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Use of EEG localizers for EEG sources localization informed by fMRI at high spatio-temporal resolution (S4 method)

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Goals

Localize the EEG sources of experiments of interest with high spatio-temporal resolution using the method **S4** « **Spatial Sparsity in the Source Space** [1] ».

→ Show the interest of the approach to the exploration of the **visual system**.

Our method (S4)

« Localizers » experiment

EEG + Eye-tracking fMRI + Eye-tracking

Combinaison:
S4 method

Spatial filters (W_{loc}^T)

EEG + Eye-tracking → Intra-saccadic motion perception
→ Saccadic choice task

Experiments of interest

→ **Good spatio-temporal localization** (based on W_{loc}^T).

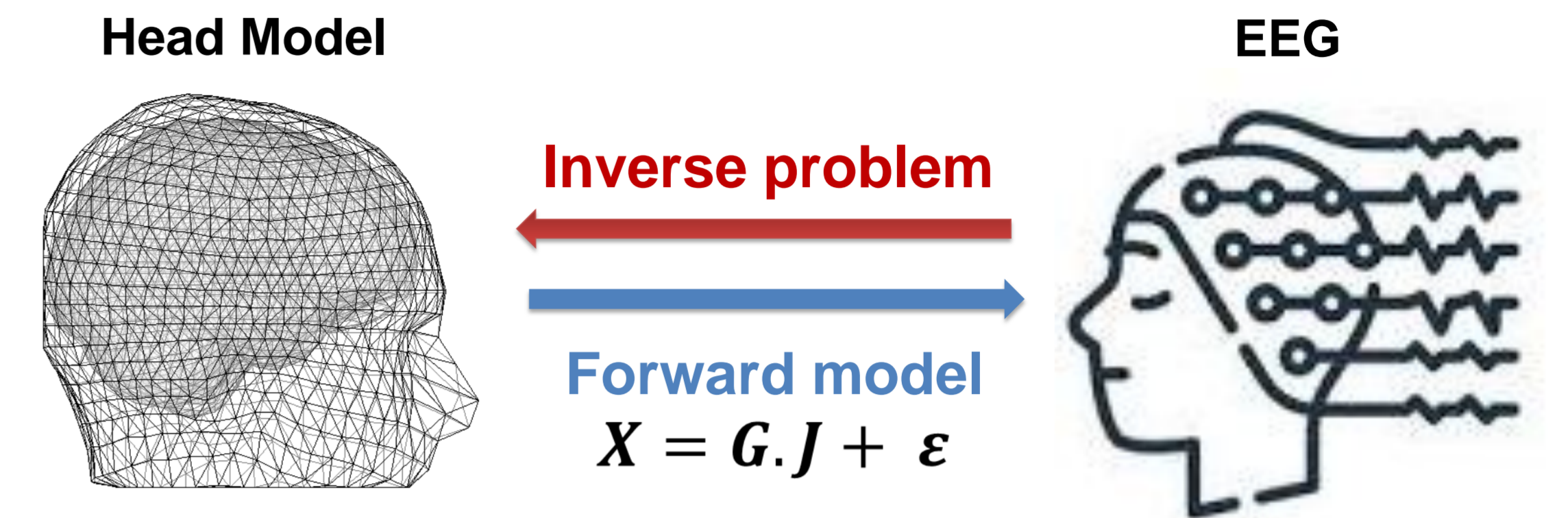
Introduction

Source localization in EEG: Estimate the cortical sources behind the signals recorded at the sensors.
→ **Ill-posed inverse problem:** Additional spatial constraints need to be applied on the activity distributions of the cortical sources.

Two classical methods :

→ **FACE**^[2] : Use of the spatial constraints of the fMRI to constrain the inversion of the head model G (sensors space).

→ **MSP**^[3] : Bayesian EEG/fMRI integration method on the same experiment (sensors space).

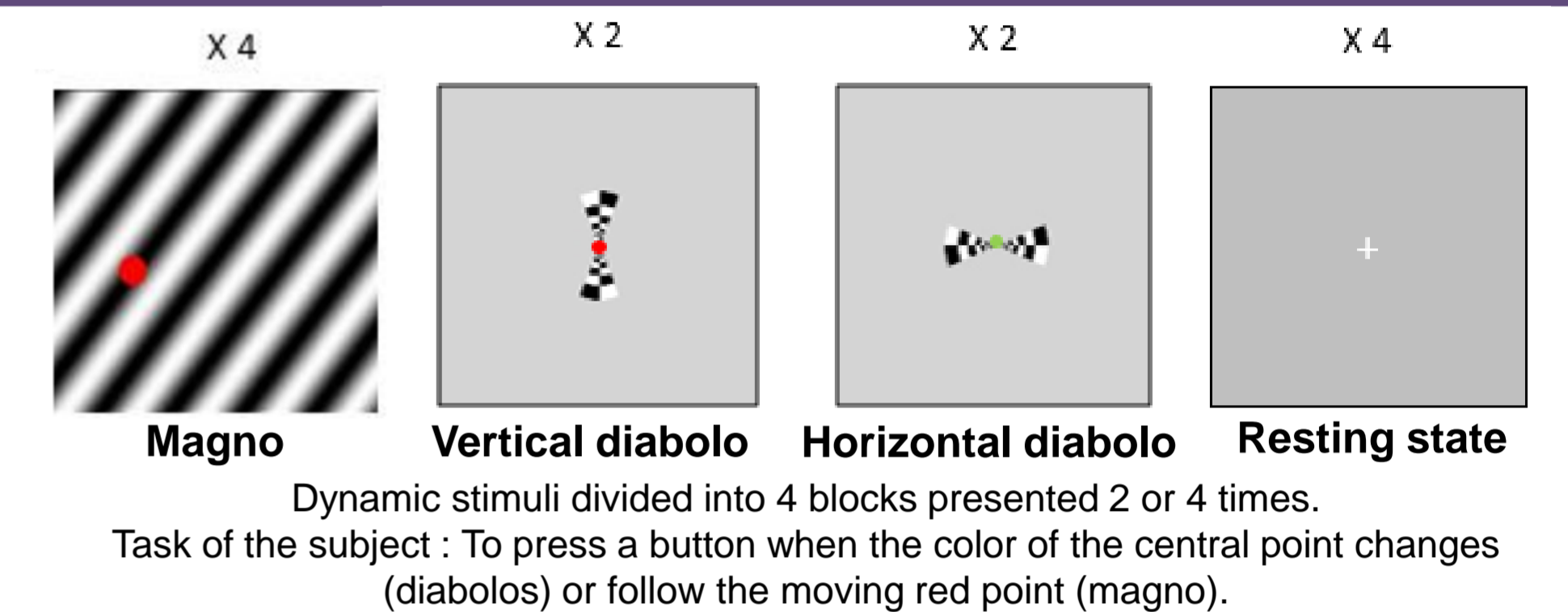


X : EEG signals [n sensors * t timesamples]
 G : Gain matrix [n sensors * m vertices] (head model)
 J : Cortical sources [m vertices * t timesamples]
 ϵ : Noise activity unrelated to the task

Experiments of interest + « Localizers »

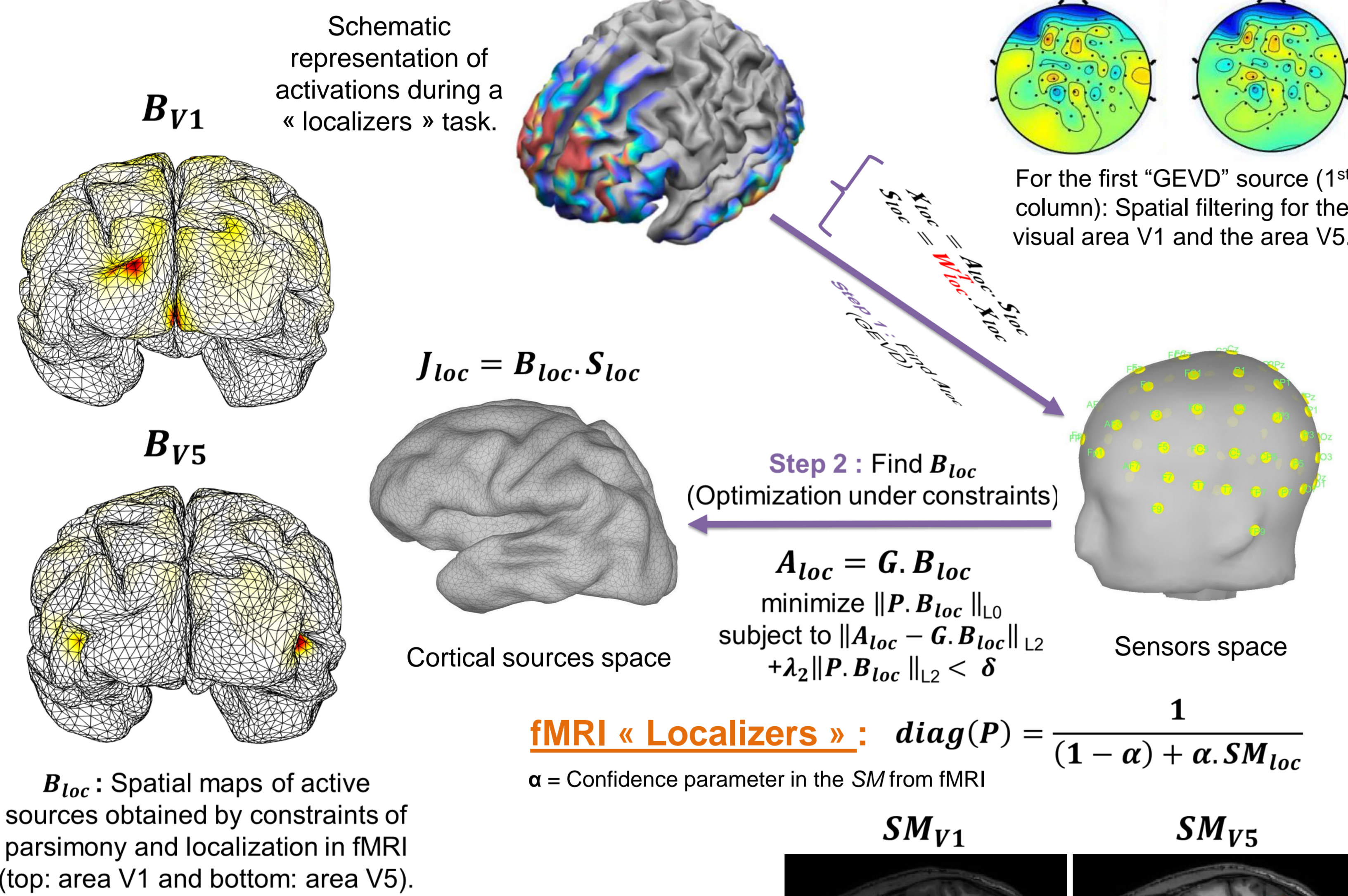
→ « **Localizers** » (EEG + fMRI) : To localize the primary visual areas V1-V2, the area V5 and the FEF.

→ **Experiments of interest (EEG):** Expected brain activations occurs in regions previously delineated by « Localizers » experiment.



From S4 applied to « Localizers » to experiments of interest

EEG « Localizers » :



Experiments of interest in EEG :

$$\hat{J}_I = B_{loc} \cdot W_{loc}^T \cdot X_I$$

X_I : EEG signals from experiment of interest [n sensors * t timesamples]
 J_I : Cortical sources from experiment of interest [m vertices * t timesamples]

A priori spatial maps (SM_{loc}) from fMRI for the visual area V1 (yellow) and the area V5 (red).

On going work

→ Apply the results of S4 to the experiments of interest : Intra-saccadic motion perception and Saccadic choice task.

→ Test the S4 method as a function of the confidence parameter (α) that we have in the spatial map resulting from the fMRI.

→ Compare S4 with a reference method such as Multiple Sparse Prior (MSP).

Evaluation Metrics

→ **F1-score** on B_{loc} according to the activation threshold.

$$F1\text{-score} = (2 \times \frac{\text{precision} \times \text{recall}}{\text{precision} + \text{recall}})$$

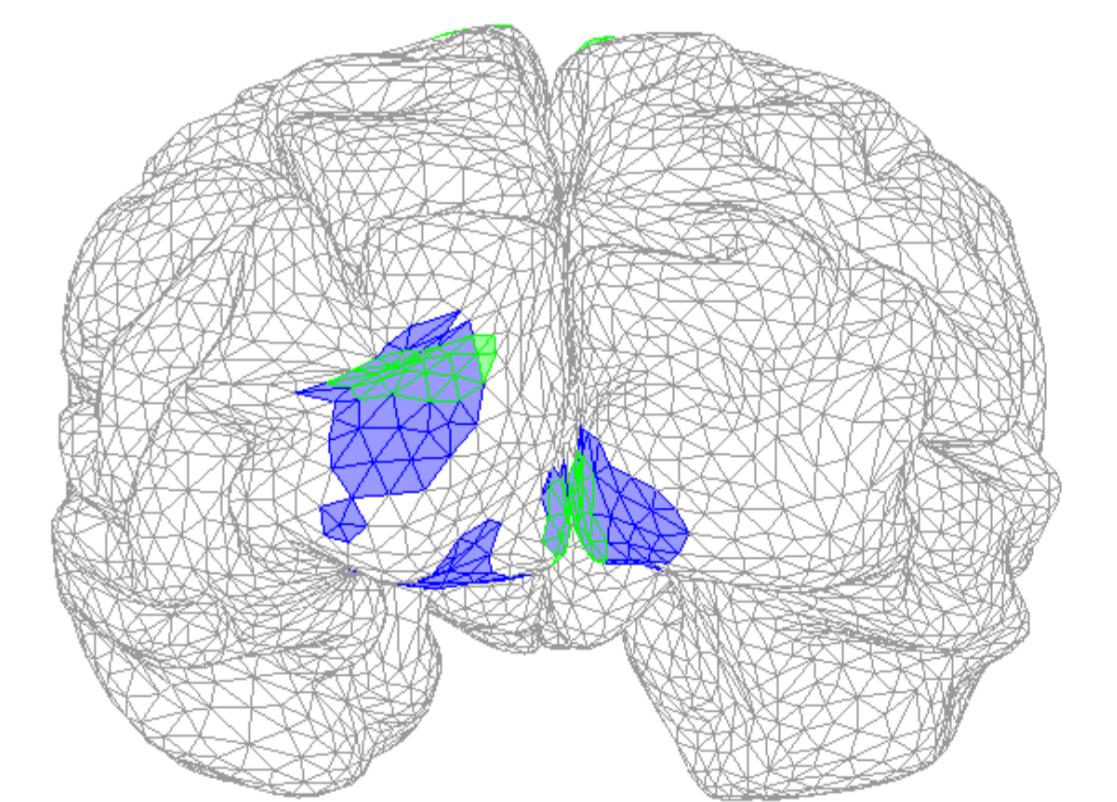
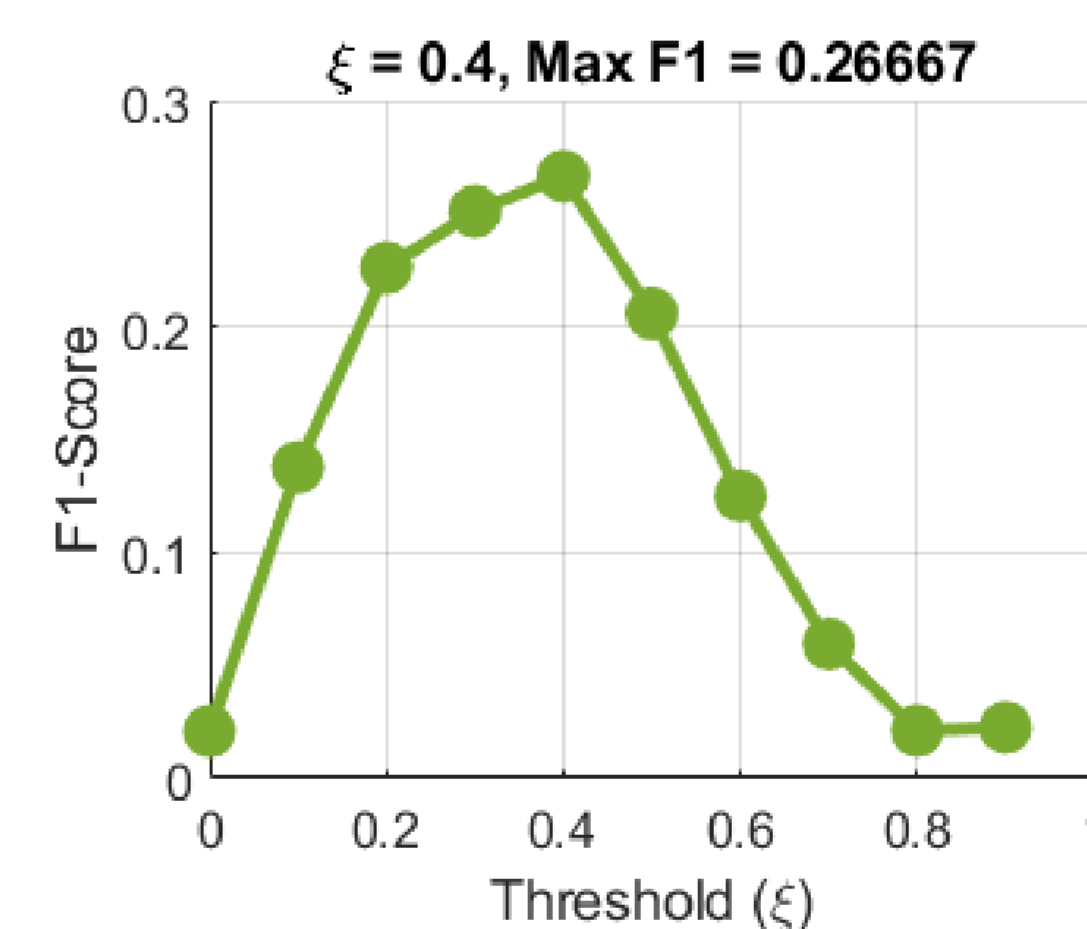
→ **Energy percentage** on J_{loc} in the a priori spatial map from fMRI.

Results

Based on the first «GEVD» source in EEG and $\alpha = 0.9$:

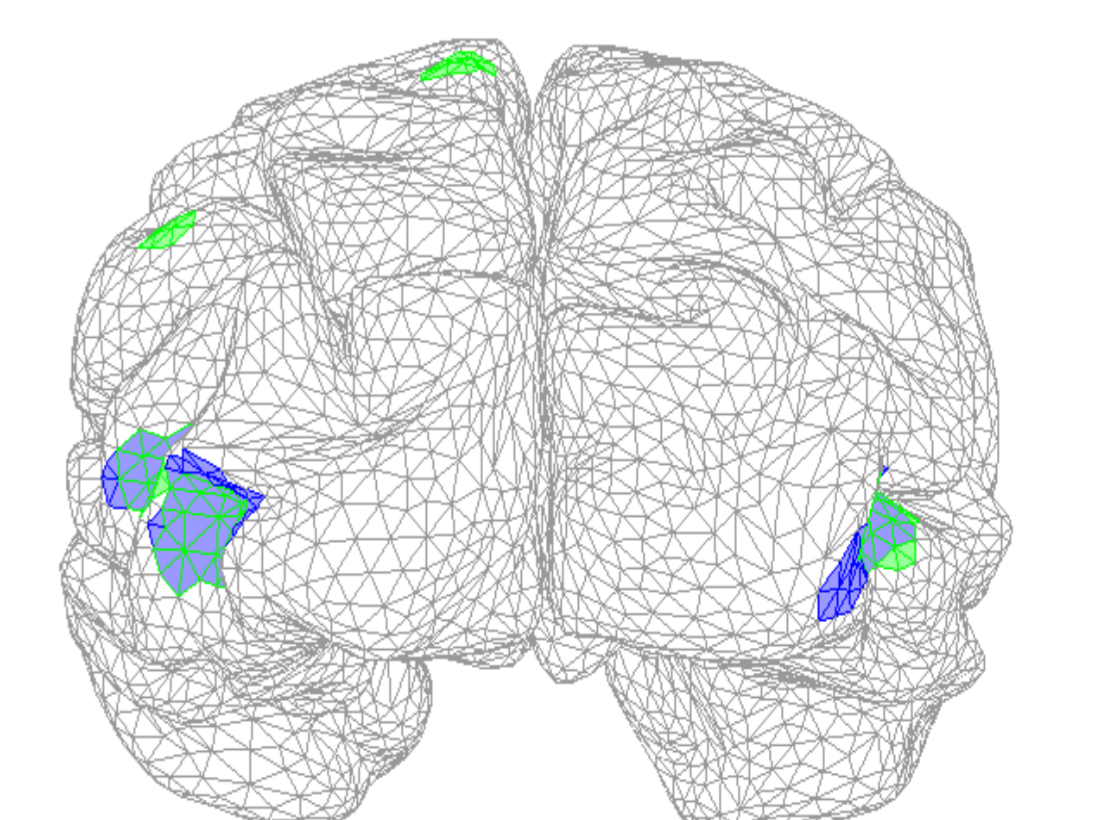
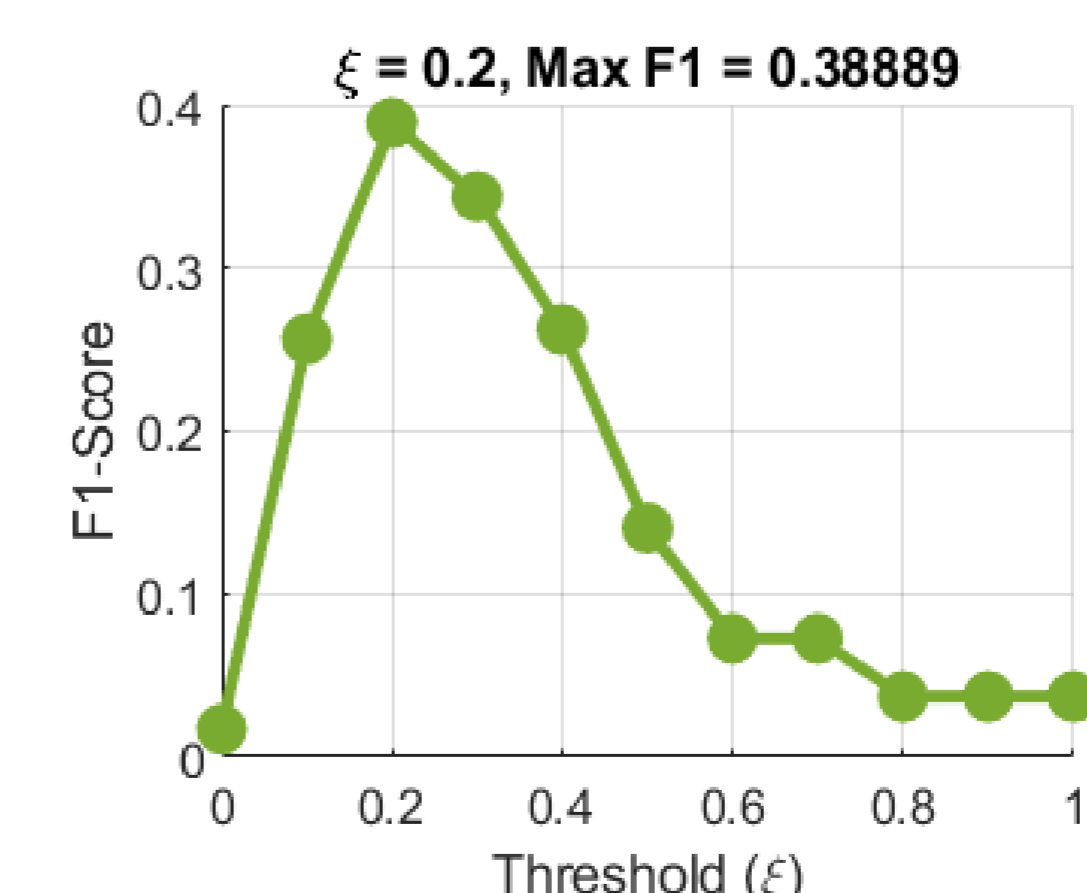
→ **Visual area V1:**

- Best F1-score (**0.26**) with a threshold $\xi = 0.4$
- Precision = **0.27** and recall = **0.25**
- **16 %** of energy in V1 (9 % in right, 7 % in left)



→ **Area V5:**

- Best F1-score (**0.38**) with a threshold $\xi = 0.2$
- Precision = **0.73** and recall = **0.26**
- **35 %** of energy in V5 (23% in right, 12% in left)



[1] Samadi, S., Soltanian-Zadeh, H., & Jutten, C. (2016). Integrated analysis of eeg and fmri using sparsity of spatial maps. *Brain topography*, 29(5), 661-678.

[2] Cottareau, B. R., Ales, J. M., & Norcia, A. M. (2012). Increasing the accuracy of electromagnetic inverses using functional area source correlation constraints. *Human brain mapping*, 33(11), 2694-2713.

[3] Friston, et al., (2008). Multiple sparse priors for the M/EEG inverse problem. *NeuroImage*, 39(3), 1104-1120