Localisation de sources
Réseaux
Avenirs des techniques

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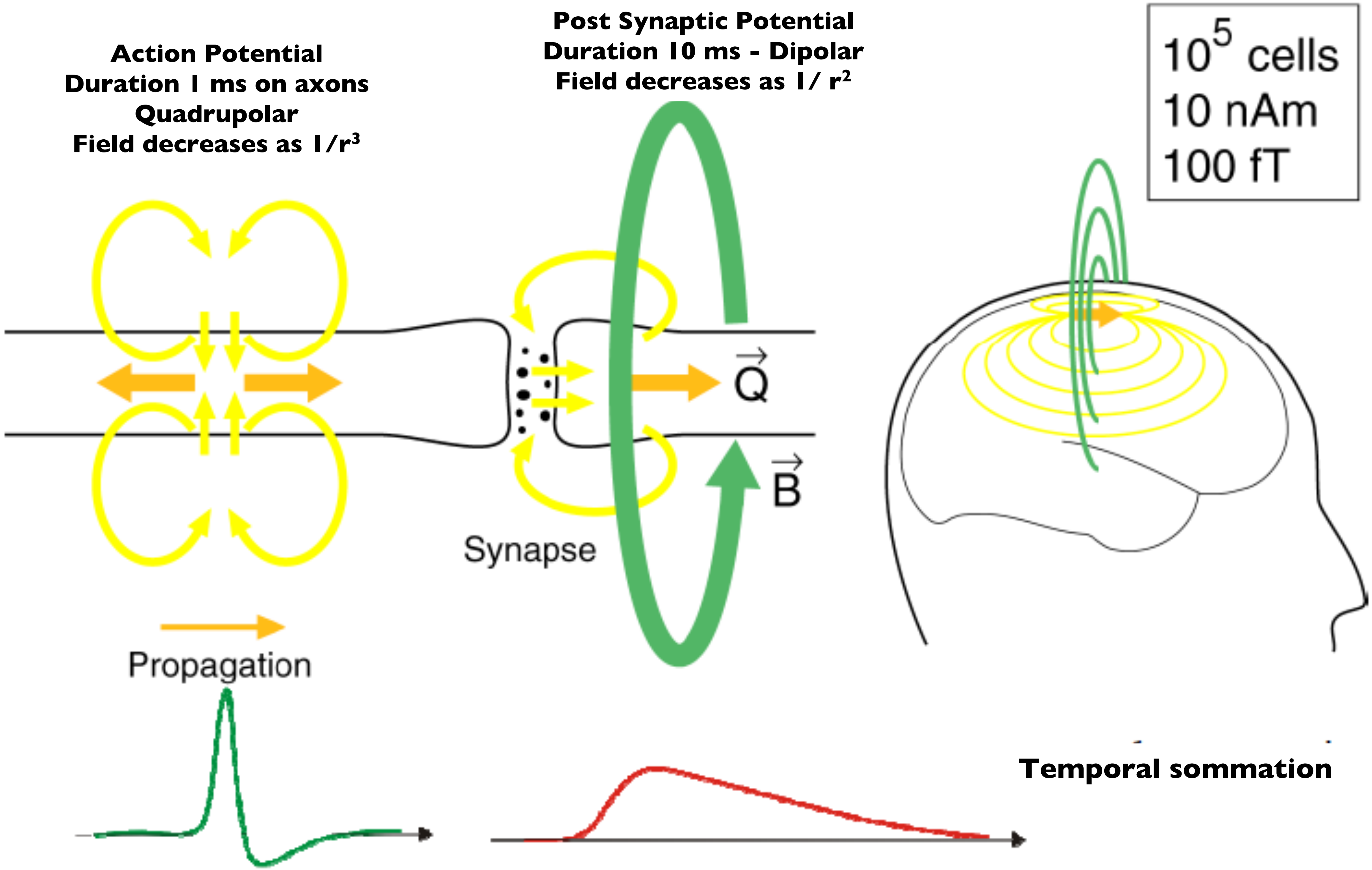
Rappels

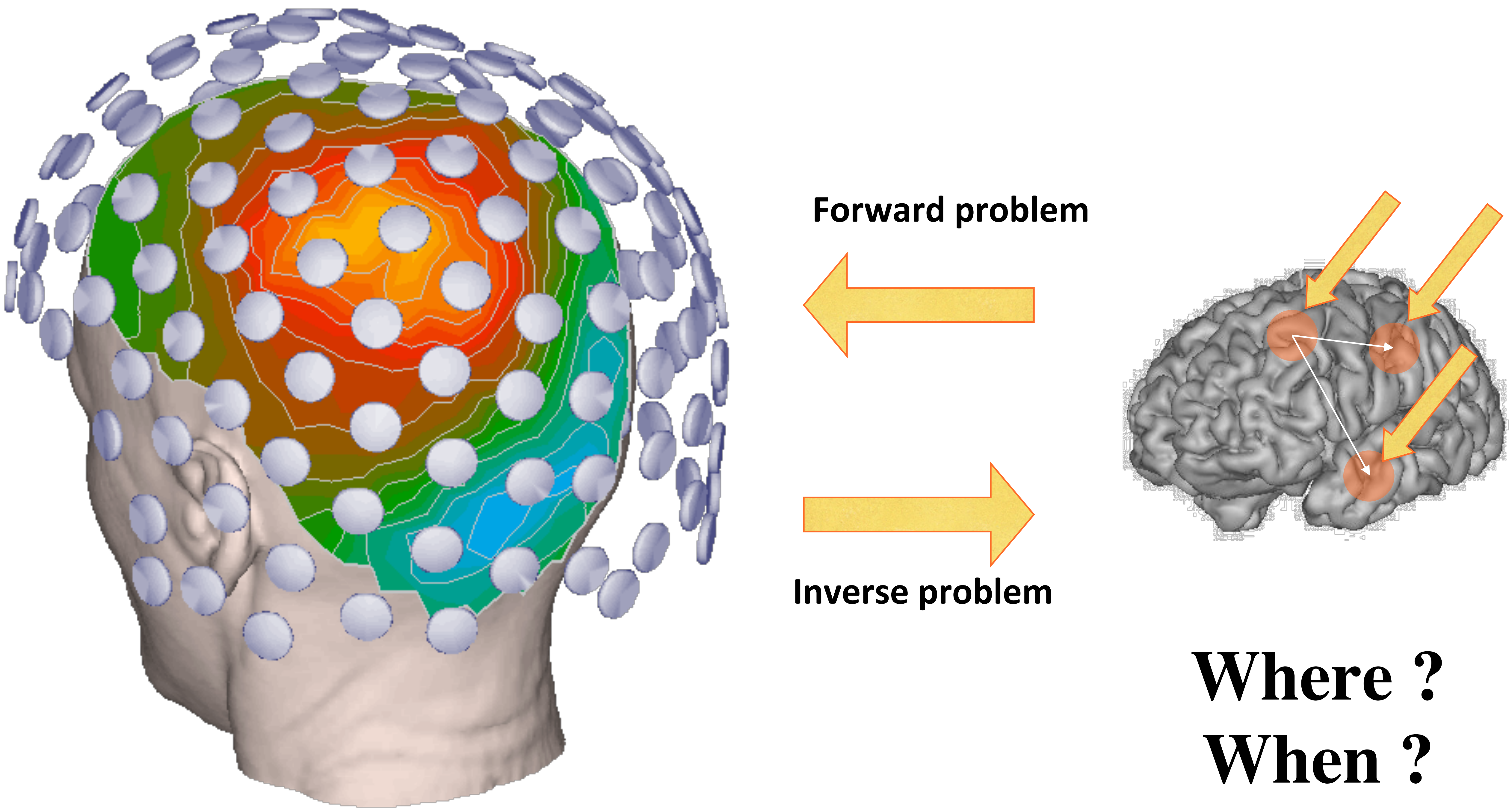
Action Potential
Duration 1 ms on axons
Quadrupolar
Field decreases as $1/r^3$

Post Synaptic Potential
Duration 10 ms - Dipolar
Field decreases as $1/r^2$



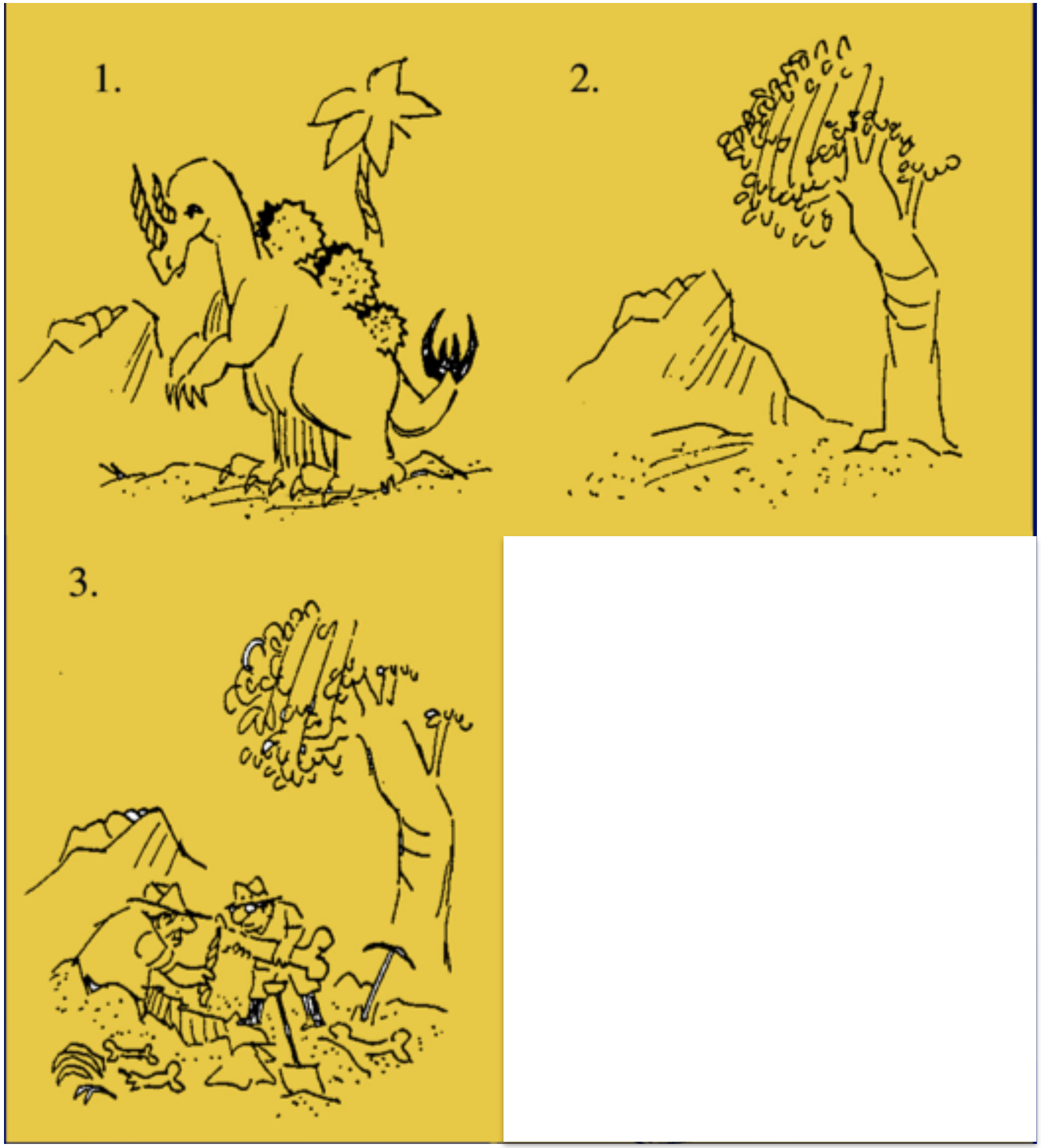
Temporal sommation

Localisation et problème inverse

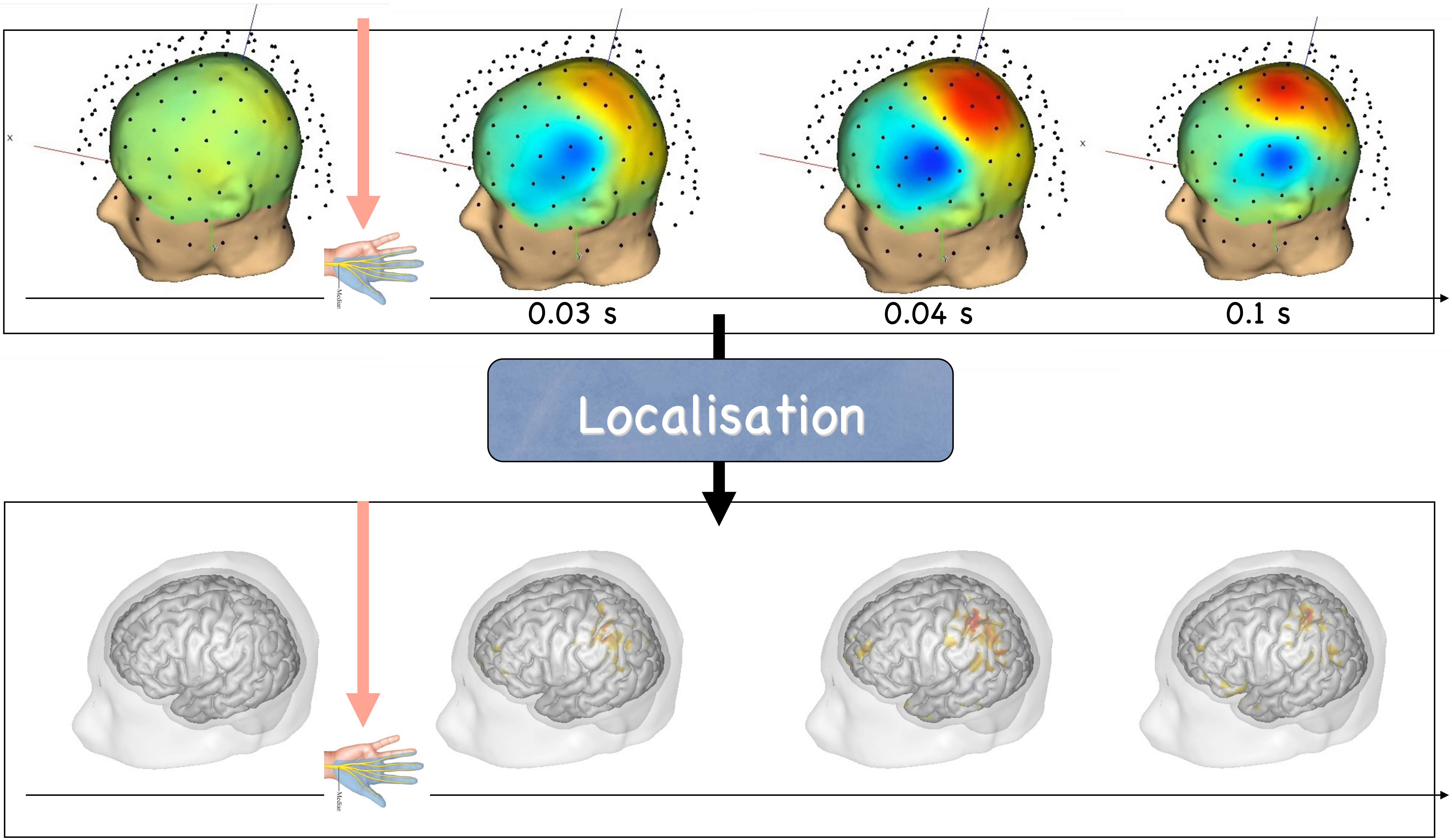


Where ?
When ?
How ?

En image …



En image



Deux étapes

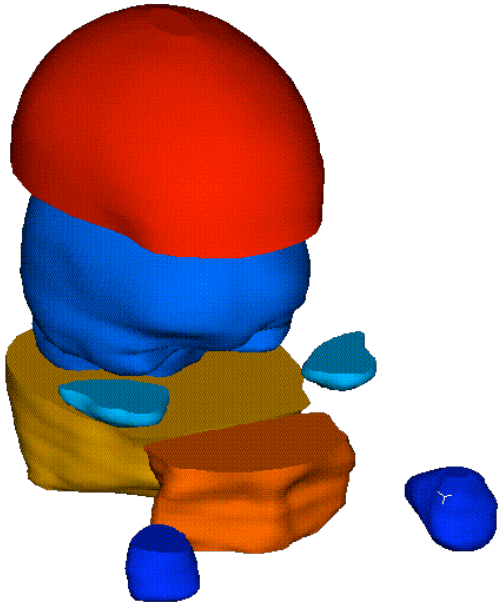
- **Model** : From Neurons to Mesures [“DIRECT” problem]

  ➡ Neurons [Current dipôles]

  ➡ Current propagation

  ☹ Complex géométry

  Numeric approach using T1 MRI



- **Estimation** : From Mesures to Neurons [“INVERSE” problem]

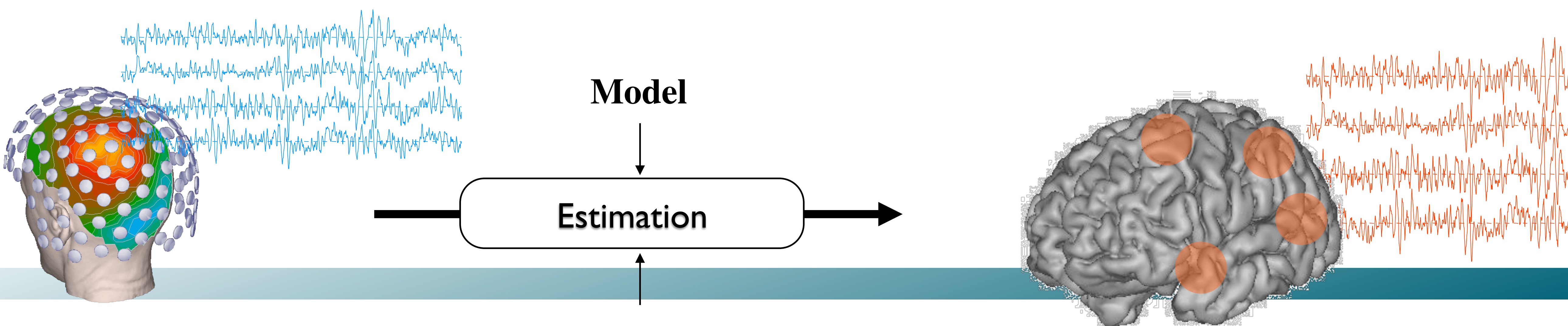
  ➡ Fit the model parameters

  ☹ Numerical instability

  ☹ Few data ☹ Non unique solution

  A priori information

  Regularization



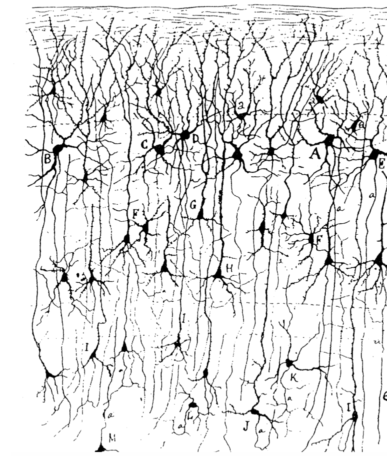
Le problème direct

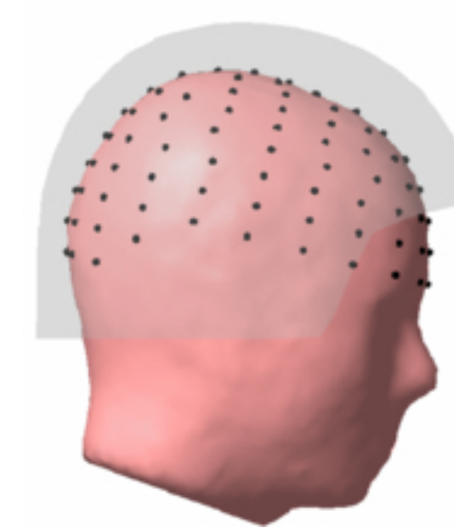
Two models:

How to model the electric current in a population of neurone?

= **Sources of brain electric activity**

Parameters : **position**, **orientation** & **amplitude** along the time

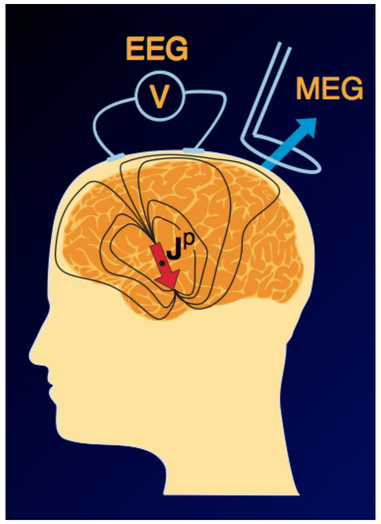




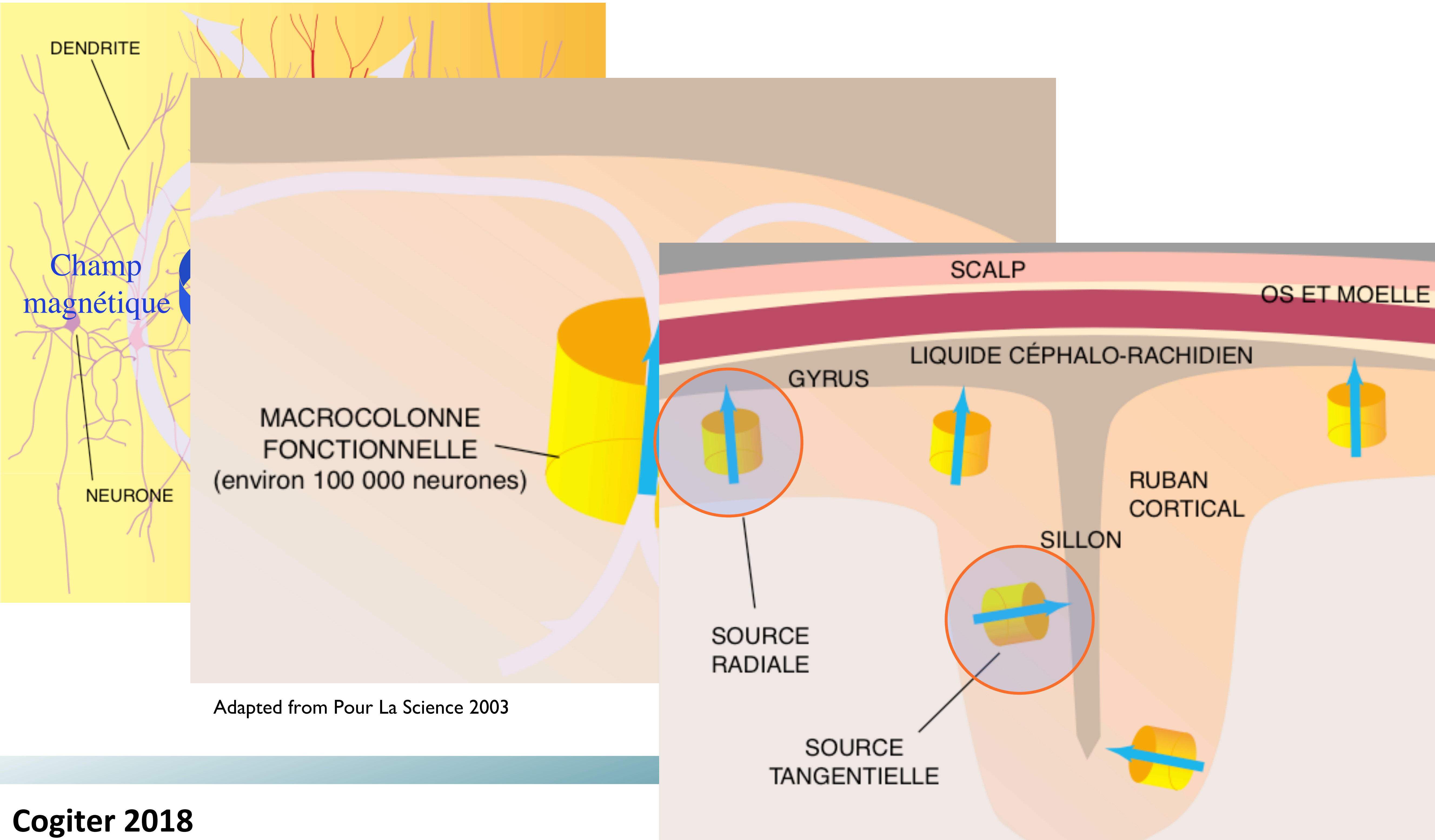
How the currents generated by the sources affect the sensors?

= **Geometrical model of the head**

Parameters : **geometry**, **conductivity** & **localisation with respect to the sensors**



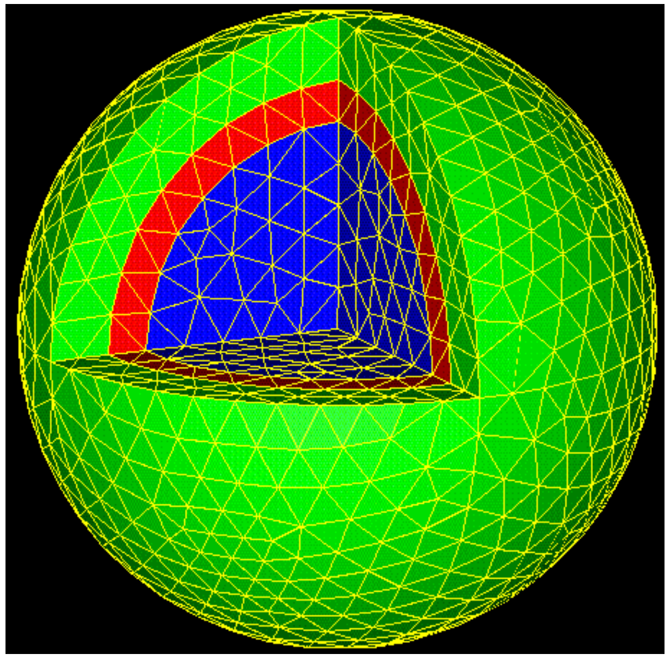
Modèle de sources



Adapted from Pour La Science 2003

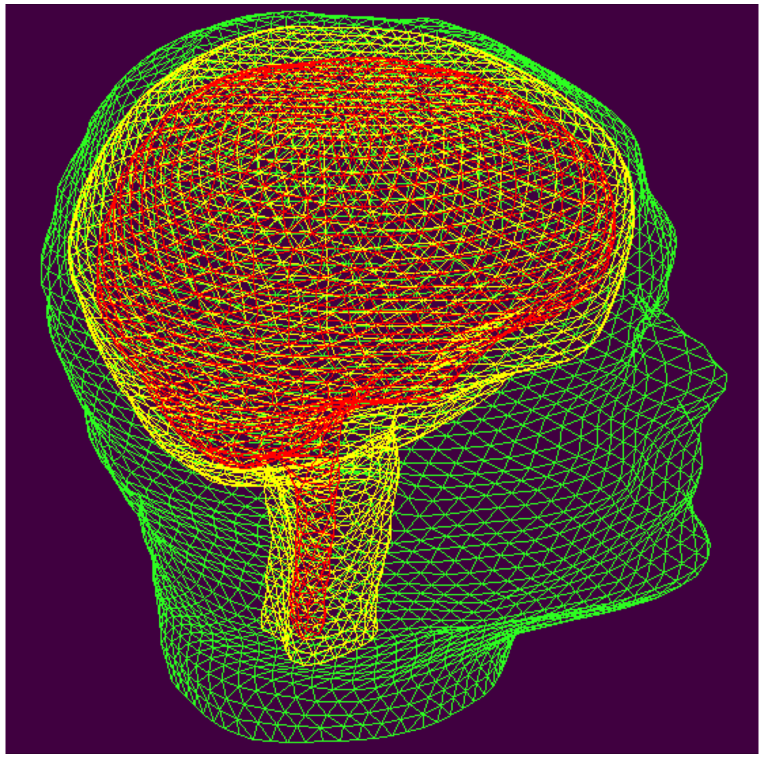
Le modèle géométrique

Spherical Model



Analytic solution for B & V

Realistic Model Homogeneous layers

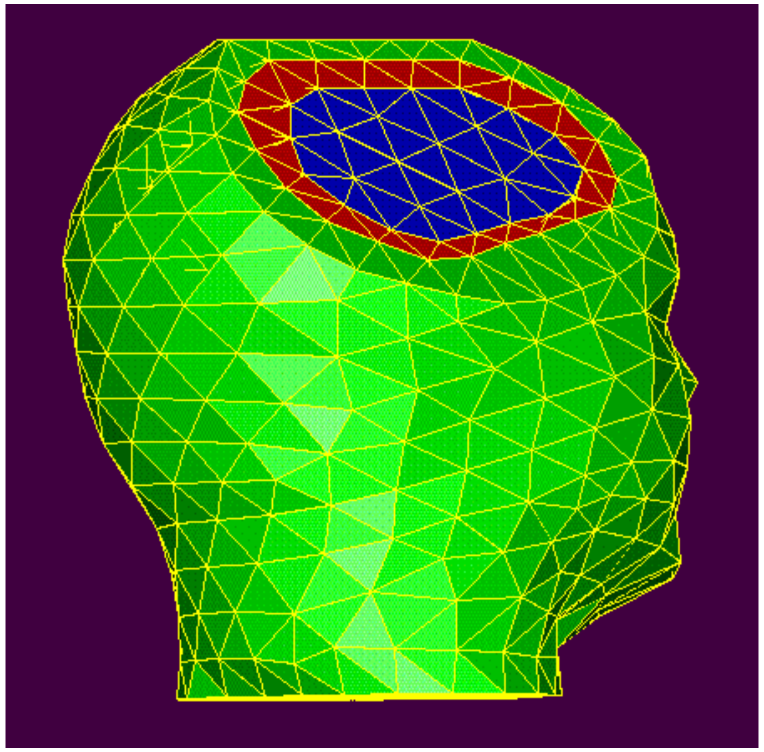


Boundaries Integrals

Homogeneous and isotrop layers

Surface meshes (brain, skull & scalp)

Realistic Model inhomogeneous



Finite elements and differences

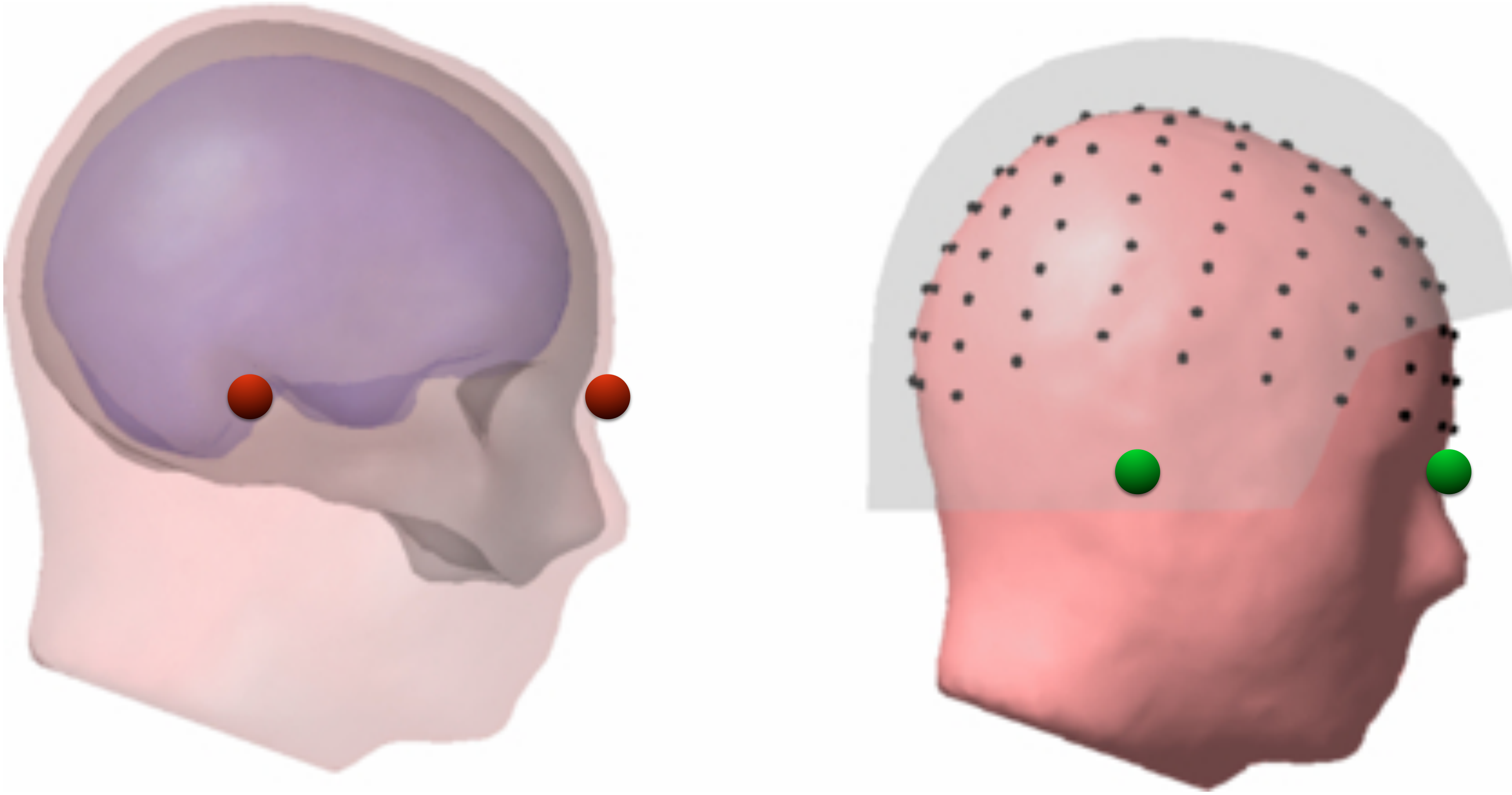
Inhomogeneous and non insotrop conductivity

3D meshes

Adapted from S. Baillet / L. Garnero

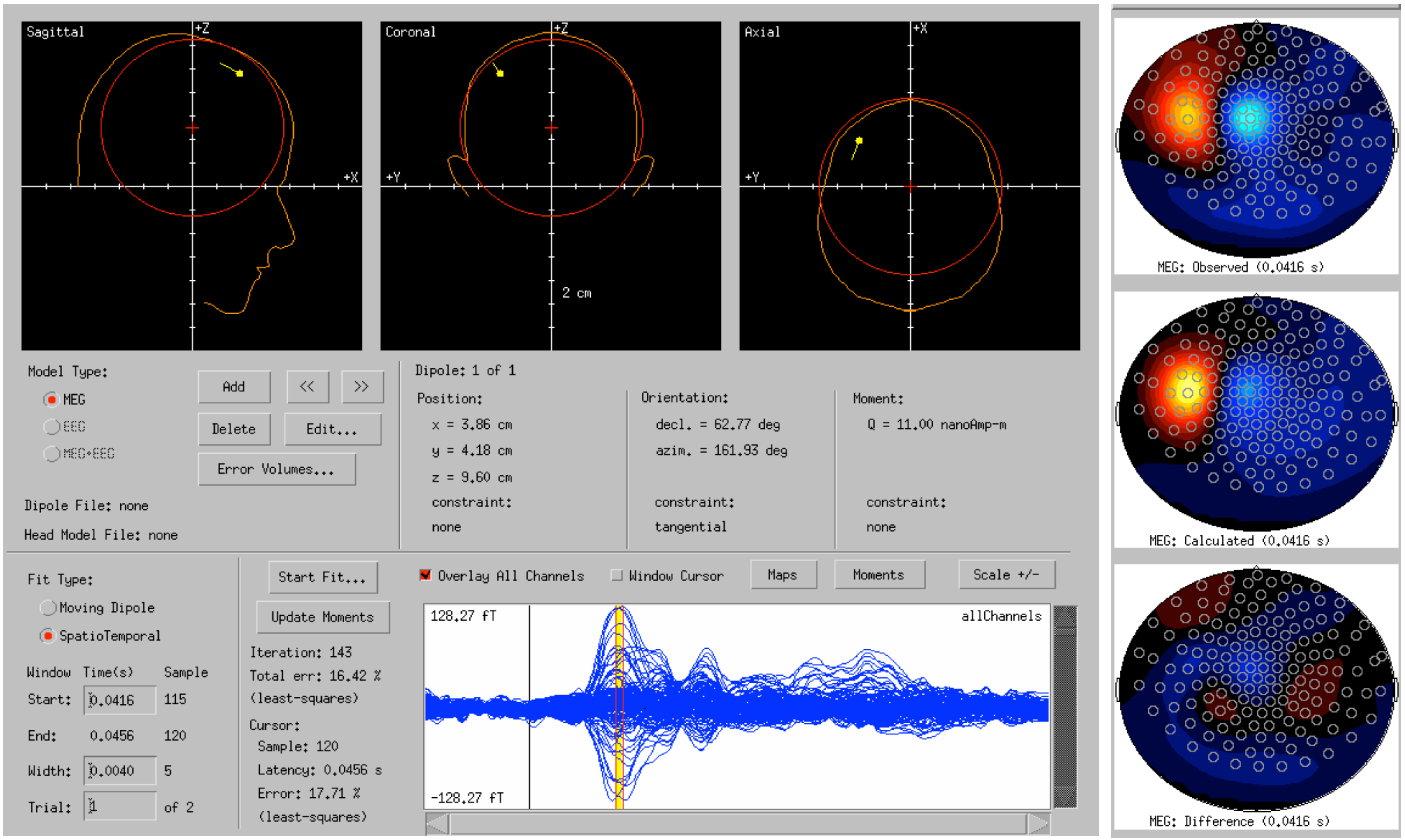
Recalage MEG + IRM

IRM ⟷ MEG/EEG Sensors



Translation + Rotation

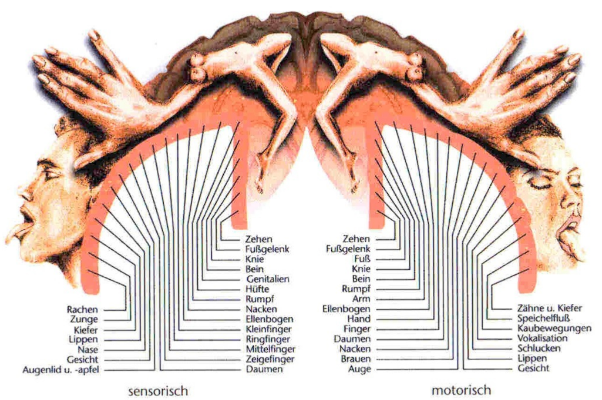
Exemple



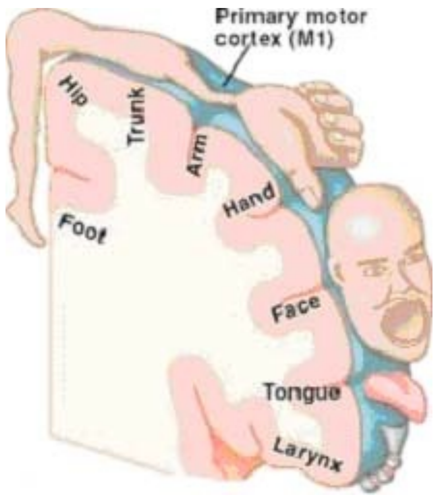
Sagittal
+Z
+X
Coronal
+Y
2 cm
Axial
Model Type:
MEG
EEG
MEG+EEG
Add
<<
>>
Delete
Edit...
Error Volumes...
Dipole File: none
Head Model File: none
Dipole: 1 of 1
Position:
x = 3.86 cm
y = 4.18 cm
z = 9.60 cm
constraint:
none
Orientation:
decl. = 62.77 deg
azim. = 161.93 deg
constraint:
tangential
Moment:
Q = 11.00 nanoAmp-m
constraint:
none
Fit Type:
Moving Dipole
SpatioTemporal
Window Time(s) Sample
Start: 0.0416 115
End: 0.0456 120
Width: 0.0040 5
Trial: 1 of 2
Start Fit...
Update Moments
Iteration: 143
Total err: 16.42 %
(least-squares)
Cursor:
Sample: 120
Latency: 0.0456 s
Error: 17.71 %
(least-squares)
Overlay All Channels
Window Cursor
Maps
Moments
Scale +/-
128.27 fT
allChannels
-128.27 fT
MEG: Observed (0.0416 s)
MEG: Calculated (0.0416 s)
MEG: Difference (0.0416 s)

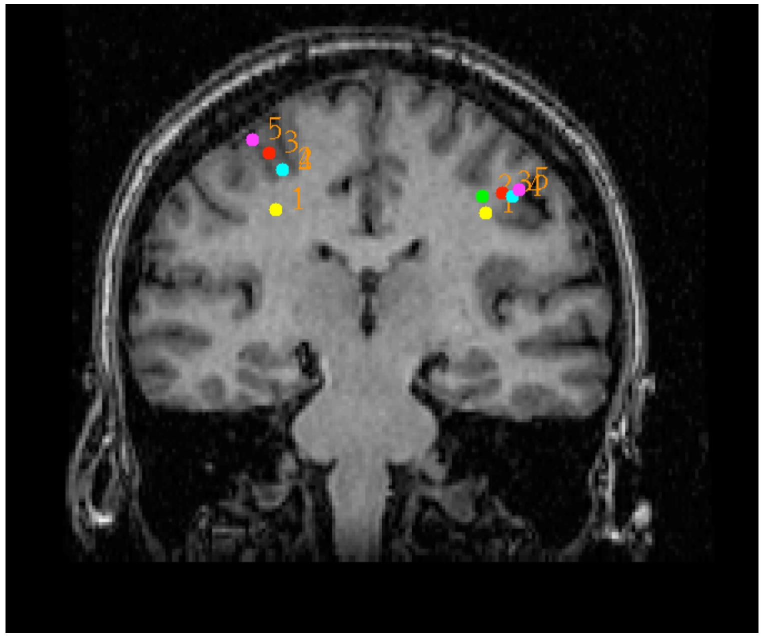
Somatotopie

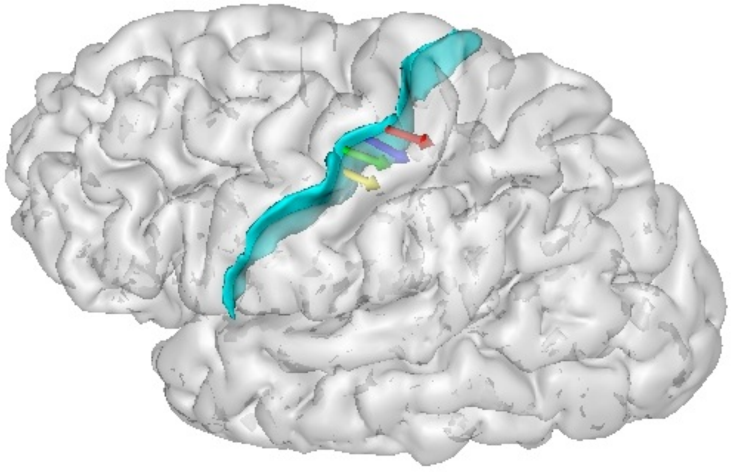
Fingers somatotopy

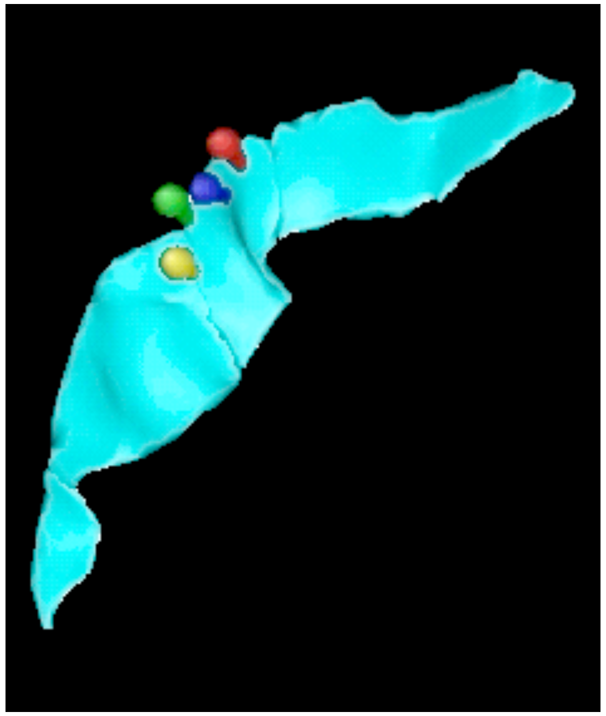


Projektionsfelder auf der Großhirnrinde (Humunculus)

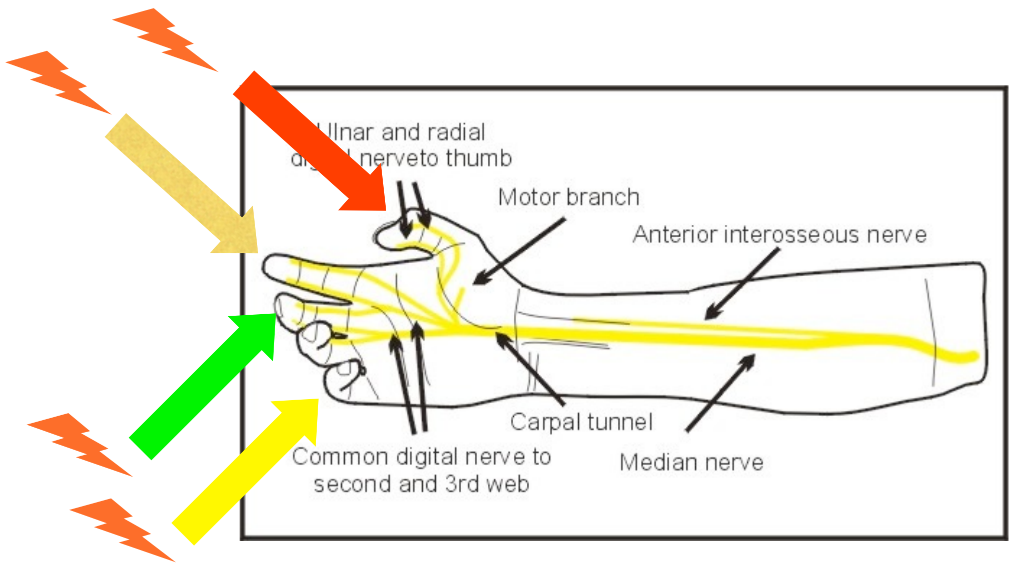


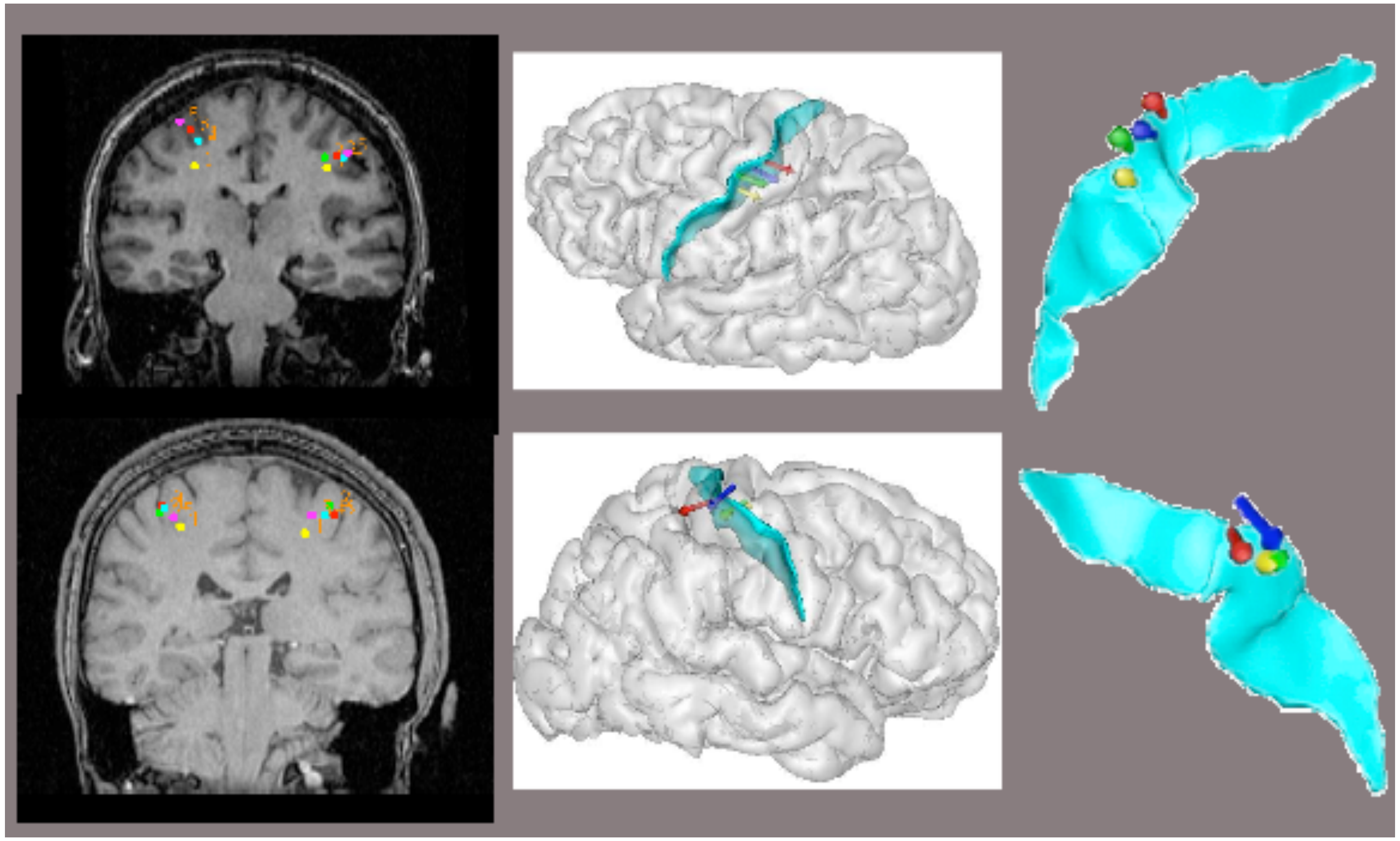






Dystonie





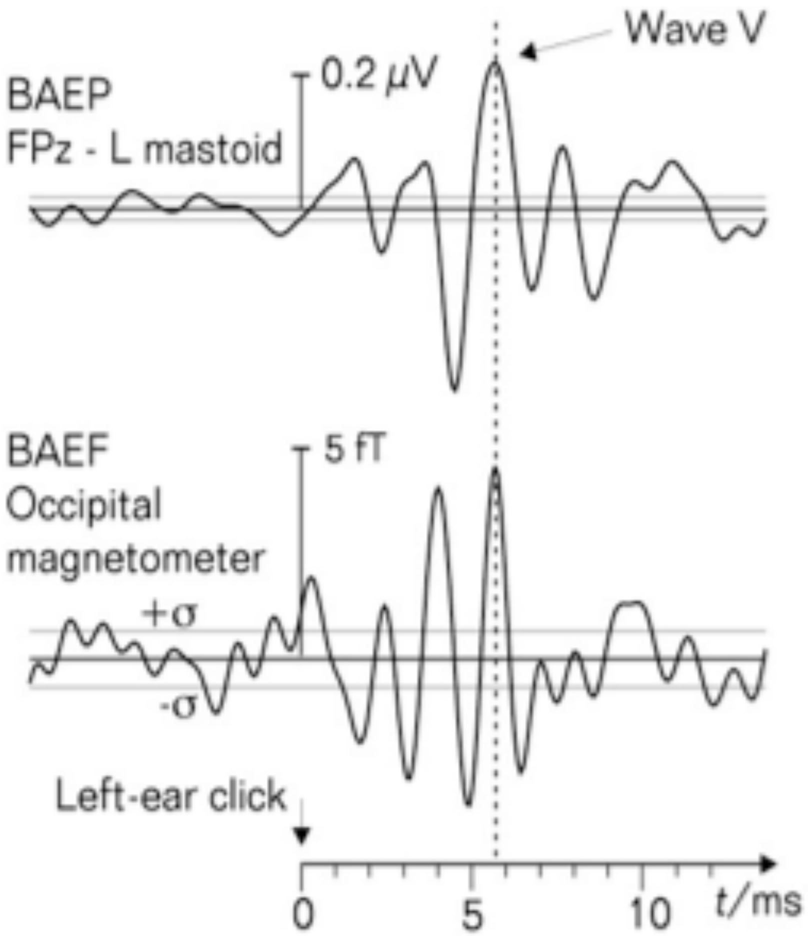
MEUNIER S., **GARNERO** L., **DUCORPS** A., MAZIERES L., LEHERICY S., TEZENAS DU MONTCEL S., **RENAULT** B., VIDAILHET M.(2001) **Human brain mapping in dystonia reveals at once endophenotype and adaptative reorganization**, Annals of Neurology, 50 :521-527.

MEUNIER S., LEHERECY S., **GARNERO** L., VIDAILHET M. (2003) **Dystonia : Lessons from Brain Mapping** . Neuroscientist, 9, 1, 76-81

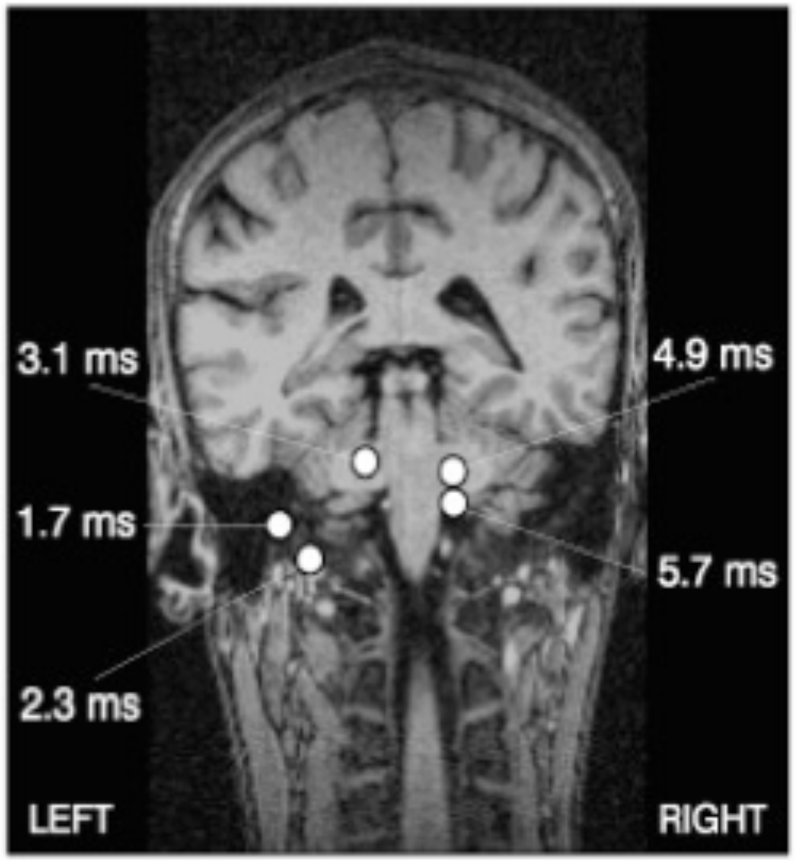
Un exemple profond …

STIMULUS:
0.6-ms auditory clicks to left ear
111 ms ISI, 15000 epochs averaged

RESPONSES:
Shown with pass-band 160 – 900 Hz



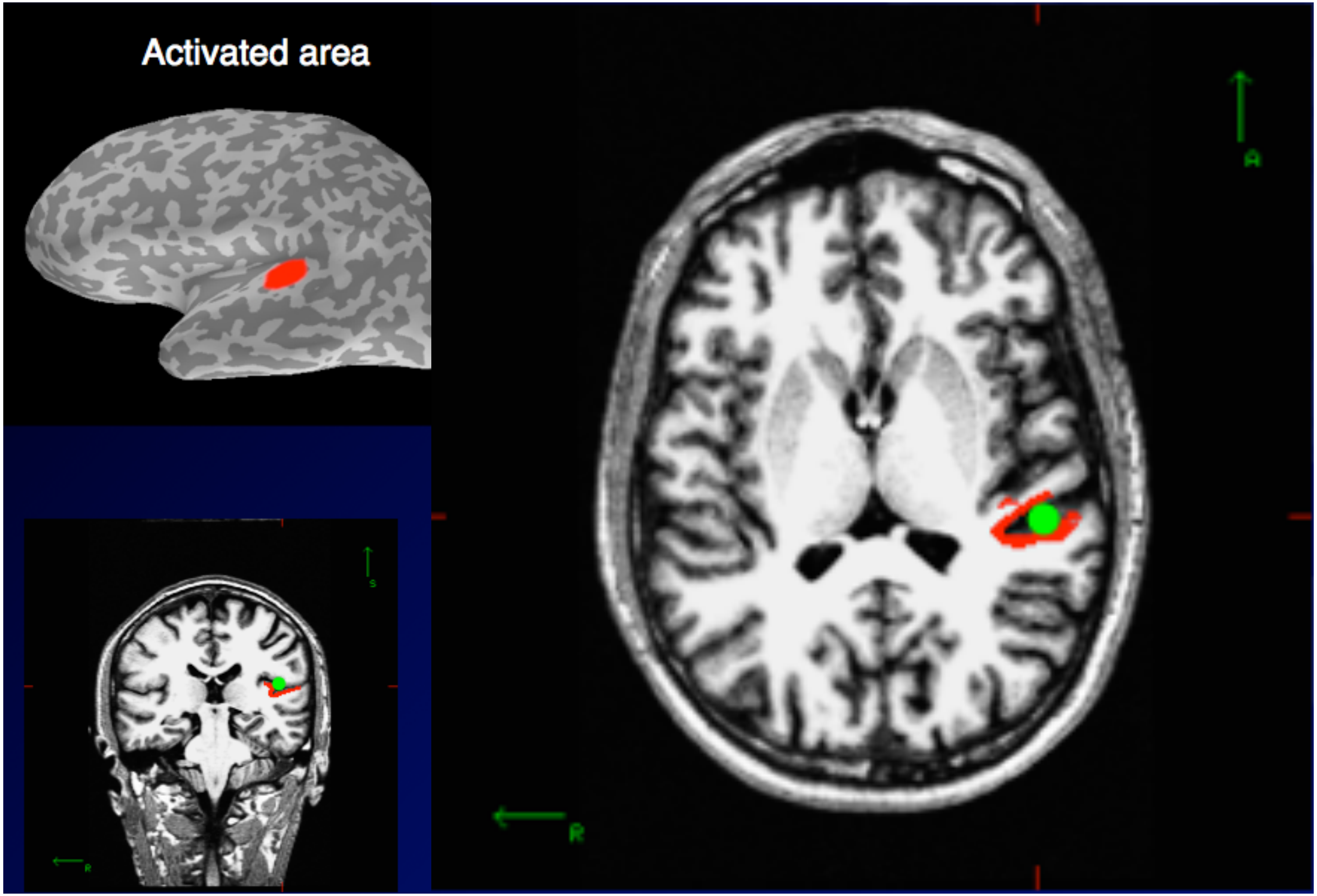
ANALYSIS:
- individual BEM models
- equivalent current dipoles



NOTE: All sources visualized on a single MRI slice.

Parkkonen et al. 2002

Les sources étendues ?



Approches Imagerie

Baillet et al 2001 - IEEE Biomed

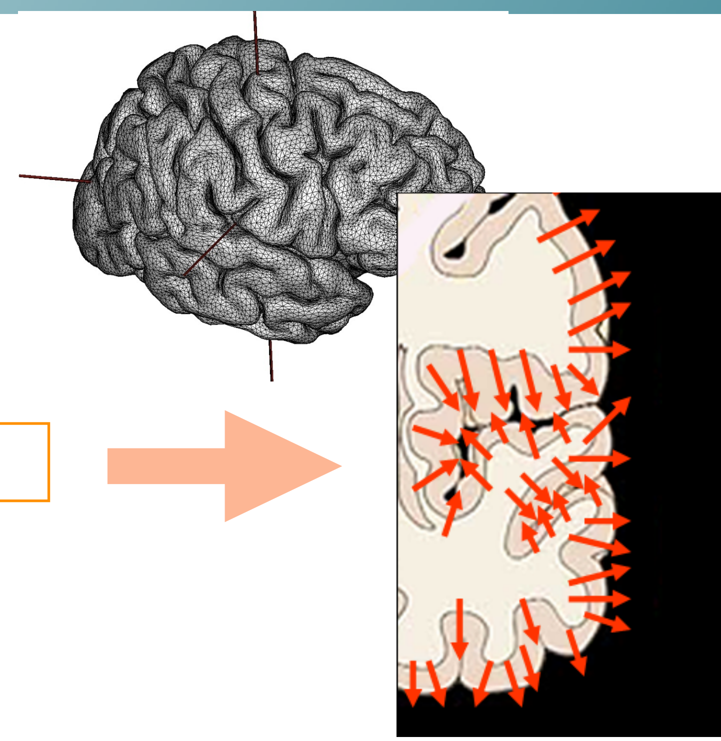
- **Mathematical model**

MEG / EEG measures

$M = G.s + n$ noise

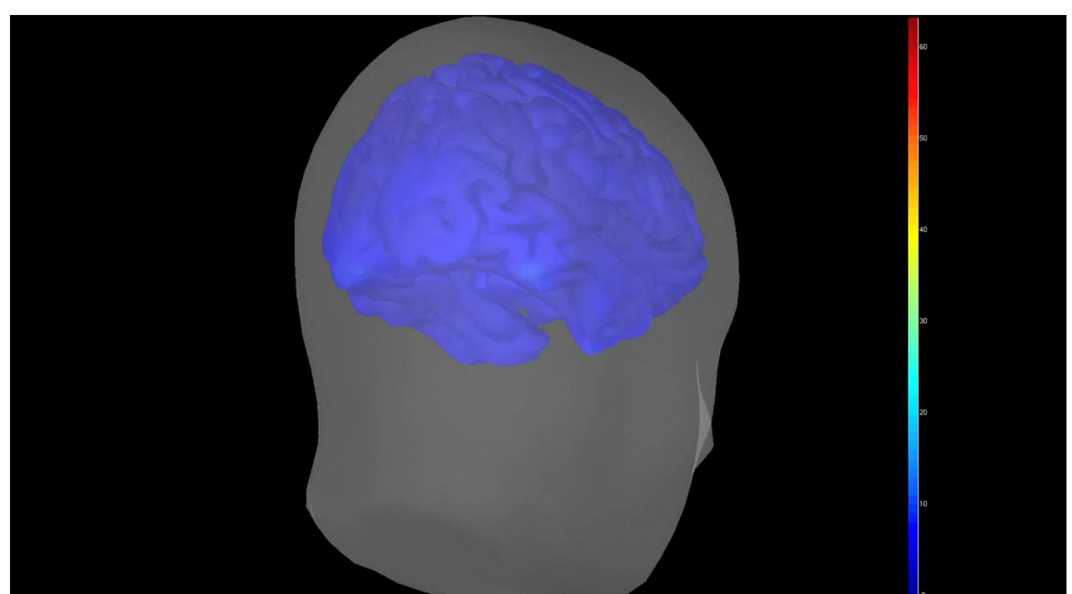
Sources activity

Direct problem



Pos. & Orient. known
Unknown : Moment
along the time

- **Inversion** : Minimum norm



Formalisation

Baillet et al 2001 - IEEE Biomed

- **Mathematical model of the data (linear!):**

Nc x Nt

MEG / EEG measures

Ns x Nt

$$M = G.s + n$$

Noise

Cortical activity

Ns x Nt

Direct Problem

Nc x Ns

Nc => Number of sensors

Nt => Number of time points

Ns => Number of sources

M => Your **known** MEG or EEG signals

G => Your **known** forward operator

S => Your unknown cortical currents

N => **Known** zero-mean additive noise

- **G** explains the magnetic field created by a source with known location & direction on each sensor
- It is sufficient to know **the noise covariance matrix** which is computable from your raw data

$$\tilde{s} = \min \left\| M\text{-}Gs \right\|^2 + f(s)^2 \quad \Rightarrow \quad \tilde{s} = \min \left\| M\text{-}Gs \right\|^2 + \lambda \left\| s^2 \right\|$$

Calcul de l'opérateur inverse

$$\tilde{s} = \min \|M\text{-}Gs\|^2 + \lambda \|s^2\|$$

$$\underset{Ns \times Nt}{\tilde{S}} = \overset{Ns \times Nc}{W} . \underset{Nc \times Nt}{M}$$

$$W = RG^T . \left(GRG^T + \lambda C\right)^{-1}$$

R:

Signal Covariance

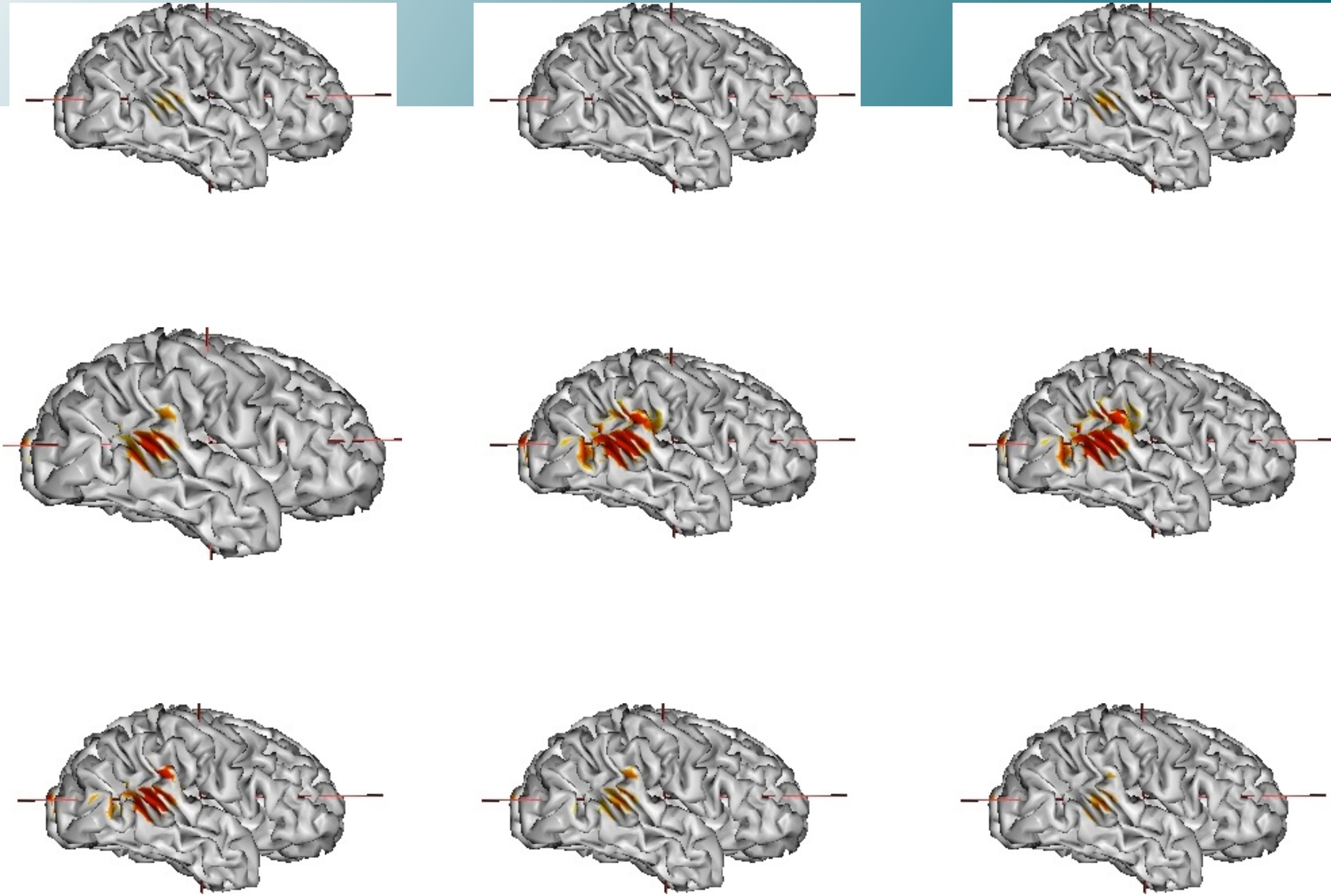
Depth Weighting

C:

Noise Covariance

Noise level on each sensor (diagonal element)

Correlation between sensors (full matrix)



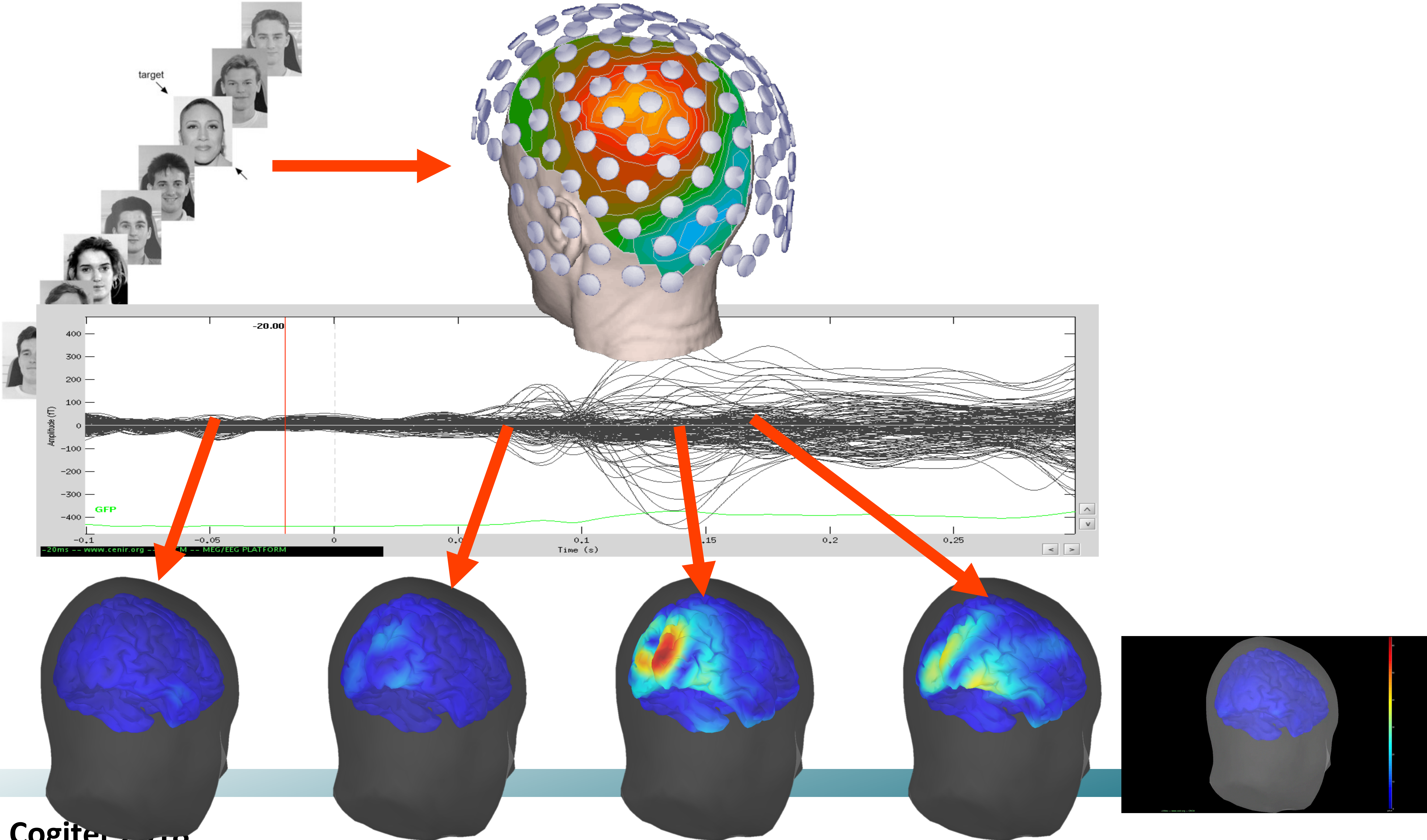
60 70 ms

70 80 ms

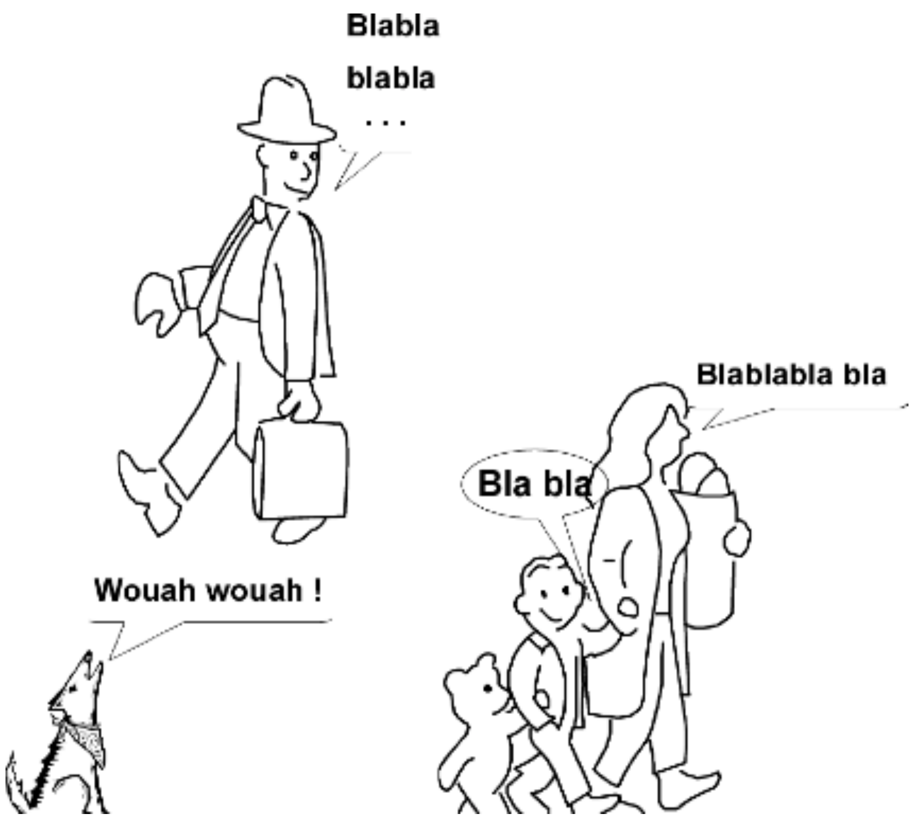
80 90 ms

Cogiter 2018

Le résultat sur le cortex

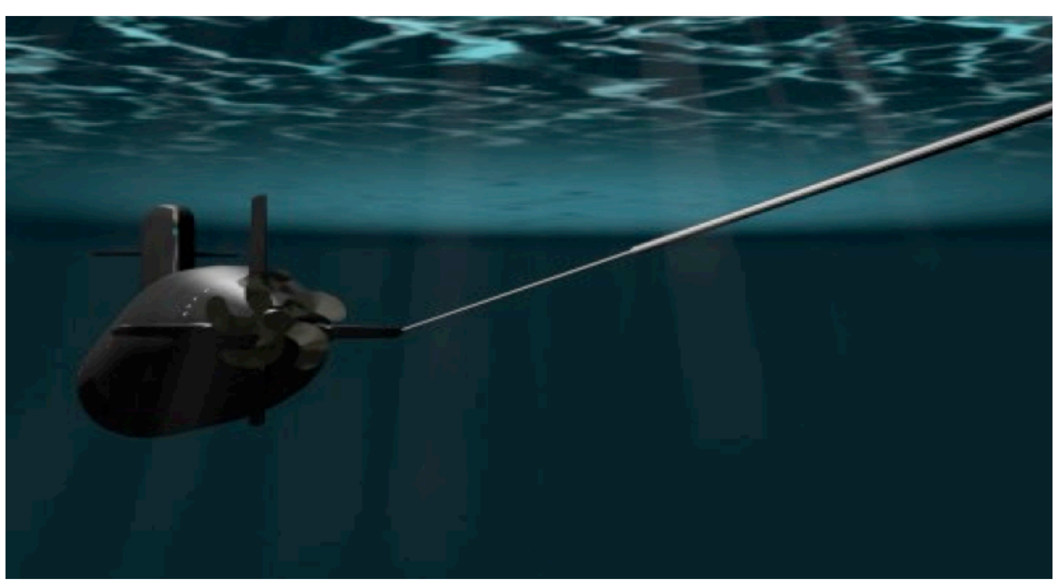


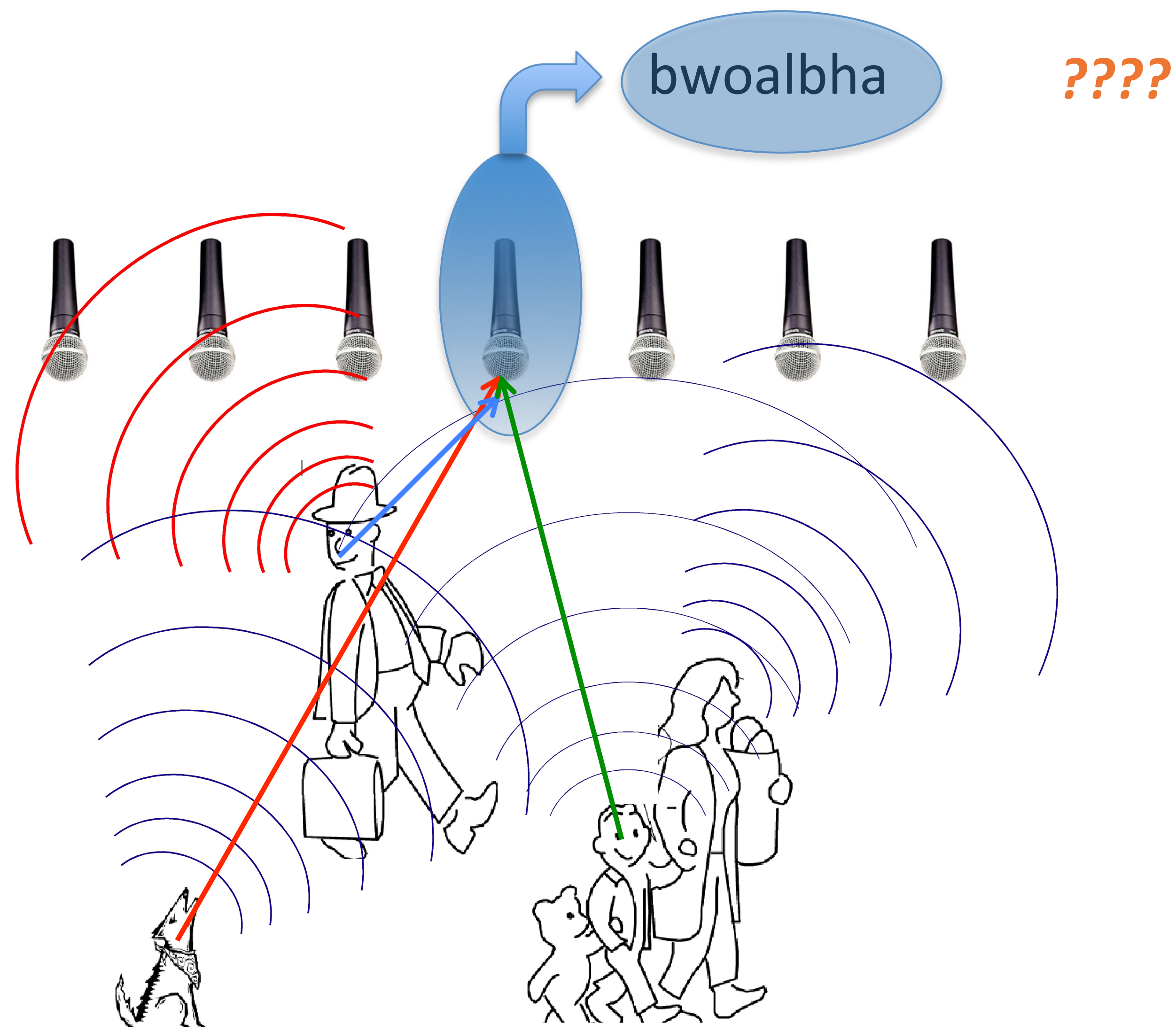
Beamforming « acoustique »



•détecter une source parmi du bruit et des interférences

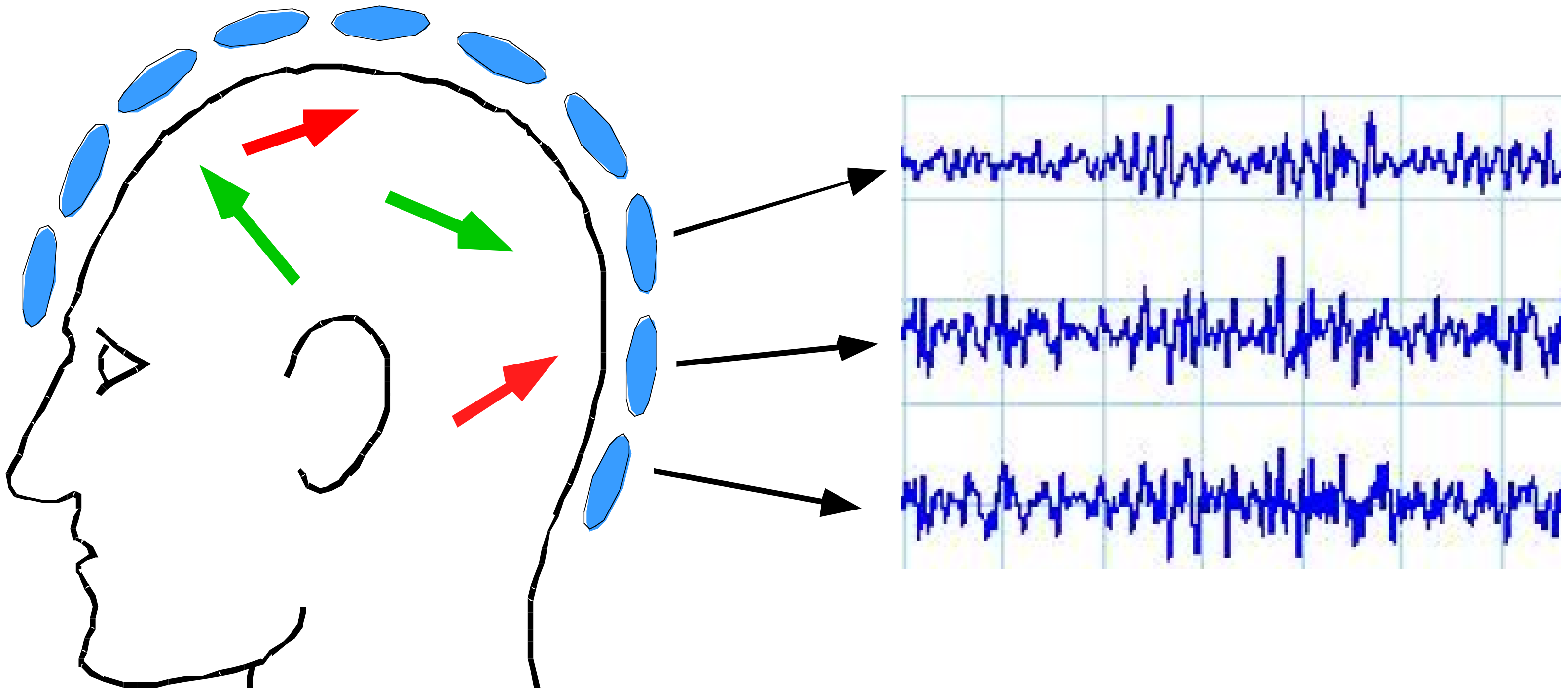
•construire une carte du milieu : caractérisation de toutes les sources et détermination de leur position spatiale





Contexte et hypothèses

contexte :

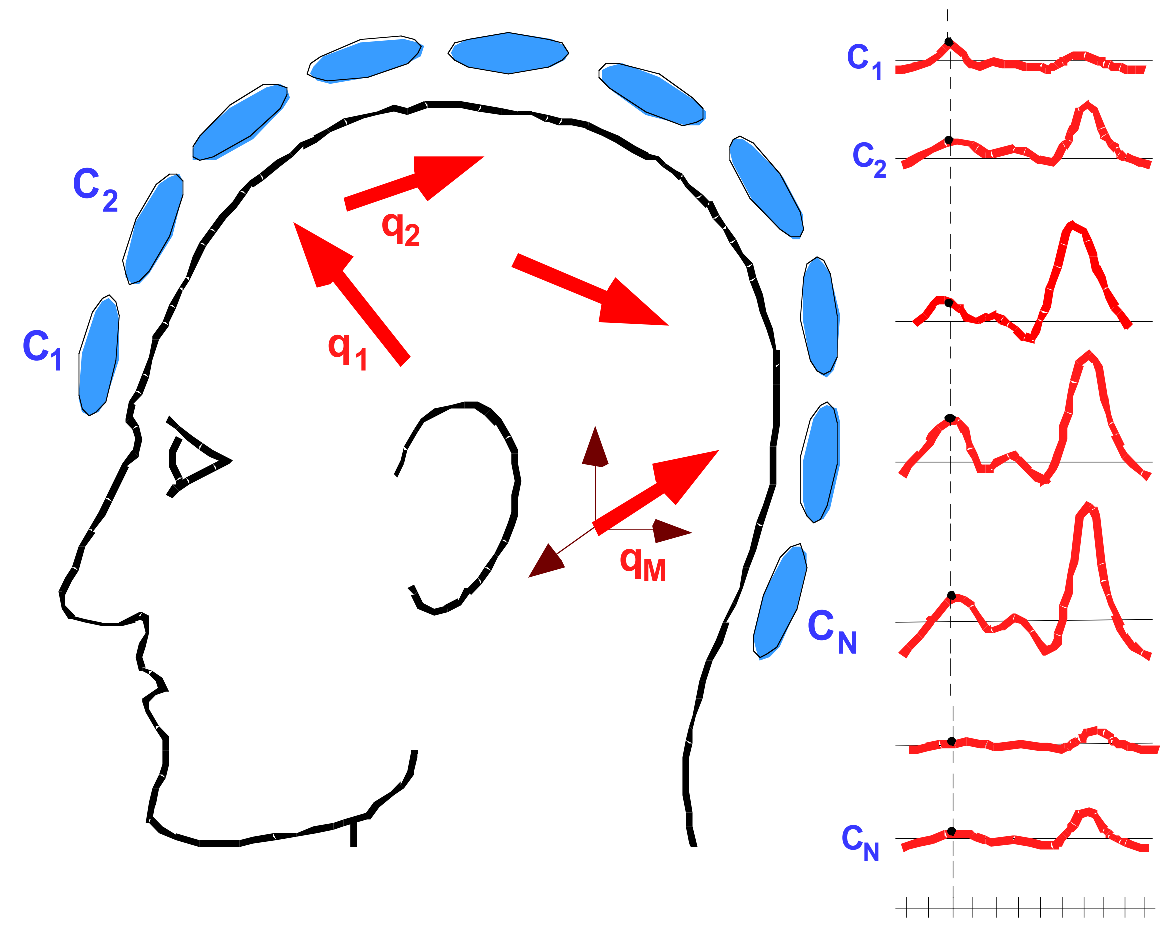


hypothèses

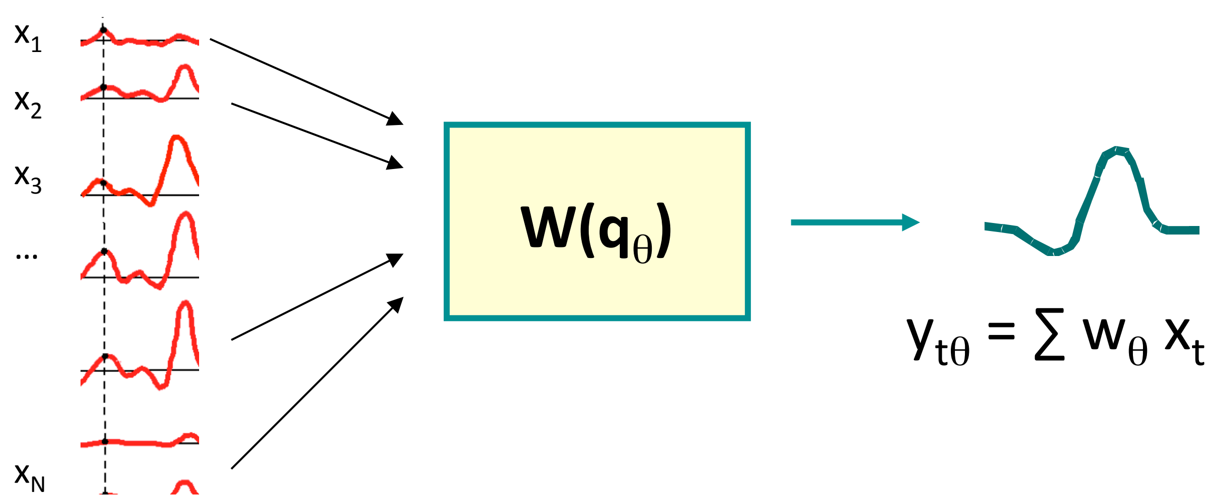
- onde plane : discrimination à partir de l'amplitude des signaux (pas de propagation)
- signaux stationnaires sur les périodes d'analyse (+-)
- nombre de sources < nombre de capteurs
- modèle dipolaire (ECD)
- sources non corrélées ou peu (< 0.8) sur la fenêtre d'analyse
- suffisamment de signal pour obtenir une solution stable

Notations

- N capteurs (C_1, C_2, C_i…C_N)
- M sources (q_1, q_2, q_q…q_M)
- K échantillons temporels



signal des capteurs



$y_{t\theta} = \sum w_\theta x_t$

sortie du filtre pour la source q_θ

Cartes SPM: « dual-state » differential imaging(4)

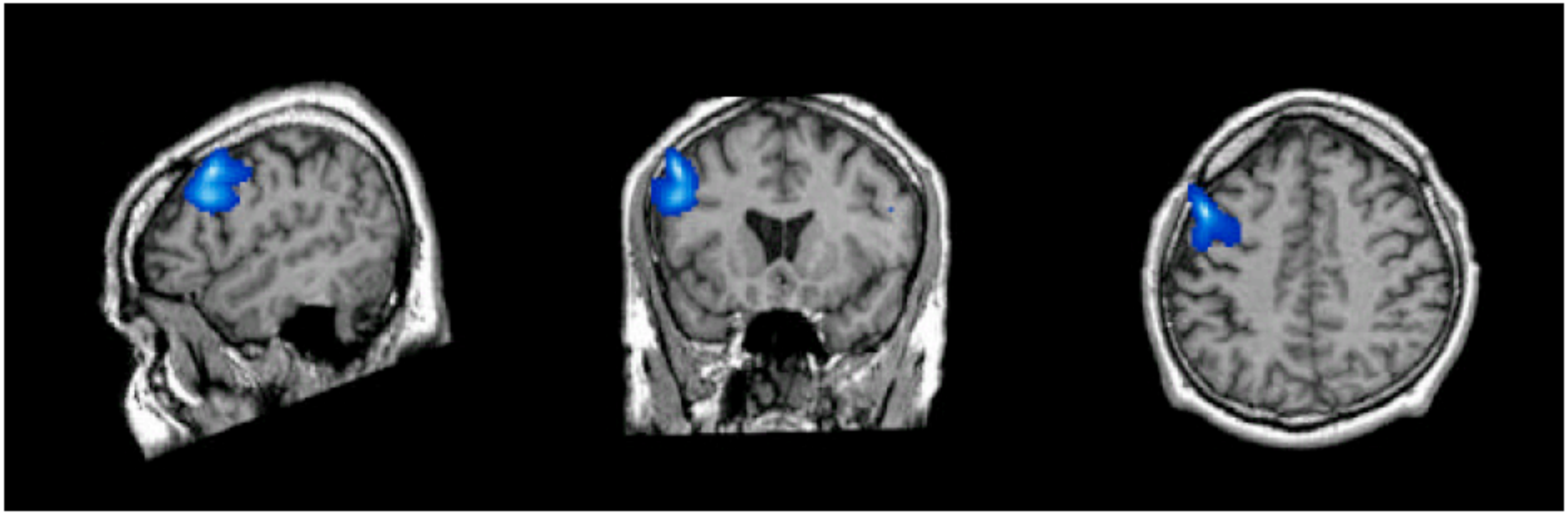


Figure 6. Dual-state SAM image in the 15 to 30 Hz frequency band of cortical activity during overt picture naming. A 143-channel MEG whole-head instrument was used to collect data in the open unshielded environment. Photographs of simple common objects were presented to the subject on an LCD screen. The subject's task was to identify the object and speak the name. The onset of vocalization was detected by a microphone, triggering each trial of data acquisition. The photograph remained on-screen for the duration of each of 100 trials. A pseudo-T image was generated from the difference in source activity between a time-segment prior to vocalization (the active state), and a time-segment after vocalization was completed (the control state). The blue coloration of the areas activated indicates event-related suppression in these regions. That is, rhythmic cortical activity was suppressed during the naming task, relative to the rest state following speech generation. Note that these changes are lateralized to the left hemisphere.

Et les sources profondes ?

Possible BUT

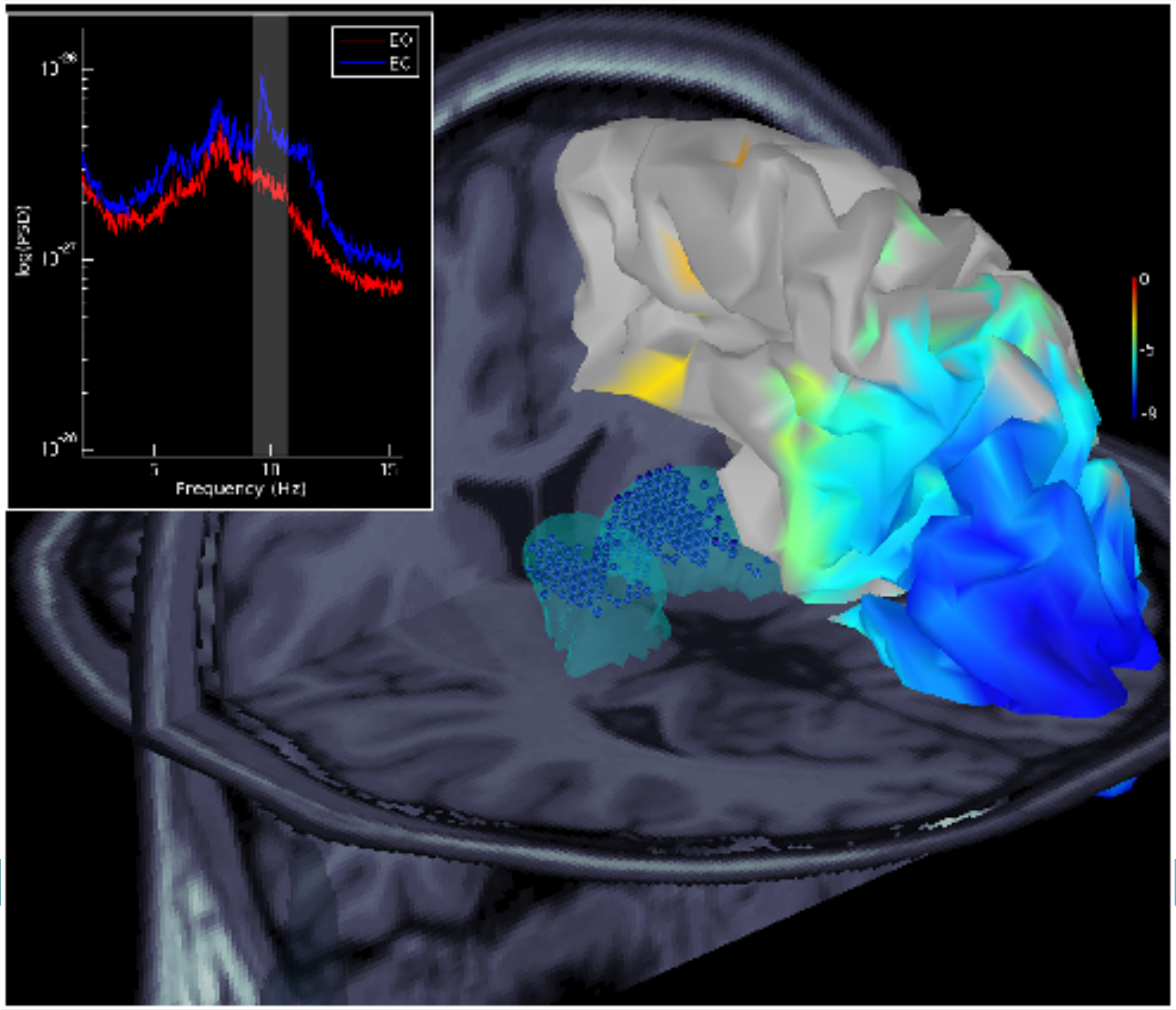
Very limited spatial resolution

Leakage from one structure to another

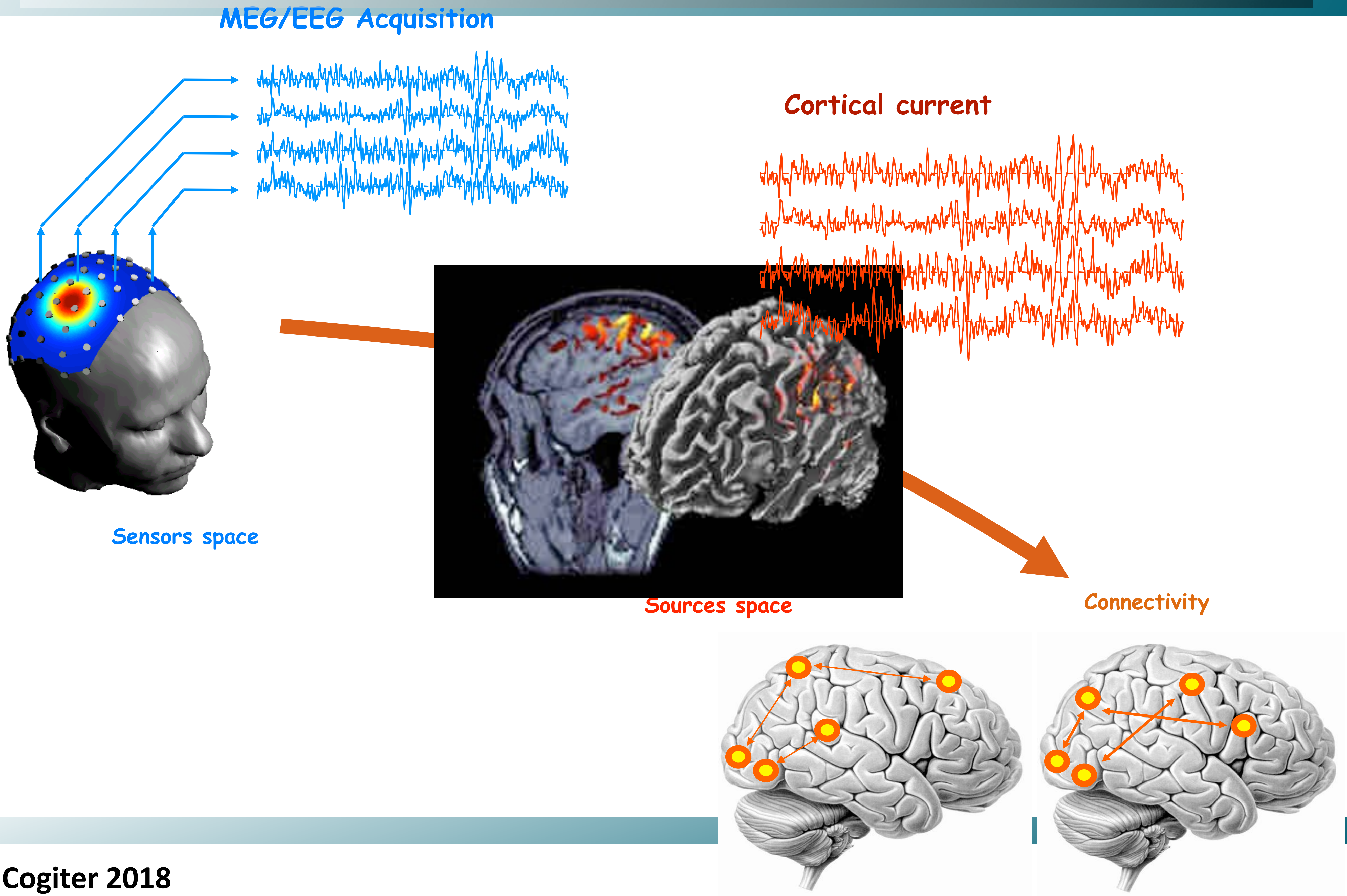
May necessitate heavy adaptation of protocols to increase SNR

Work quite well for Amygdala, Hippocampus, cerebellum

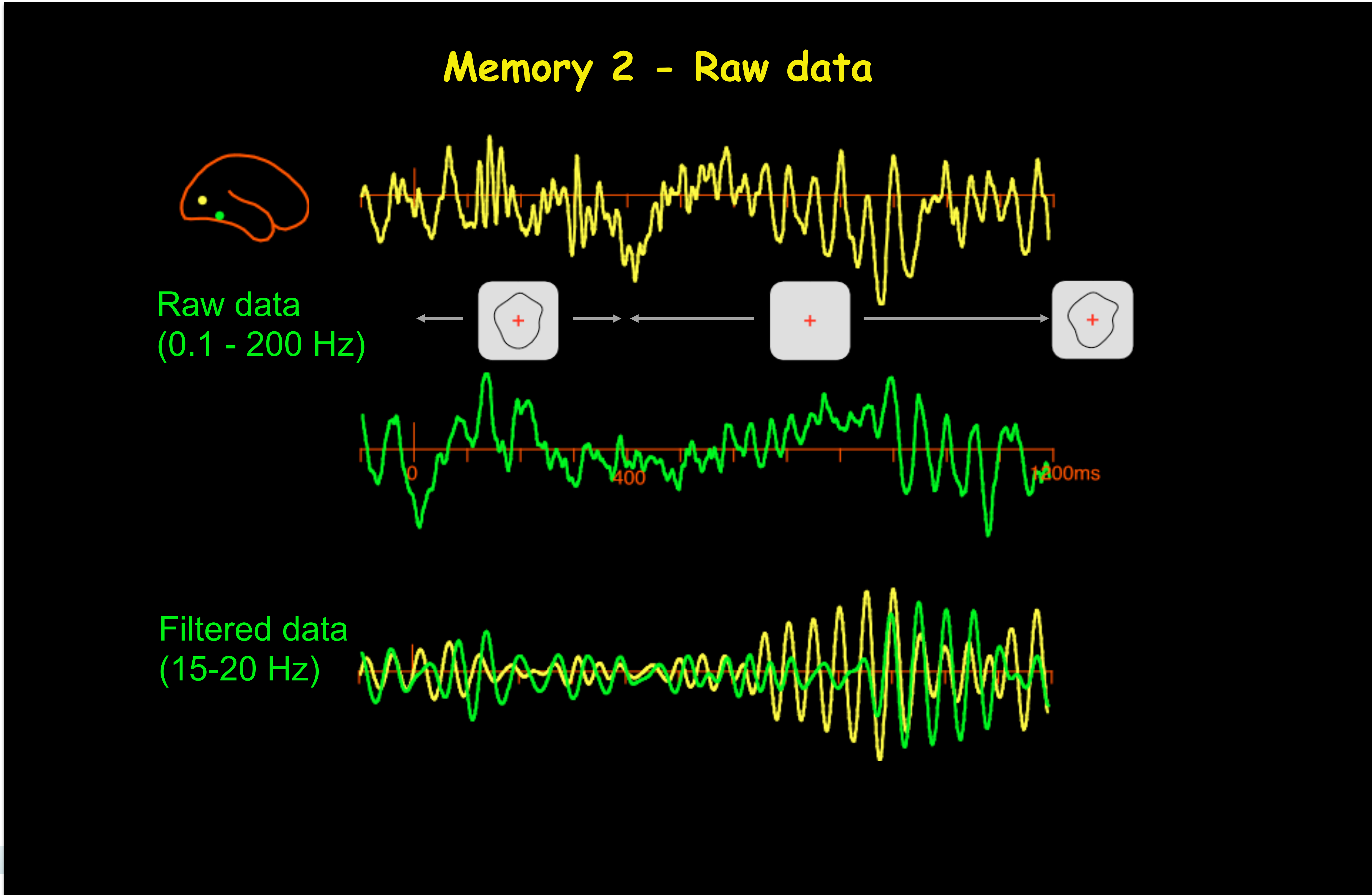
May work for thalamus



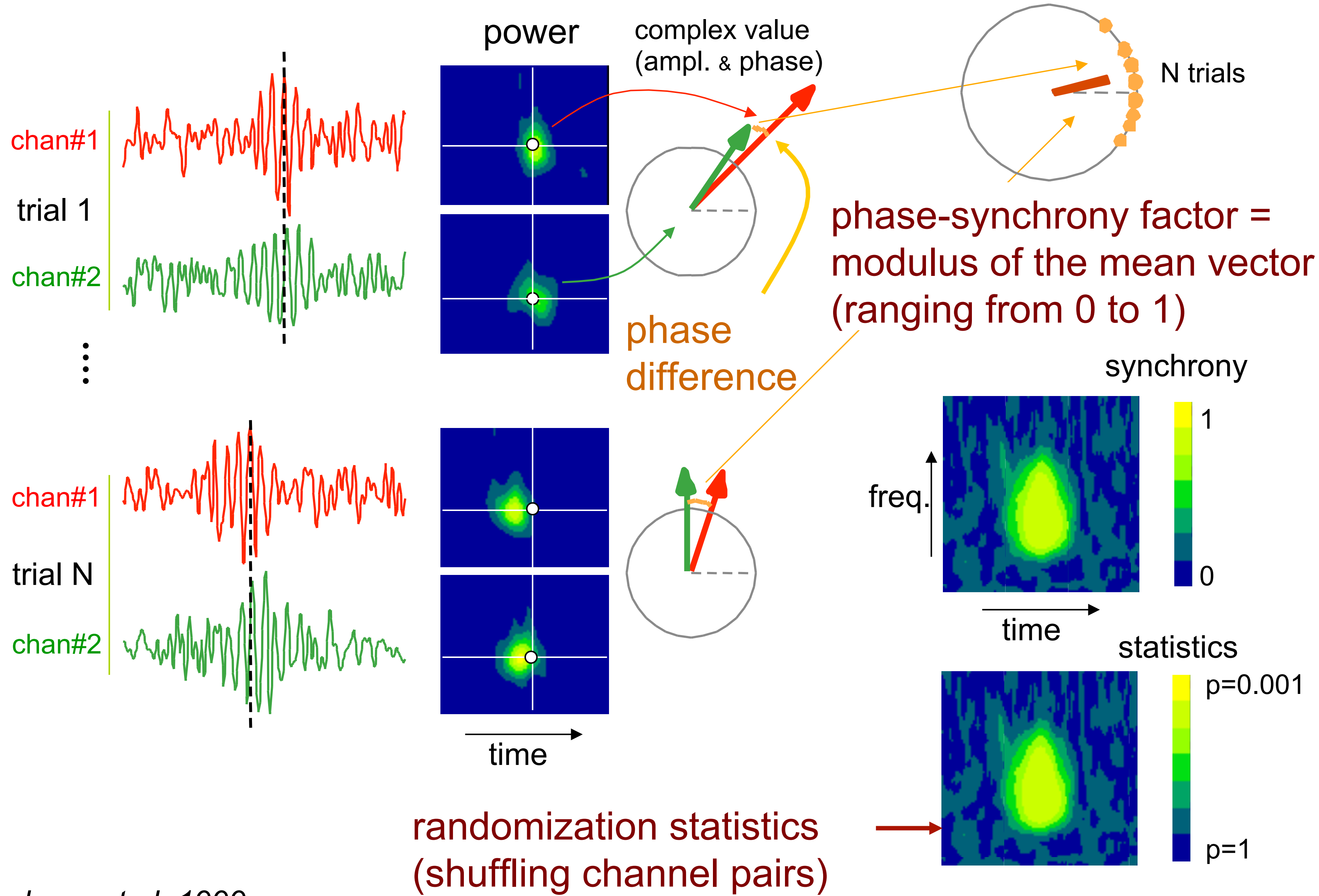
Connectivity?



Synchronies?

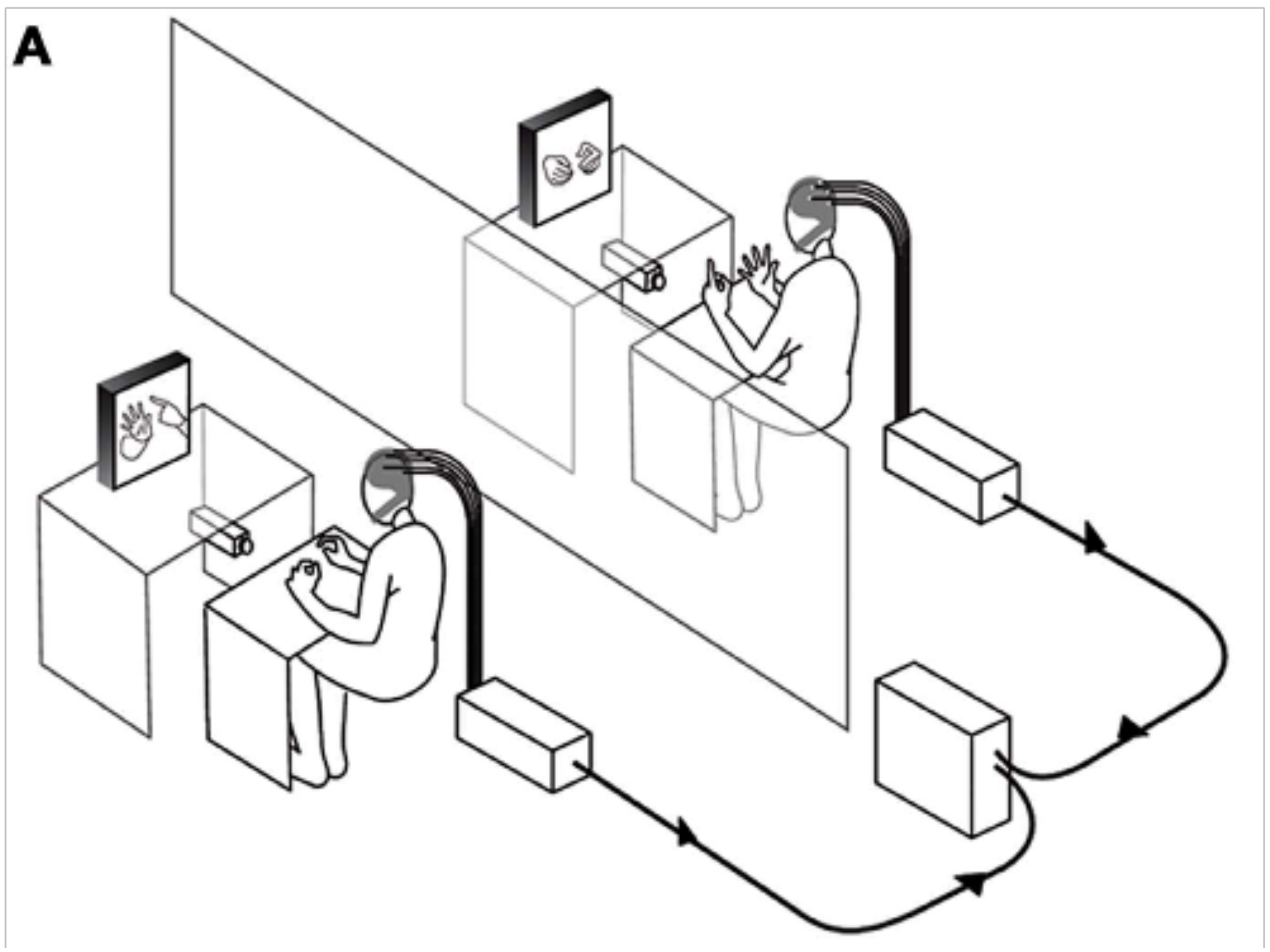


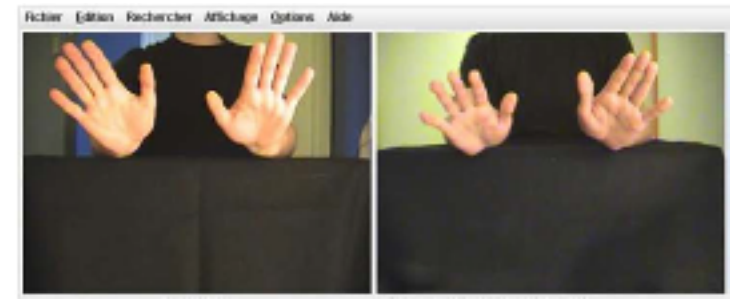
How do we measure synchronies?

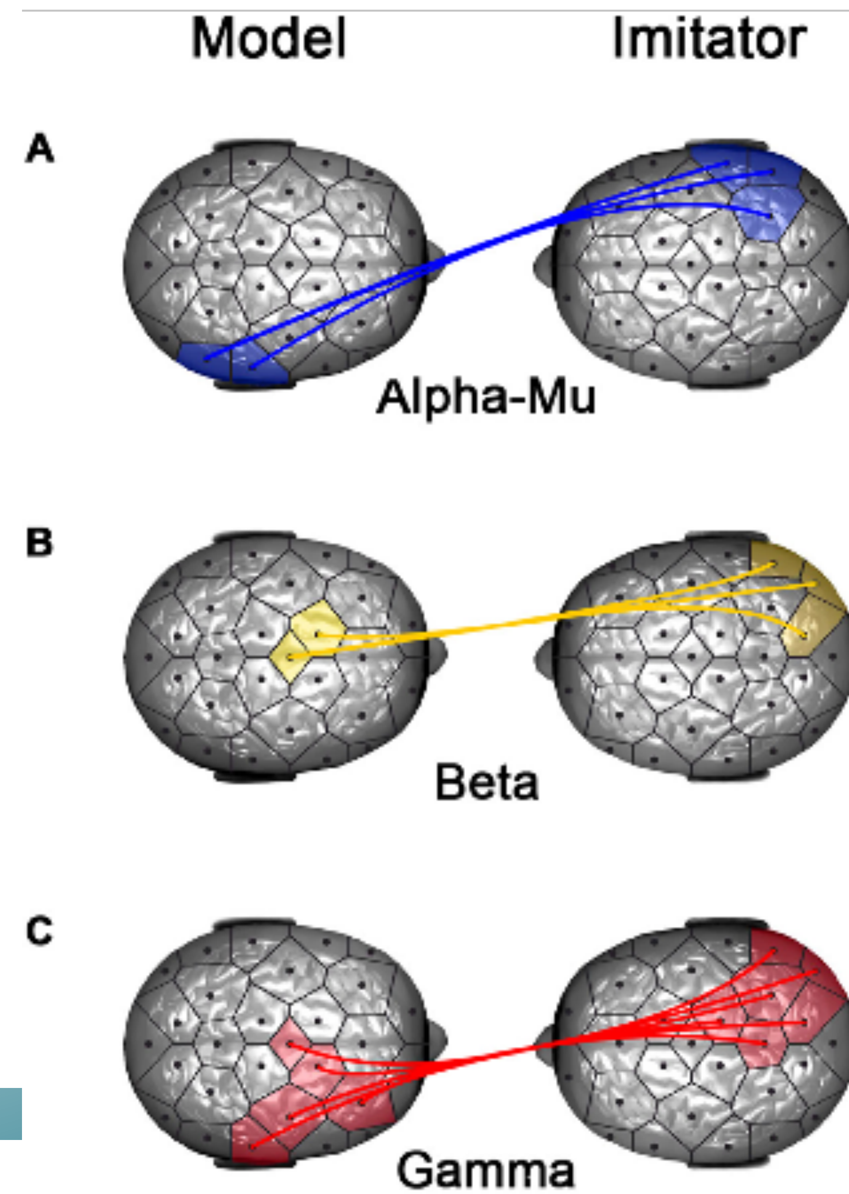


Lachaux et al. 1999

Between subjects????



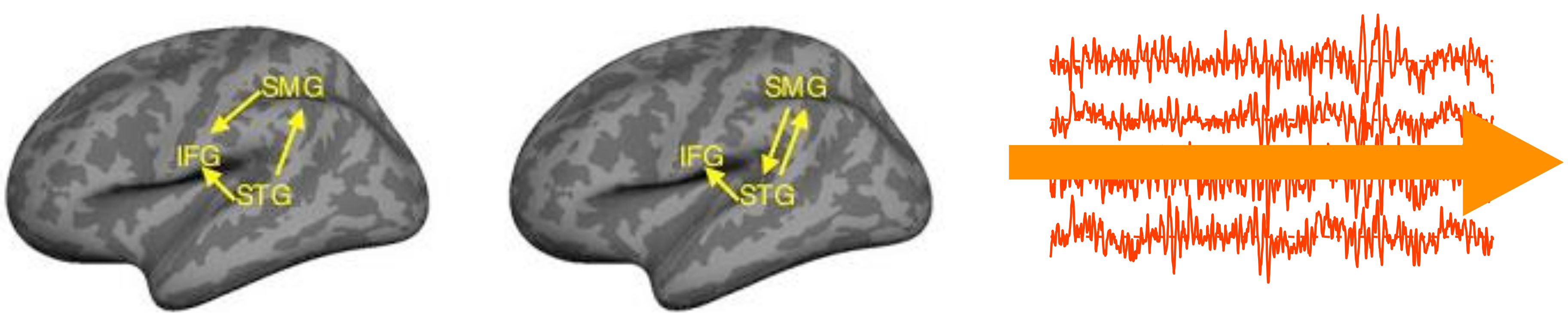




A few words on causality

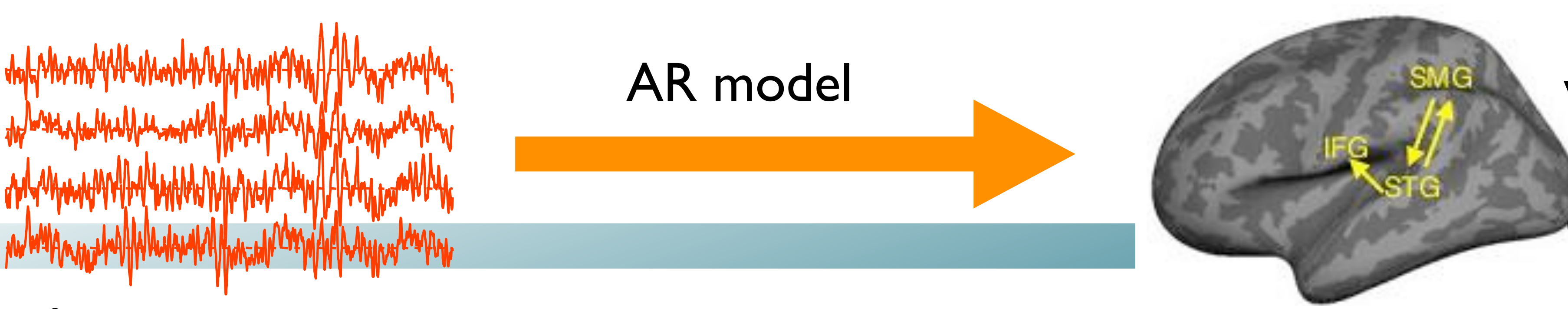
Describe the direction of the information flows

- Two possible ways
  - Dynamic Causal Modeling [Model driven]



Model likelihood

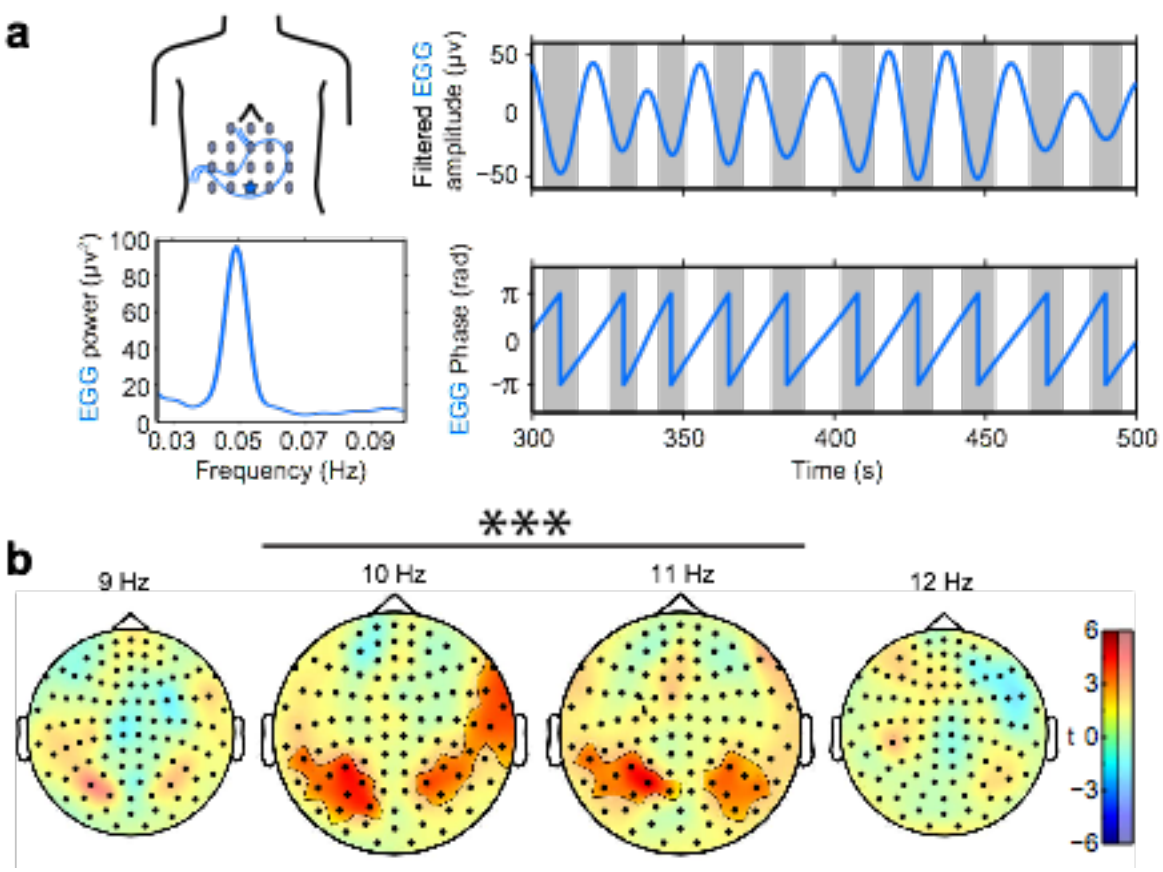
  - Granger Causality [Data Driven]

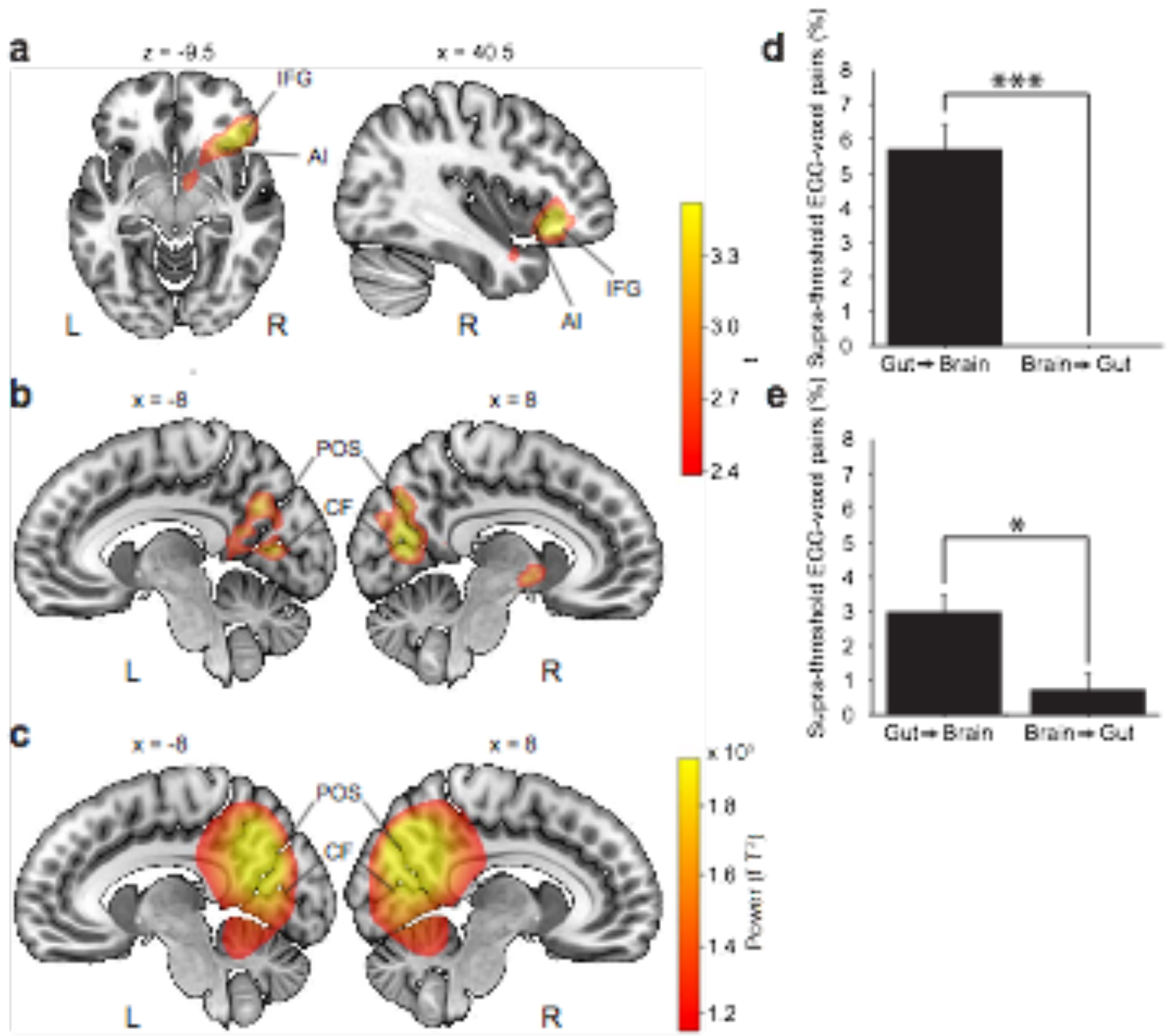


Weights and direction of links

Stomach and brain interactions

The amplitude of spontaneous alpha rhythm fluctuations varies with the phase of the infra-slow gastric basal rhythm. Ritcher et collaborateurs, NeuroImage 2016.





MEG in alpha band coupled to gastric basal rhythm

Causality shows mainly Gut to Brain information flow.

LETTER

doi:10.1038/nature26147

Moving magnetoencephalogra… hy towards real–world applications wit… earable system

Elena Boto[1*], Niall Holmes[1*], James Leggett[1*], Gillian Robe… Meyer[3,4], Leonardo Duque Muñoz[3], Karen J. Mullinger[1,5], Tim M. Tierney[3], Sven Bestmann… Bowtell[1]§ & Matthew J. Brookes[1]§

Contents lists available at ScienceDirect

NeuroImage

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

A new generation of magnetoencephalography: Room temperature measurements using optically-pumped magnetometers

Elena Boto[a,1], Sofie S. Meyer[b,1], Vishal Shah[c], Orang Alem[c], Svenja Knappe[c], Peter K… Mark Fromhold[d], Mark Lim[c], Paul M. Glover[a], Peter G. Morris[a], Richard Bowtell[a,1], … R. Barnes[b,1], Matthew J. Brookes[a,*,1]

Letters to the Editor

PUBLICATION of brief reports of important discoveries in physics may be secured by addressing them to this department. The closing date for this department is five weeks prior to the date of issue. No proof will be sent to the authors. The Board of Editors does not hold itself responsible for the opinions expressed by the correspondents. Communications should not exceed 600 words in length and should be submitted in duplicate.

Modulation of a Light Beam by Precessing Absorbing Atoms

H. G. Dehmelt

University of Washington, Seattle, Washington

(Received January 7, 1957)

DETECTION OF VERY WEAK MAGNETIC FIELDS (10^{-9} GAUSS) BY ^{87}Rb ZERO-FIELD LEVEL CROSSING RESONANCES

J. DUPONT-ROC, S. HAROCHE and C. COHEN-TANNOUDJI

Faculté des Sciences, Laboratoire de Spectroscopie Hertzienne de l'ENS, associé au C.N.R.S., Paris, France

Received 8 January 1969

Zero-field level crossing resonances have been observed on the ground state of ^{87}Rb. The width, a few microgauss, and the signal to noise ratio, about 2.5×10^3, allow the measurement of 10^{-9} gauss fields.

NUCLEAR INSTRUMENTS AND METHODS 110 (1973) 259–265; © NORTH-HOLLAND PUBLISHING CO.

Part IV. Hanle effect 259 – 300

THE HANLE EFFECT AND ITS USE FOR THE MEASUREMENTS OF VERY SMALL MAGNETIC FIELDS

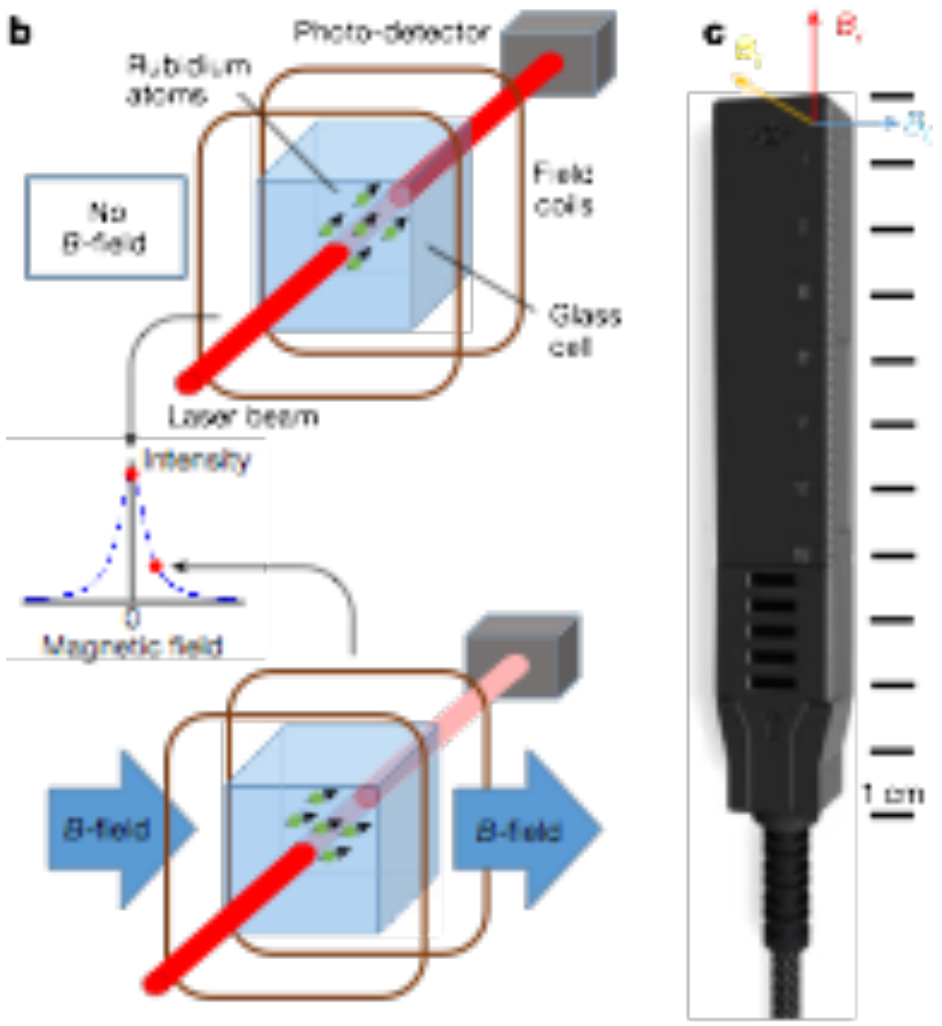
ALFRED KASTLER

Laboratoire de Physique, École Normale Supérieure, Université de Paris, 24, Rue Lhomond, Paris (5e), le, France

The Hanle effect is briefly reviewed. It is shown that optical pumping can be used to create alignment of states. The combined use of Hanle effect and optical pumping then permits one to measure magnetic fields as small as 10^{-9} G.

OPM - Principles

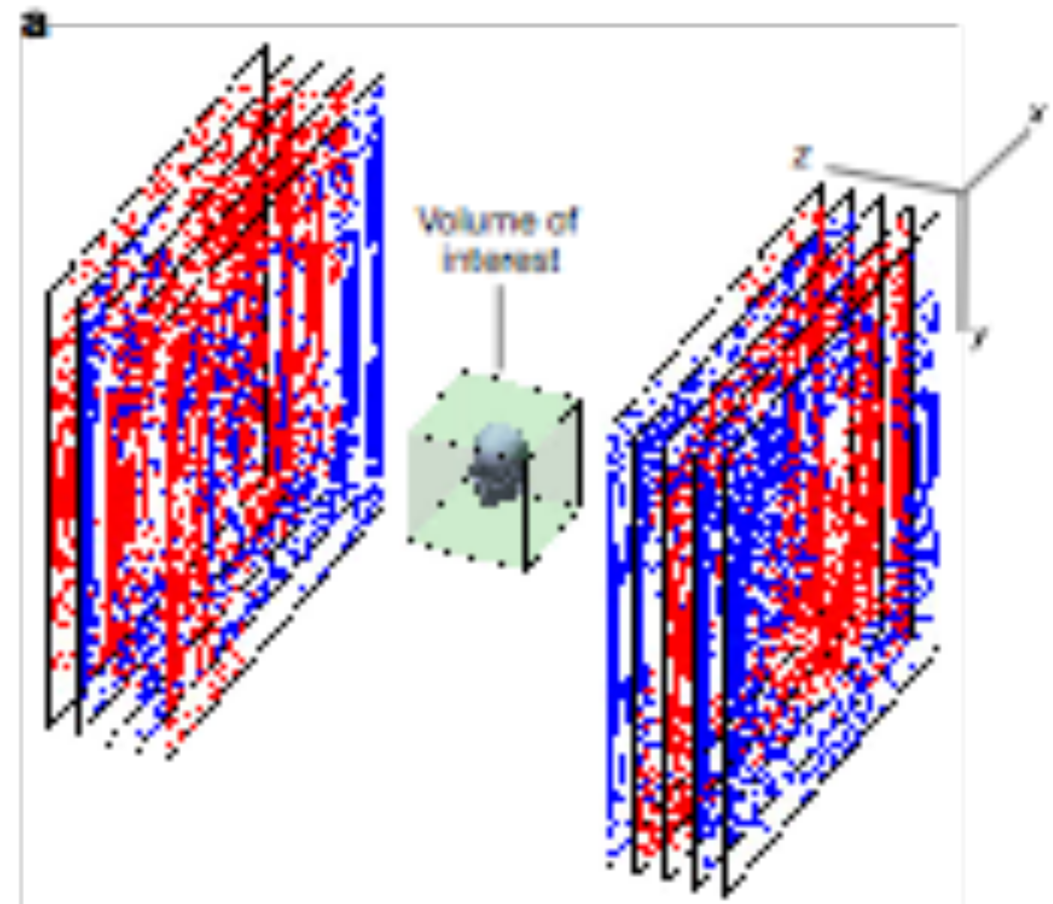
Vector / Scalar measure of small magnetic field through light transmission properties of gas

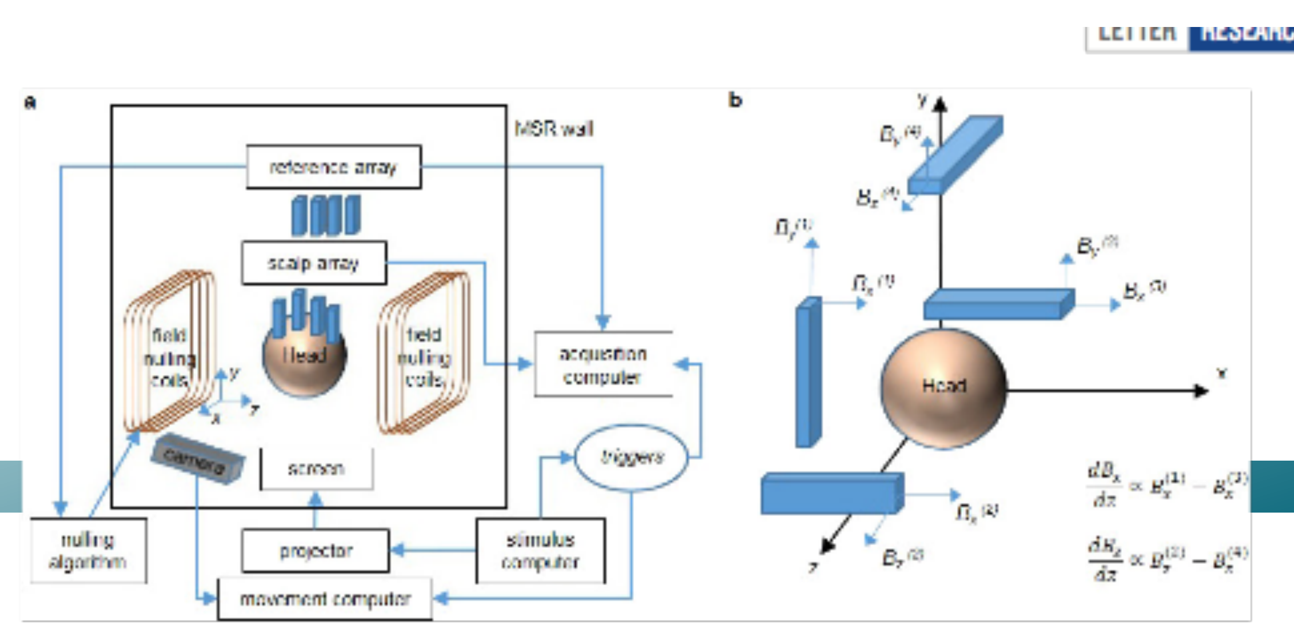


How? Thanks to precession and resonance phenomena

Sensitivity equivalent to SQUID < 130 Hz near ambient temperature

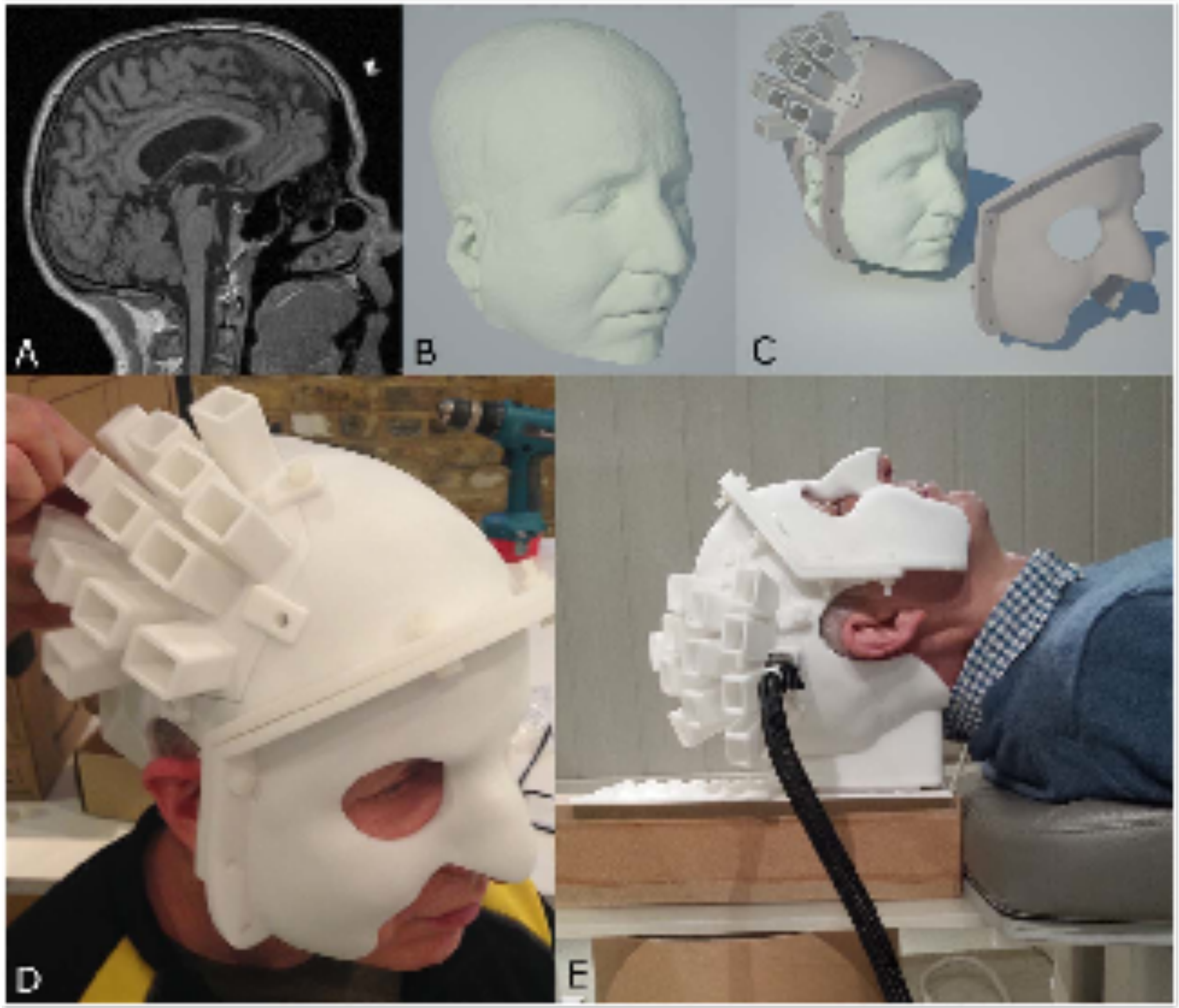
MEG system


Volume of
interest

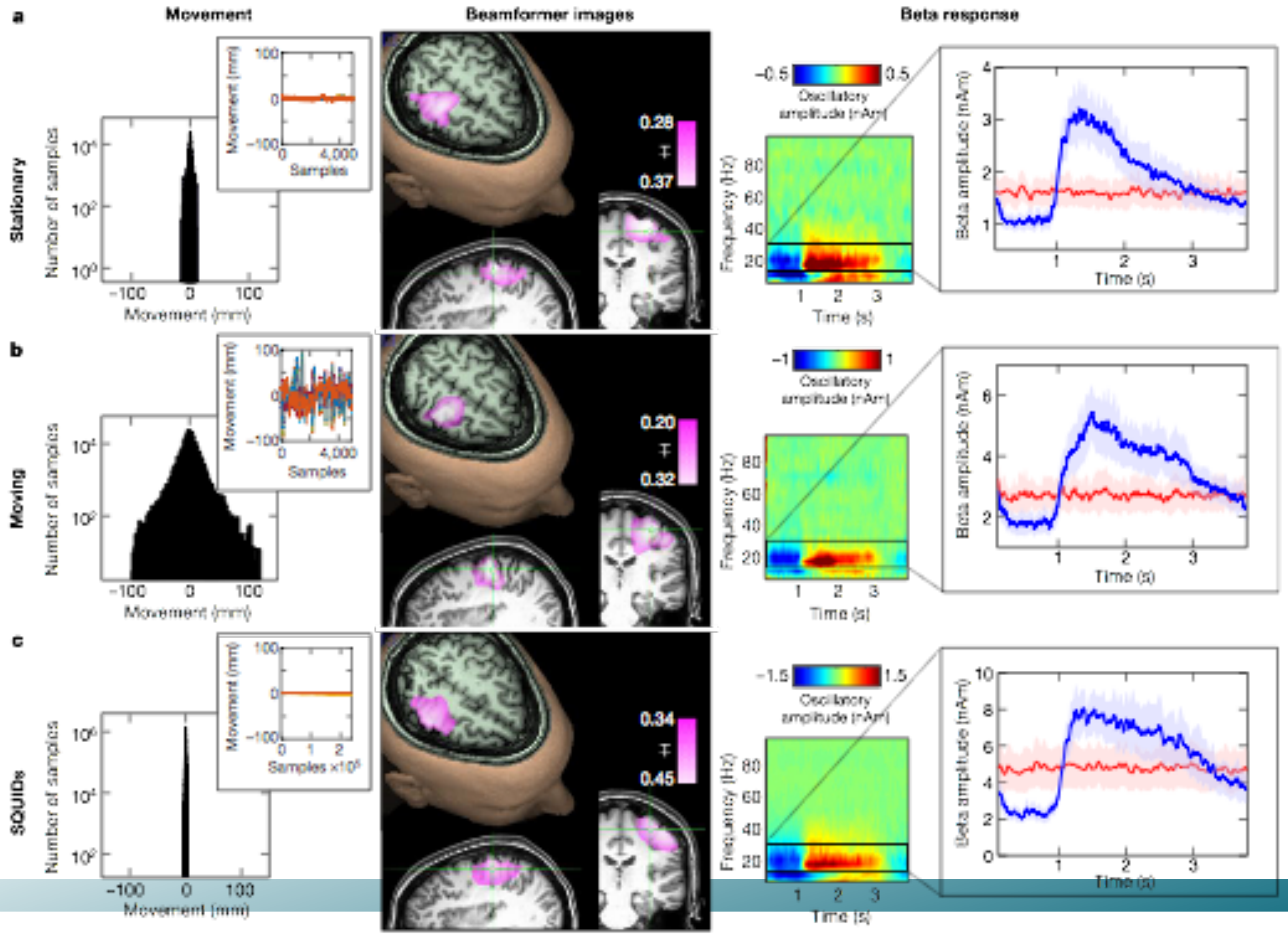

MSR wall
reference array
scalp array
field nulling coils
Head
field nulling coils
acquisition computer
camera
screen
triggers
nulling algorithm
projector
stimulus computer
movement computer
Head

Helmet

an array of sensors that were mounted in a **3D-printed** 'scanner-cast'. The scanner-cast[12] was designed using an **anatomical magnetic resonance imaging** (MRI) scan, such that the **internal surface snugly fits the subject's** head, while the external surface accommodates the OPMs



it works :)



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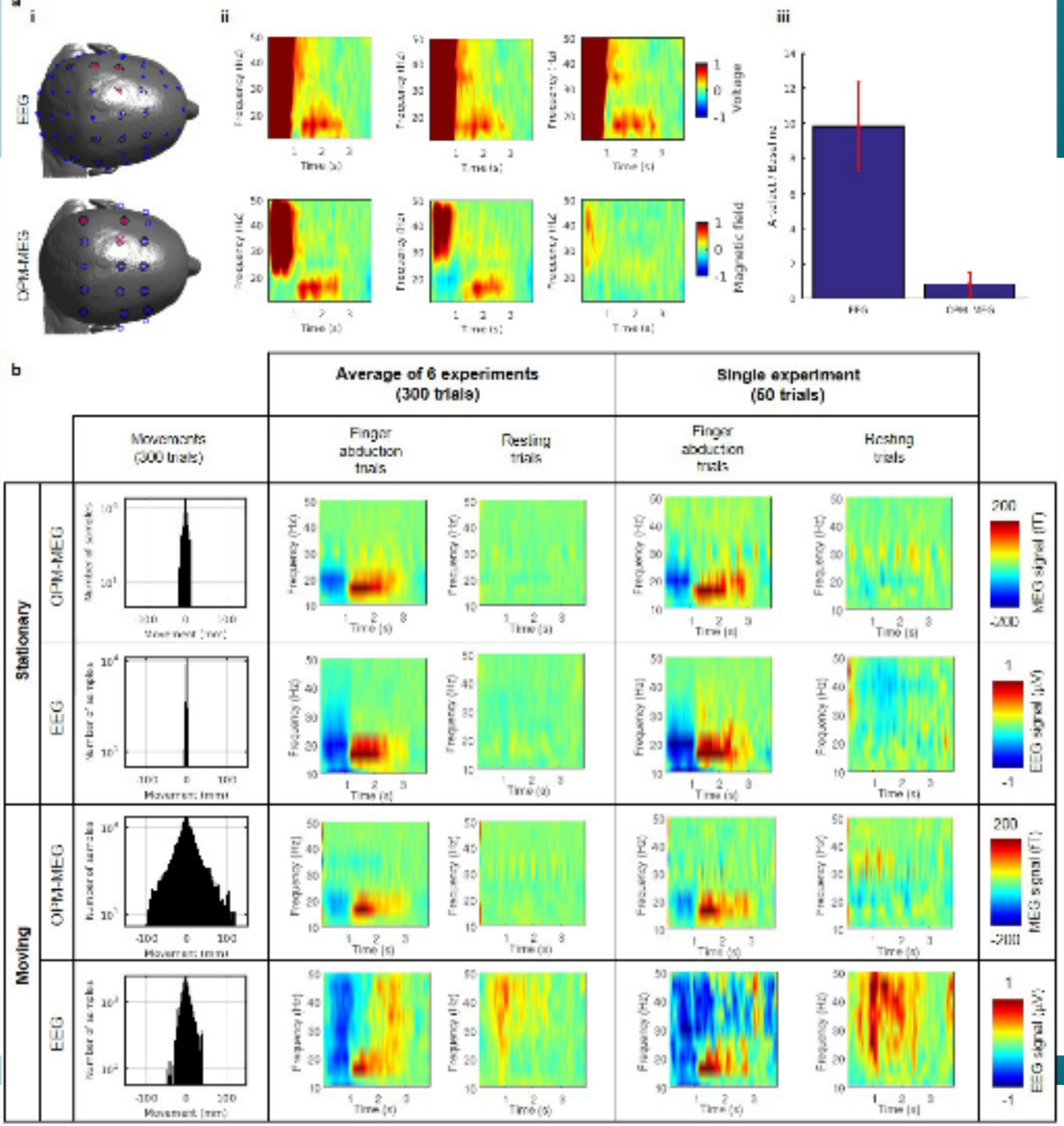

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EEG

Portable / wireless EEG, Dry / Active Electrode

Multimodality