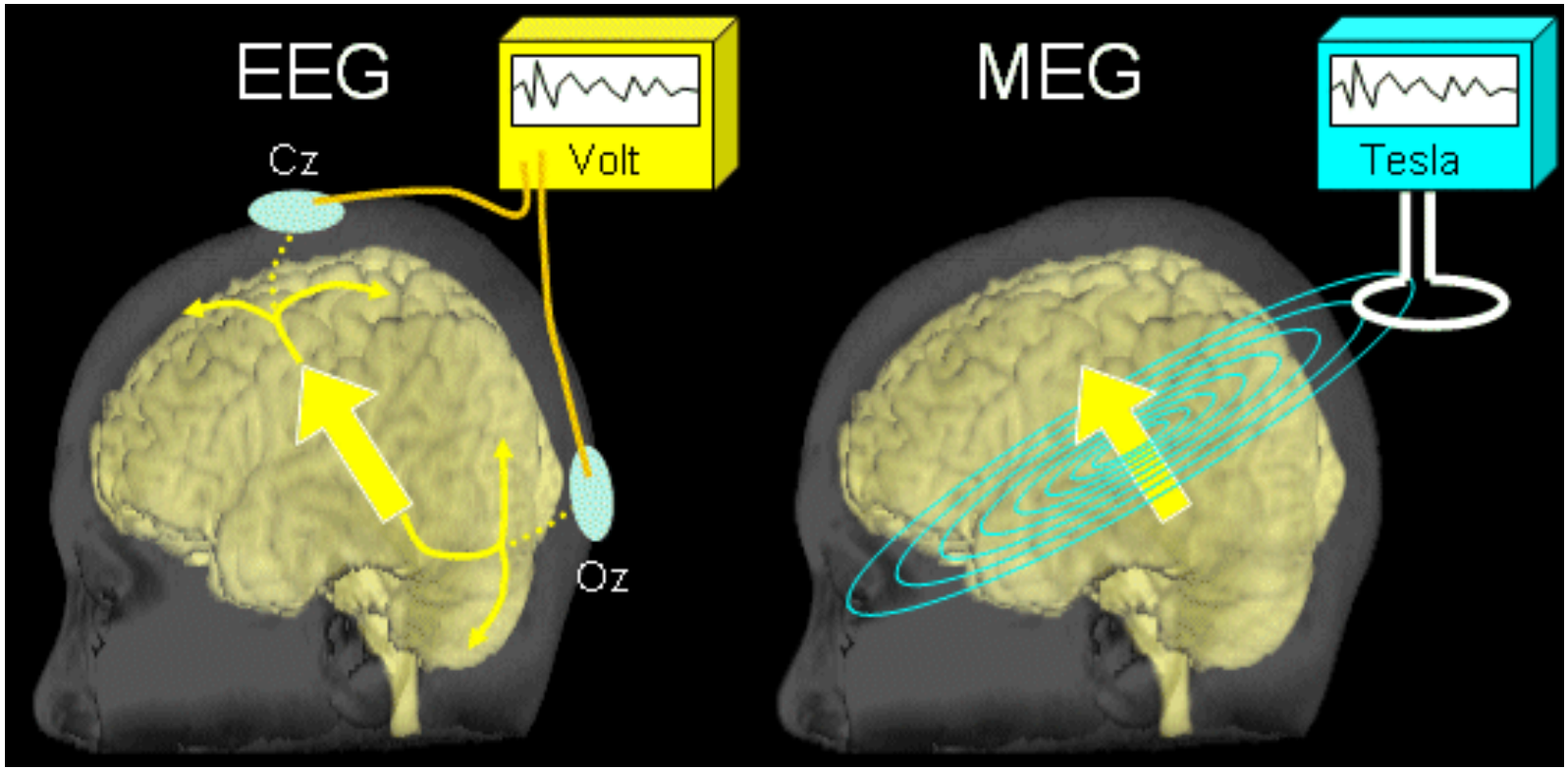


Technology: SQUIDs

Magnetic field strengths:

Picotesla





http://meg.aalip.jp/vsEEG/vsEEGE.html

MEG vs. EEG

- Many arguments for superiority of one over the other
- Differences…
  - EEG is cheaper, and portable
  - EEG localization is sensitive to the details of the head model
  - MEG misses radial sources & deep sources
  - MEG sensor locations vary run by run
- Localization accuracy generally ~equivalent given good head model for EEG
- Scalp projections are orthogonal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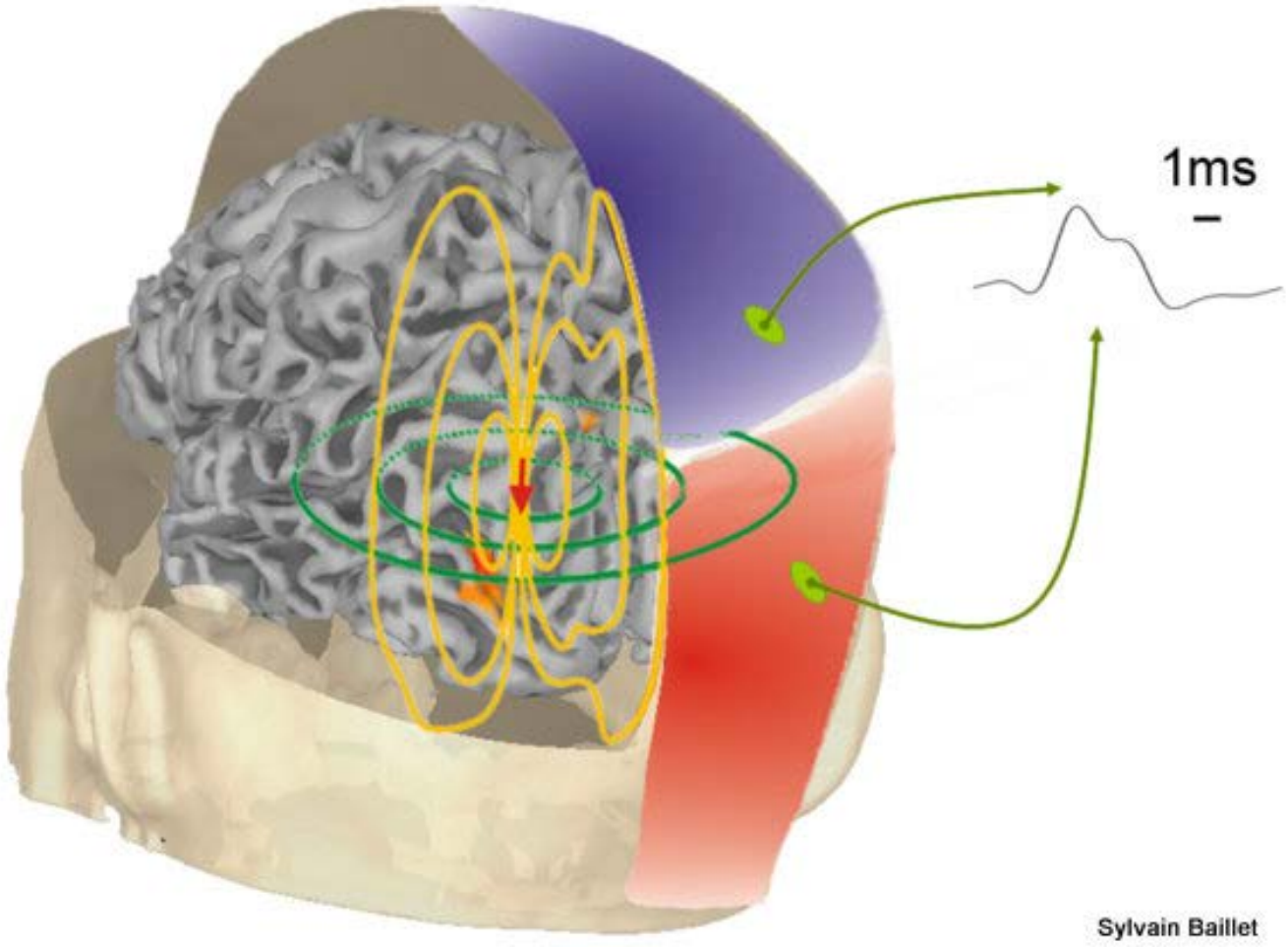
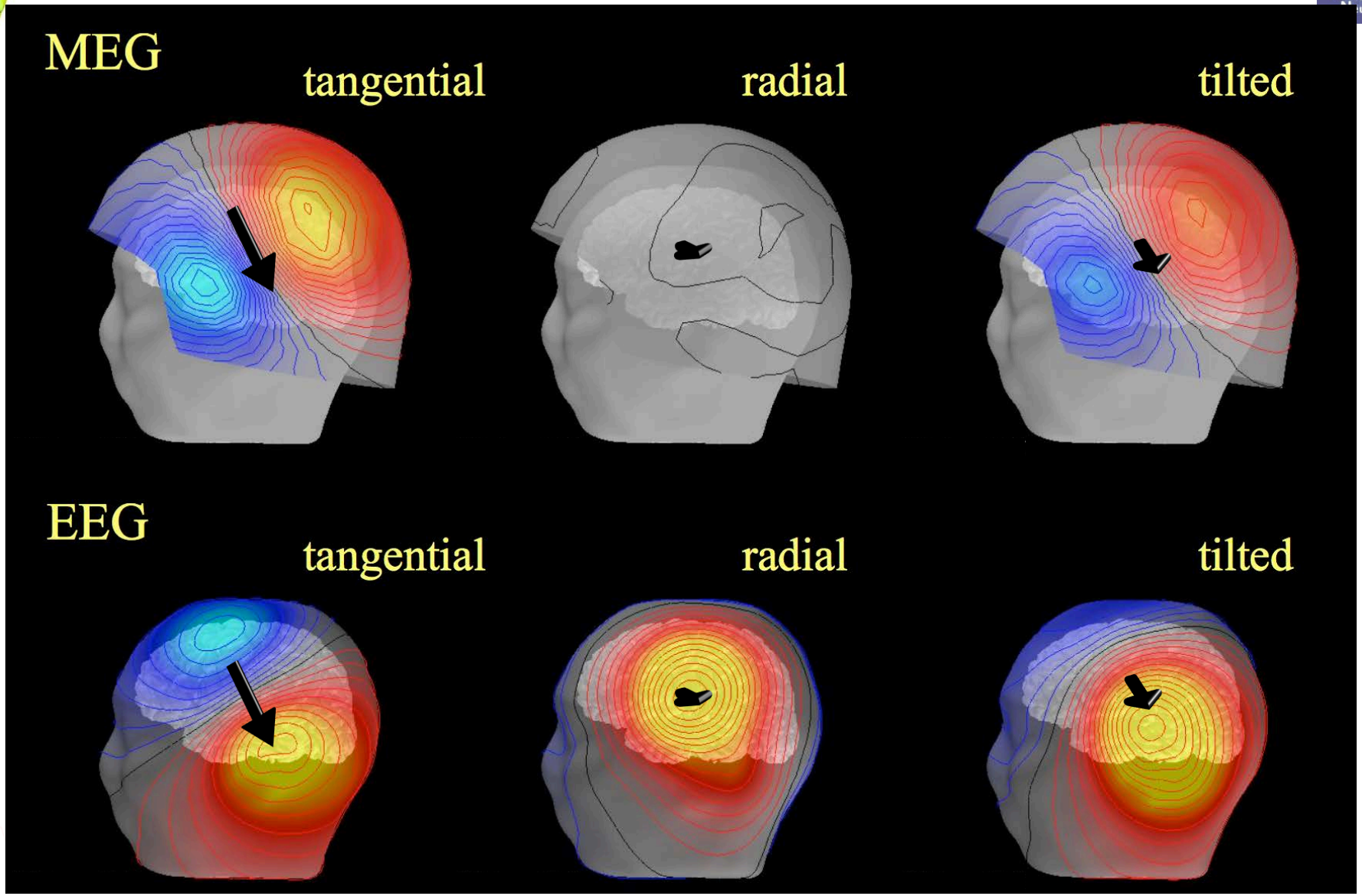

1ms
Sylvain Baillet

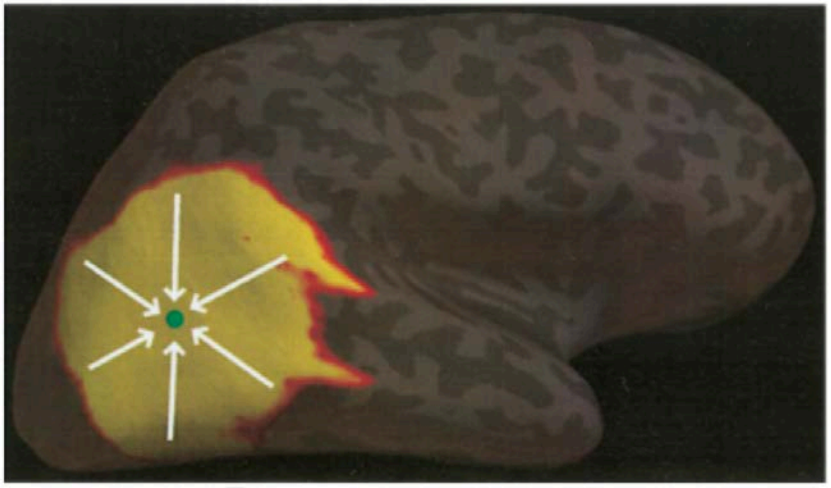
Orientation and Orthogonality



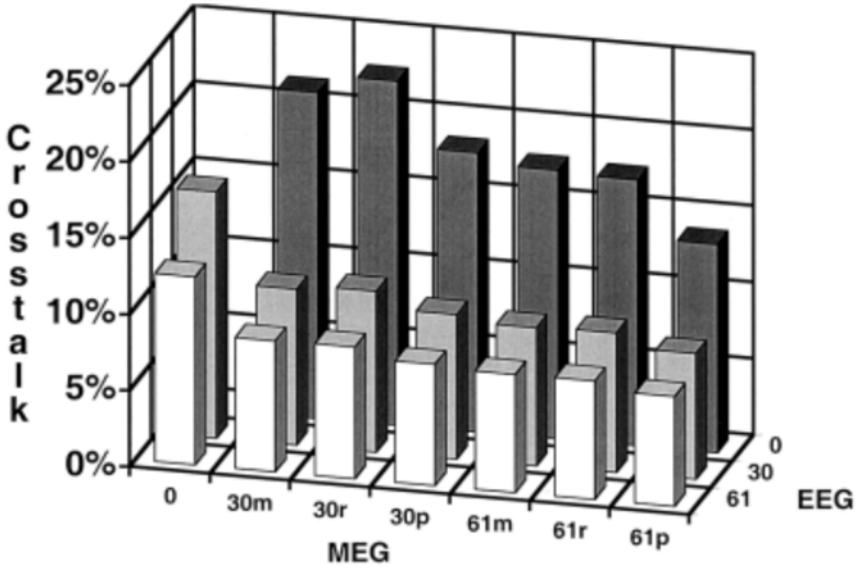
(Hamalainen) 20071109-Hamalainen-inverse-dipoles.pdf

MEEG

- Simultaneous MEG & EEG recording
  - Relatively rare
  - Adding even relatively few EEG/MEG channels to the other modality has *localization advantages*



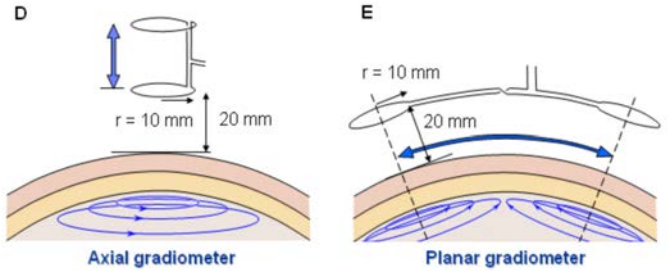
Crosstalk



Liu et al. (2002) Human Brain Mapping 16:47– 62

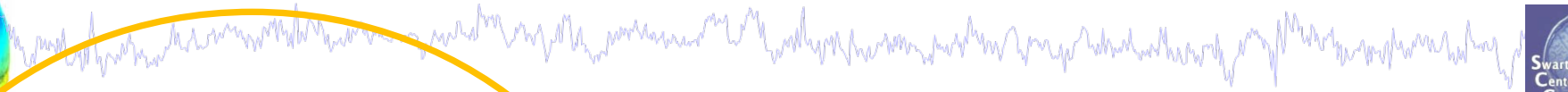
MEG in EEGLAB Considerations

- Multiple MEG sensor types, some vector
  - Magnetometer (scalar)
  - Radial gradiometer (scalar)
  - Planar gradiometer (vector*)



- Dual head models, sensor specifications & lead fields
- Signal units and magnitudes are different
- How do ICA?

MEEG ICA



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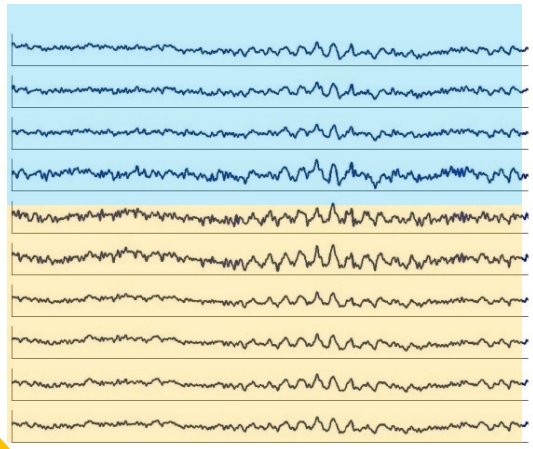
x = scalp MEEG



* S_{EEG}

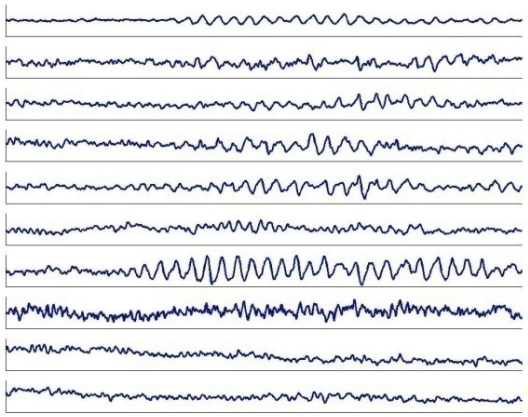
* S_{MEG}

W = unmixing matrix

W*x = u

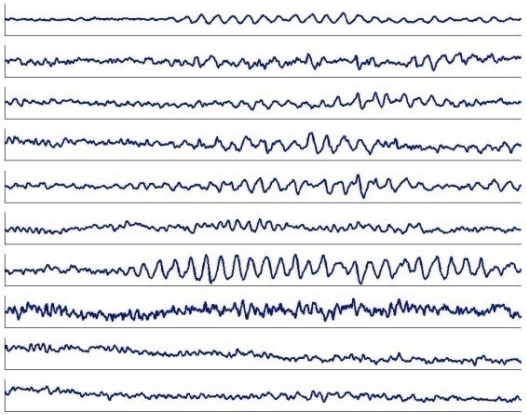
ICA

u = sources

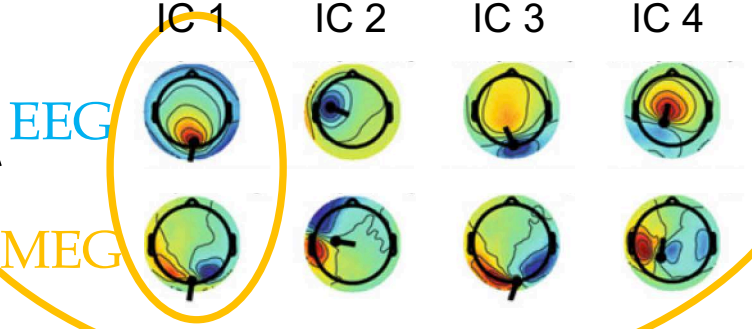


$x = W^{-1}*u$

u = sources



W^{-1} (scalp projections)



*

Plain English → MATLAB

Source activation = unmixing * Channel data

Channel data = mixing (topo) * Source activation

Prior to ICA: separately sphere EEG and MEG channels

```
EEG.icaact = (EEG.icaweights*EEG.icasphere) * EEG.data
```

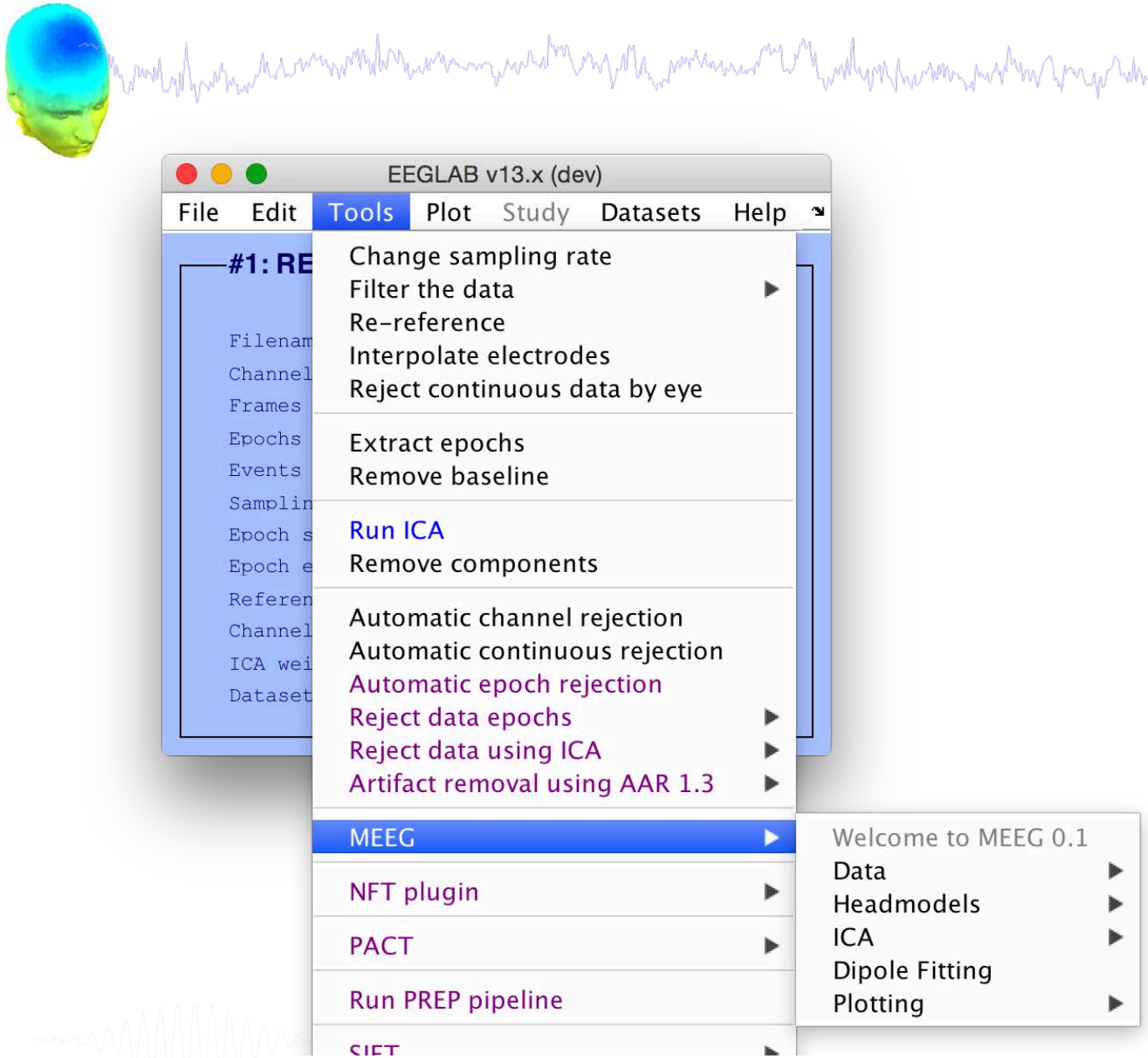
```
EEG.icasphere(:,echans) = EEG.icasphere(:, echans) * EEG.etc.meeg.Se
EEG.icasphere(:,mchans) = EEG.icasphere(:, mchans) * EEG.etc.meeg.Sm
```

```
EEG.data = EEG.icawinv * EEG.icaact
```

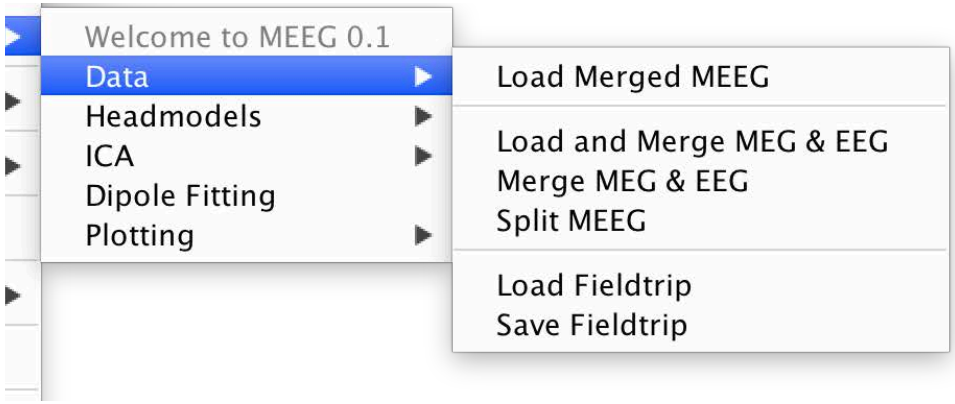
Implementation Details

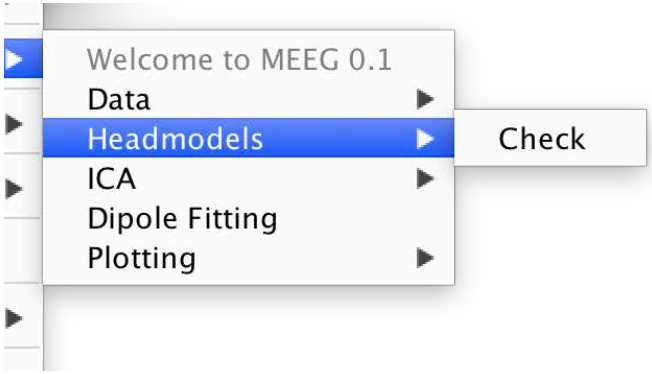
- Uses NFT & Fieldtrip 'under the hood'
  - Custom dipolefitting routines
  - Enhanced `eeglab2fieldtrip` and `fieldtrip2eeglab`
- Data
  - `EEG.chanlocs.type = 'EEG'  or  'MEG'`
  - `EEG.etc.meeg, EEG.etc.fieldtrip, EEG.etc.nft`
- EEGLAB
  - Modified ICA-related functions
  - Replacements for plotting functions to handle two headmaps

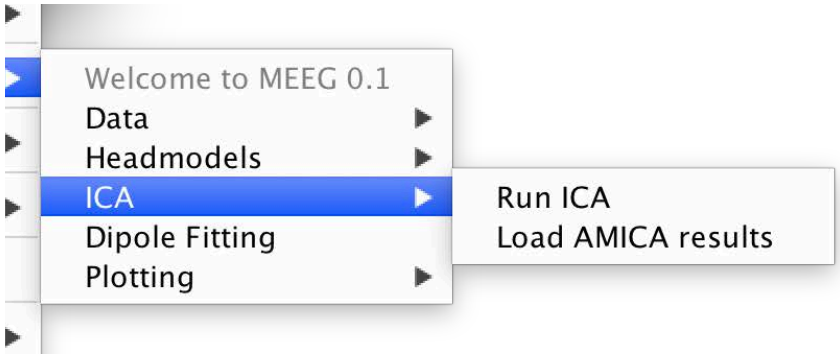
MEEG Toolbox

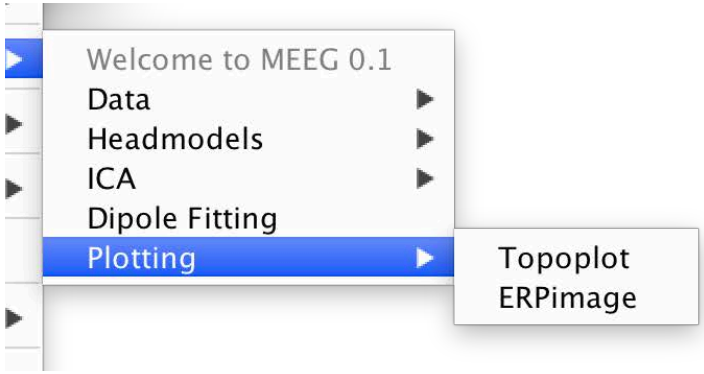


MEEG Toolbox





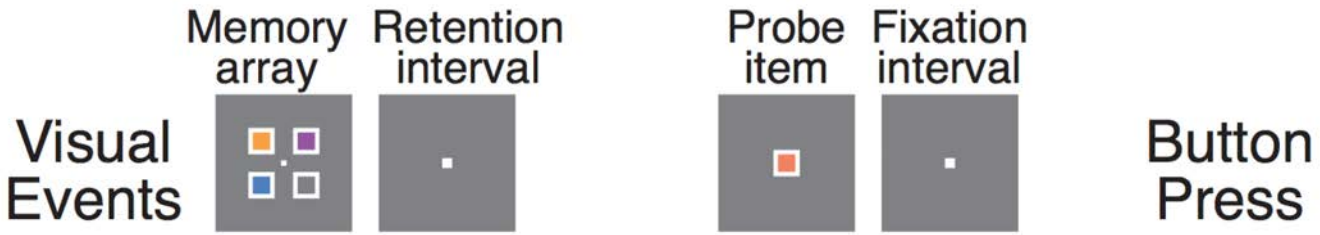




Example Results

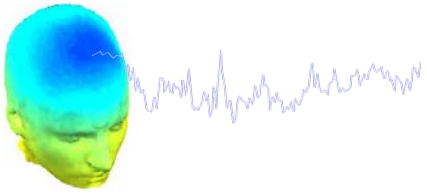
Iversen & Makeig (2014), **MEG/EEG Data Analysis Using EEGLAB**

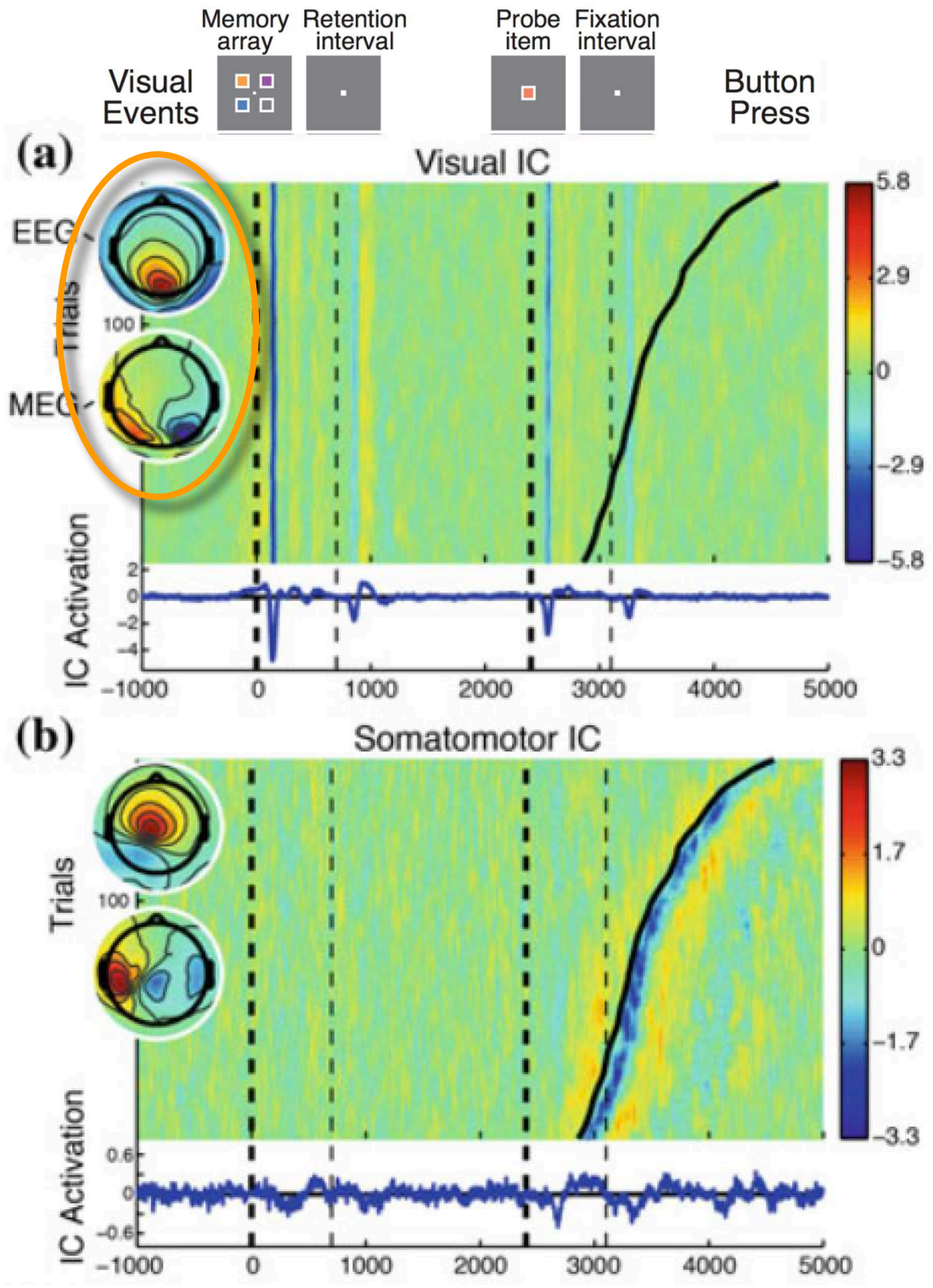
in S. Supek and C. J. Aine (eds.), *Magnetoencephalography*, Springer-Verlag.

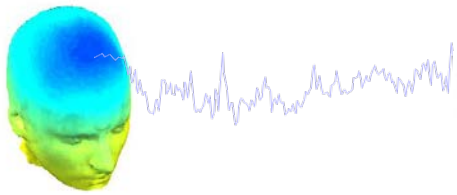


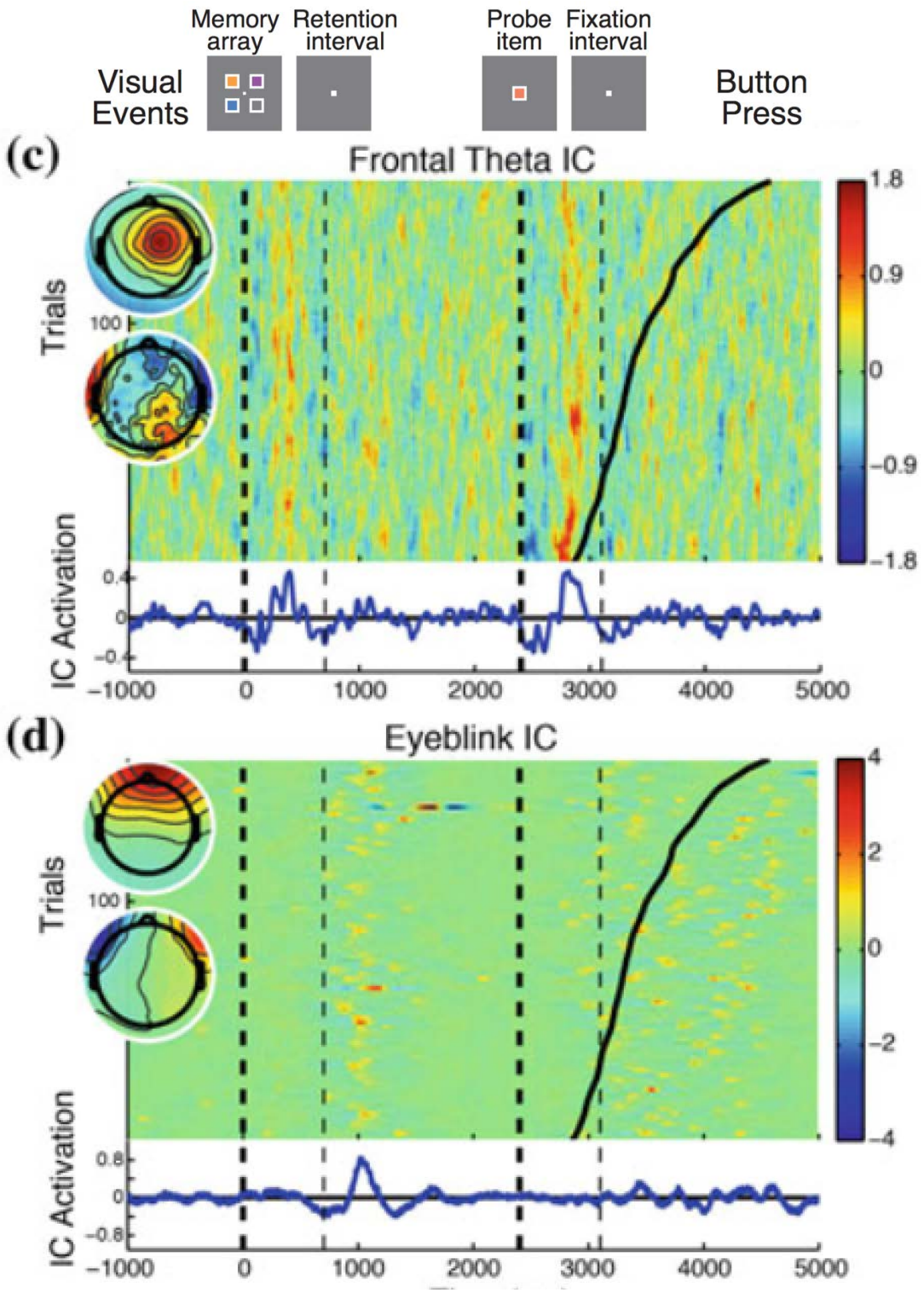
Bledowski C, Kaiser J, Wibral M, Yildiz-Erzberger K, Rahm B:
Separable Neural Bases for Subprocesses of Recognition in Working Memory. *Cereb Cortex* 2012, **22**:1950–1958.

```
                          Data

162 trials

MEG: CTF (275 radial gradiometers)

EEG: 64 Channels

Head Model: digitized headshape & electrode locations
                                (warped template head model)
```

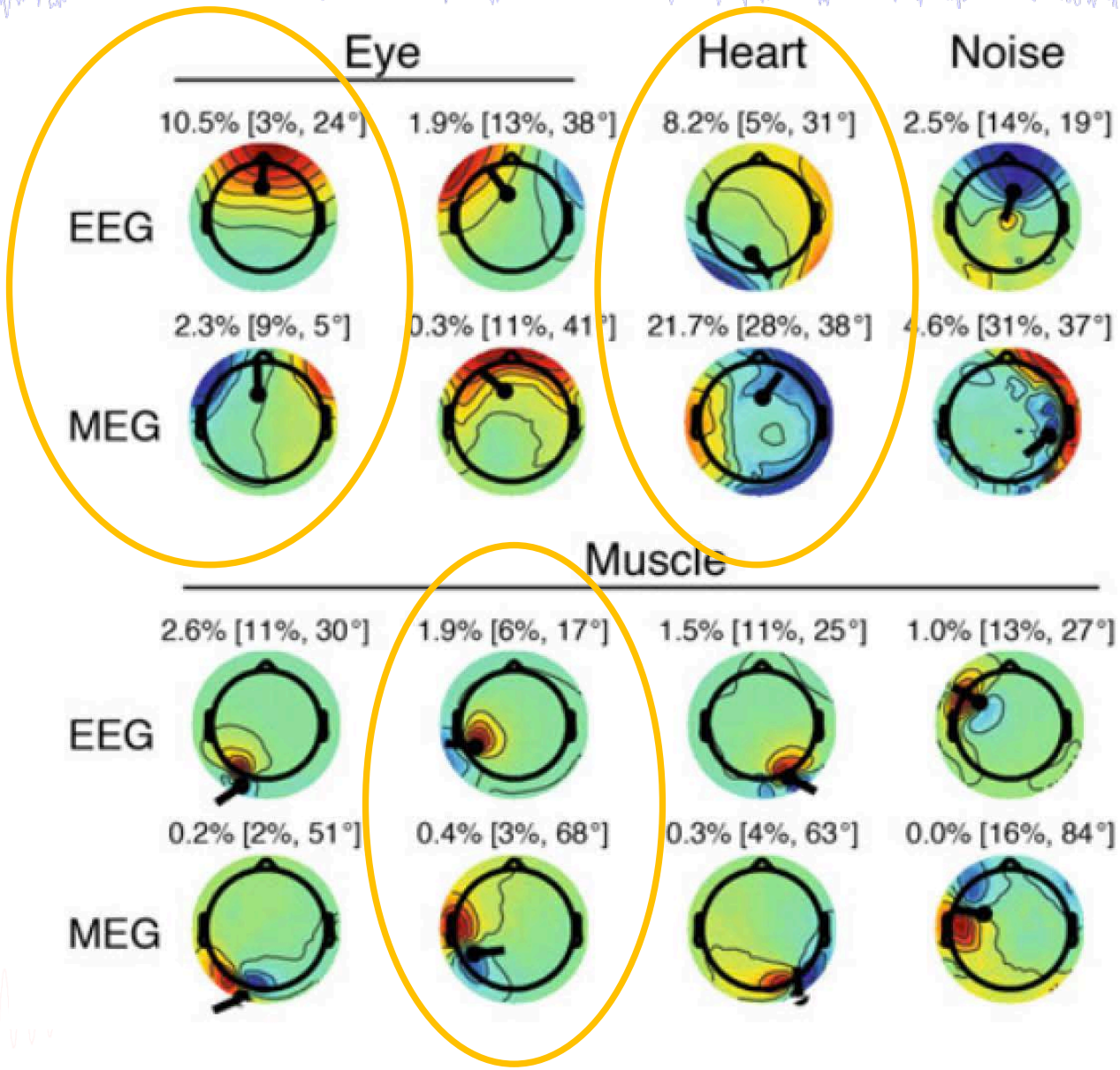



Memory array
Retention interval
Probe item
Fixation interval
Visual Events
Button Press
(a)
Visual IC
EEG
MEG
Trials
100
IC Activation
5.8
2.9
0
-2.9
-5.8
-1000
0
1000
2000
3000
4000
5000
(b)
Somatomotor IC
Trials
100
IC Activation
3.3
1.7
0
-1.7
-3.3
-1000
0
1000
2000
3000
4000
5000

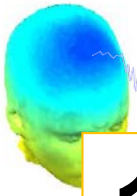



Memory array
Retention interval
Probe item
Fixation interval
Visual Events
Button Press
(c)
Frontal Theta IC
Trials
100
IC Activation
0.4
0
-0.4
-1000
0
1000
2000
3000
4000
5000
1.8
0.9
0
-0.9
-1.8
(d)
Eyeblink IC
Trials
100
IC Activation
0.8
0
-0.8
-1000
0
1000
2000
3000
4000
5000
4
2
0
-2
-4

Artifact Components

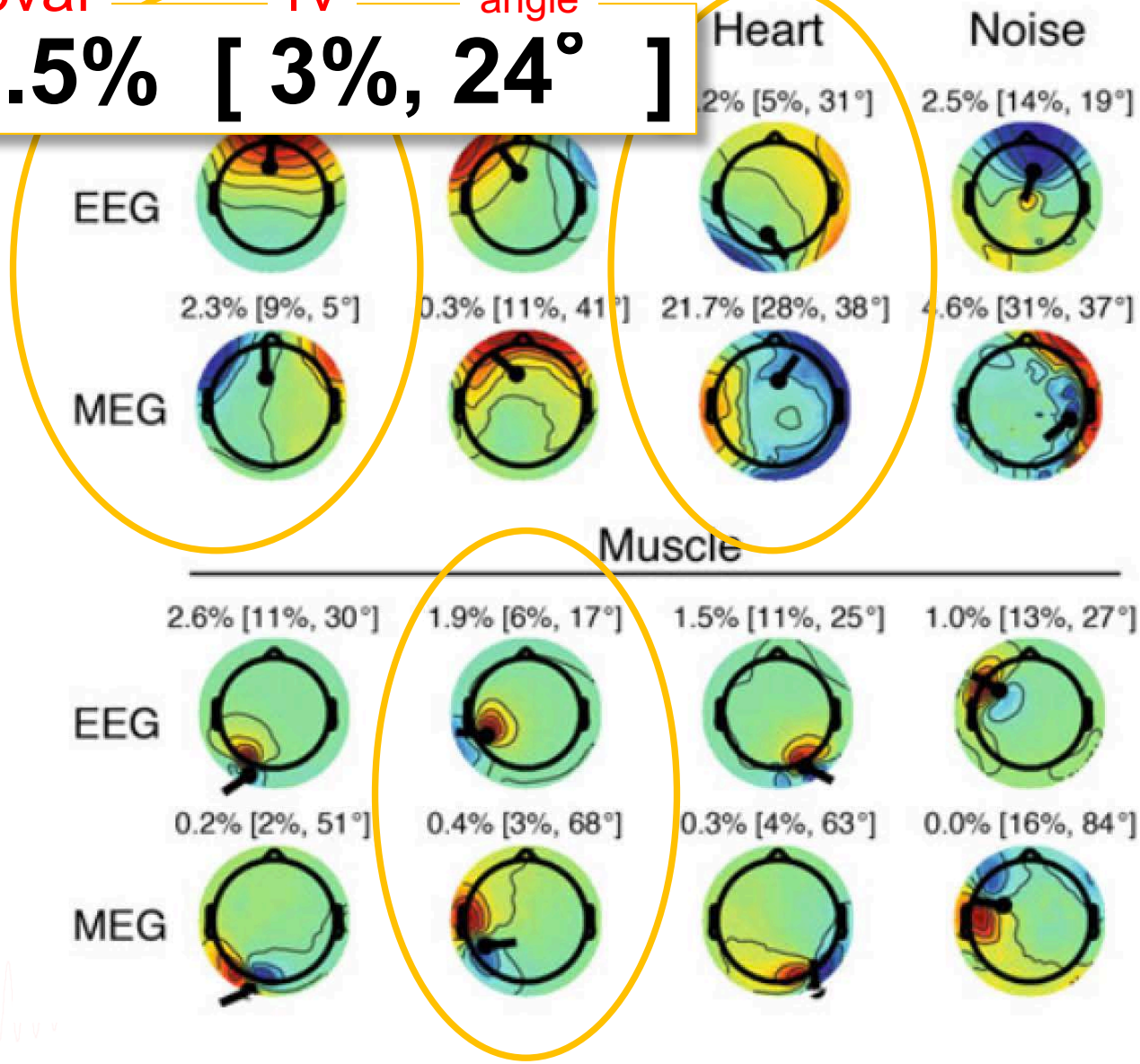


Artifact Components

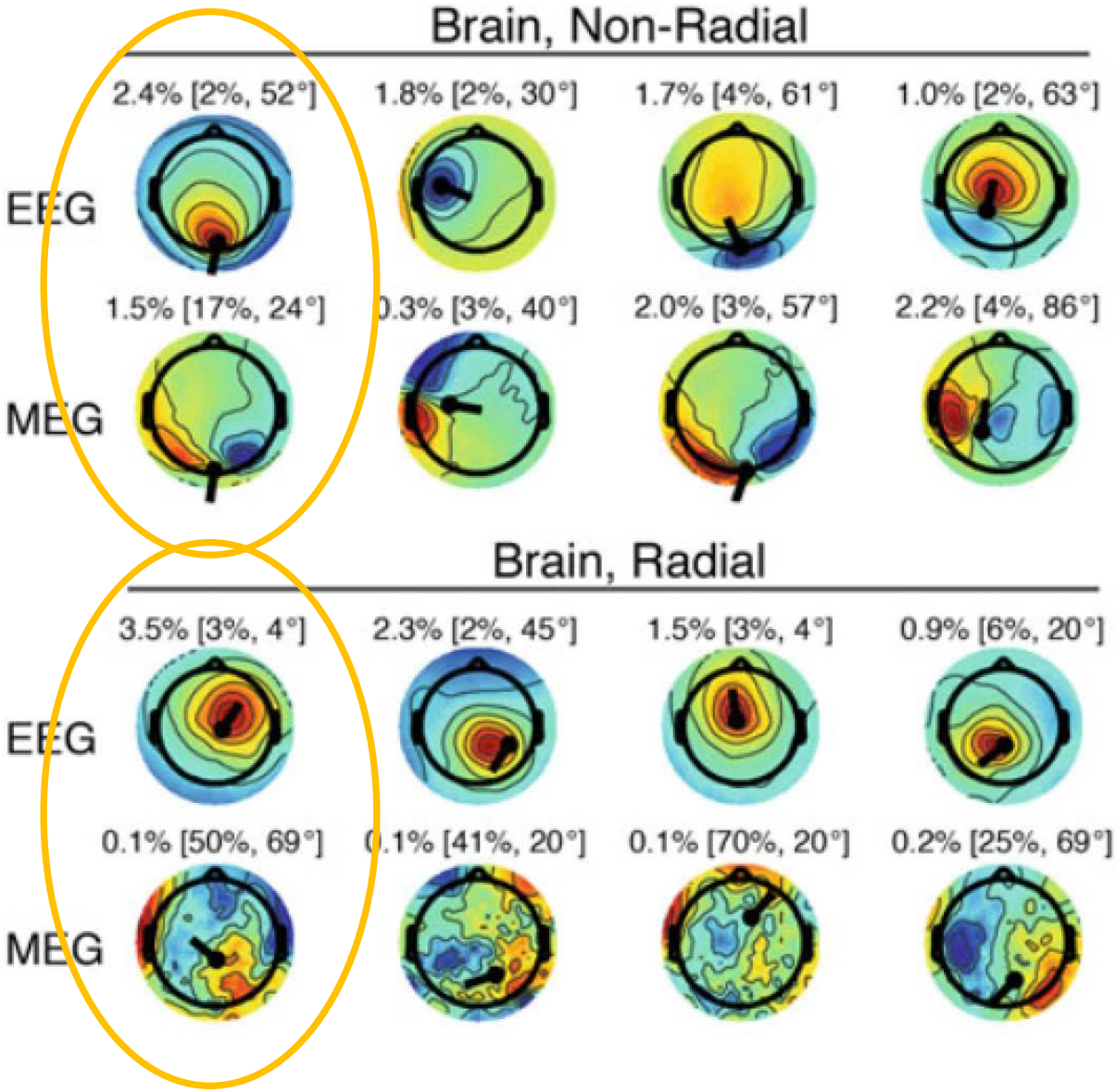


pvaf — rv — radial angle

10.5% [3%, 24°]



Brain Components



Experimental validation of radial angle dependence

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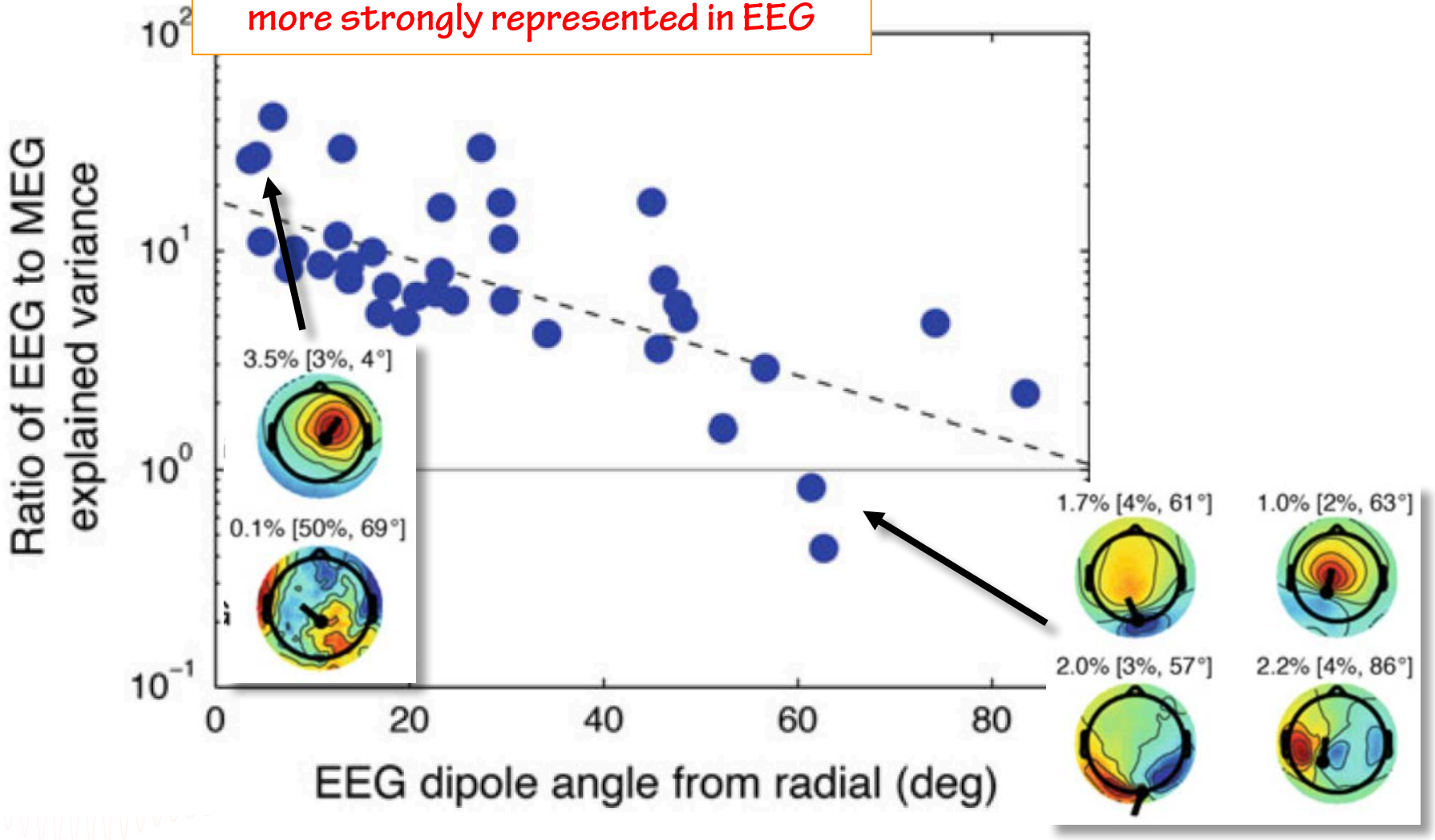
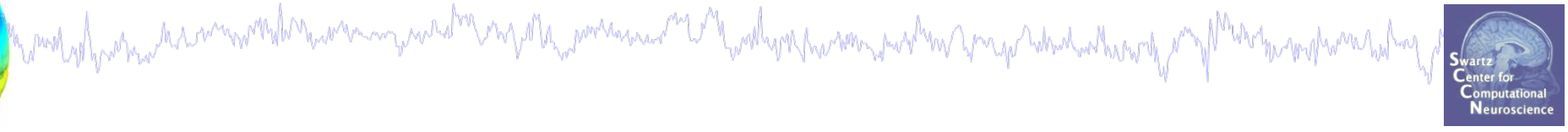
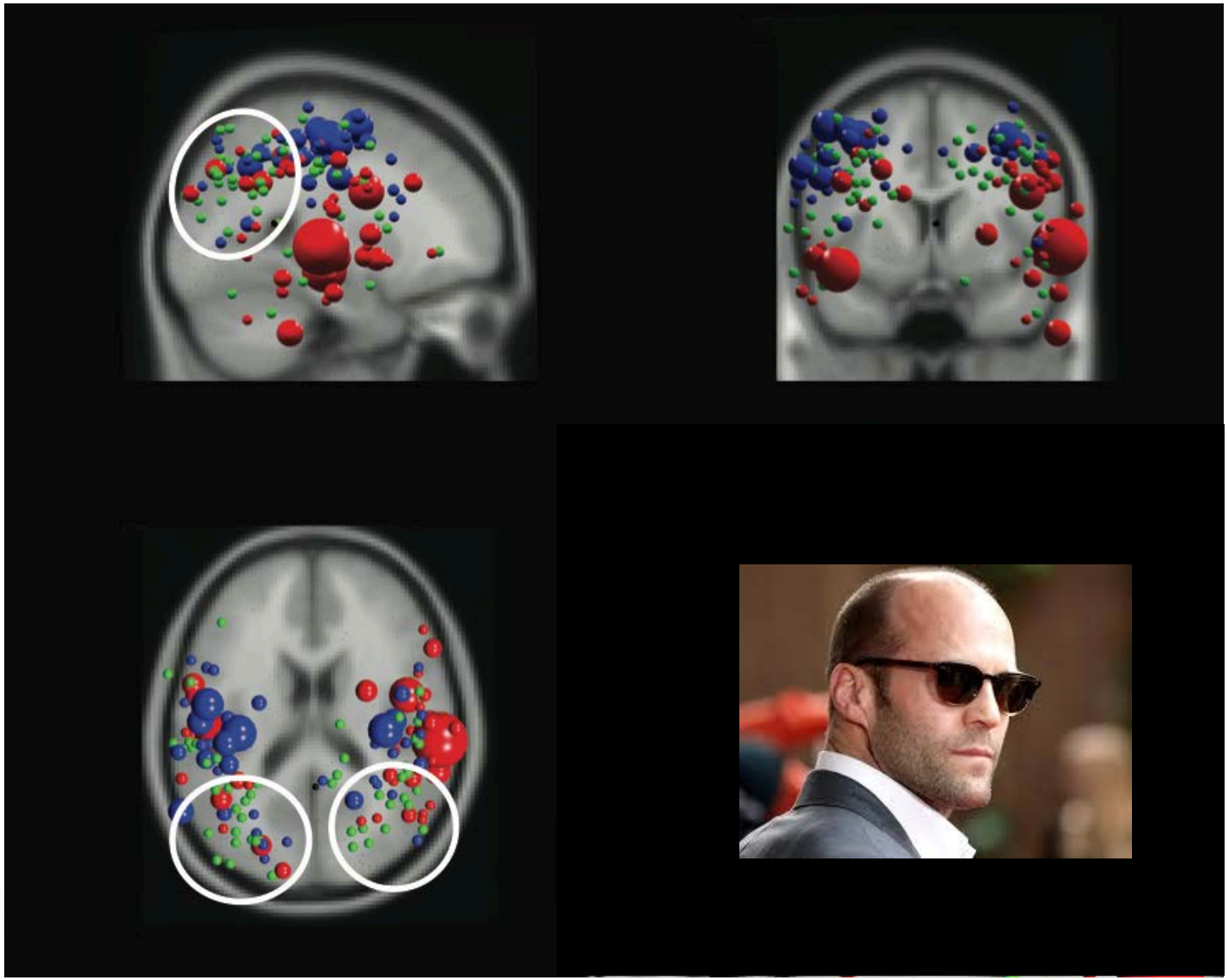
Radially-oriented sources are 10-50x more strongly represented in EEG



MEG Data (Rhythm perception)

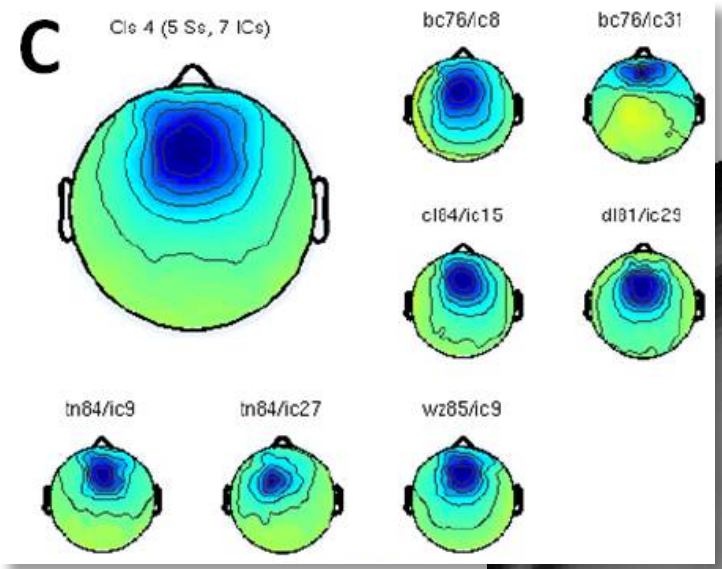


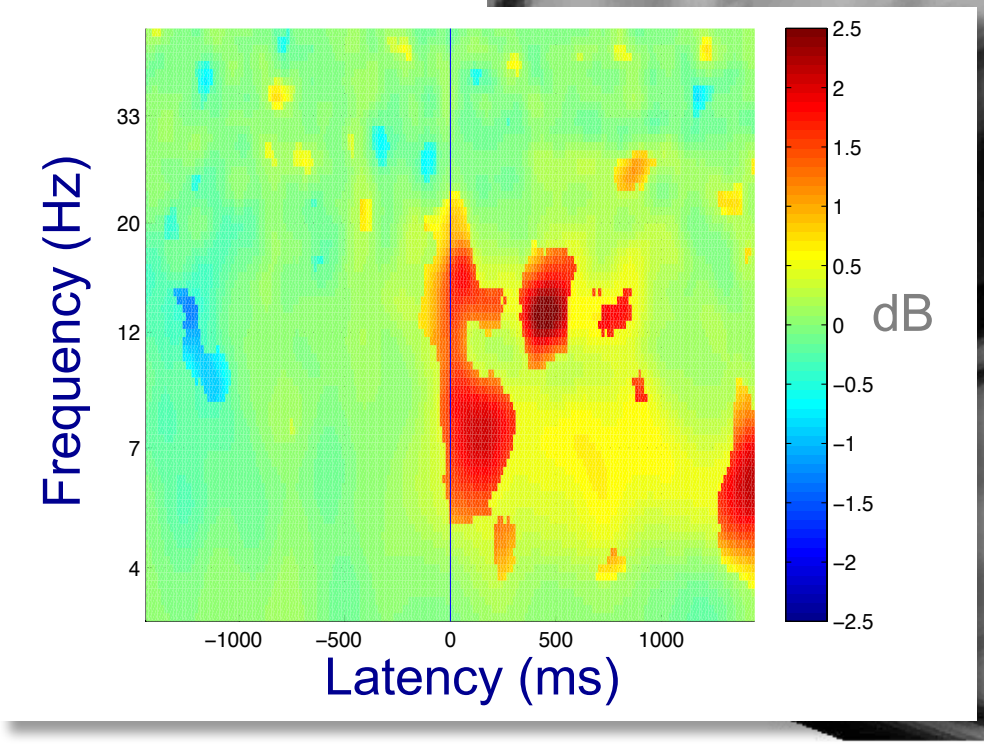


Iversen (2009; in prep)

EEG IC Source Cluster 4 (*Frontal Midline*)

Rhythm Task





Makeig, Nguyen, Onton, Nauvel, Iversen (in prep)

Conclusions

- A new method for fusing EEG & MEG data to find unified sources
  - Expect localization accuracy to benefit

- Verified the theoretical prediction of MEG-blindness to radial sources

- Repeat MEG experiments using EEG…

Thanks

- Seeking beta testers with MEEG datasets
  - Contact me: jiversen@ucsd.edu

- Acknowledgements
  - Jason Palmer
  - Michael Wibral
  - Zeynep Akalin Acar