Two approaches to tackle the sign ambiguity of MEG beamformed source-reconstructed data

Chiara Rossi[1], Diego Vidaurre[2], Guy Nagels[1], Jeroen Van Schependom[1]

[1]AI-supported modelling in clinical sciences, Vrije Universiteit Brussel, Belgium
[2]Center of functionally integrative neuroscience, Aahrus University, Denmark

VRIJE UNIVERSITEIT BRUSSEL

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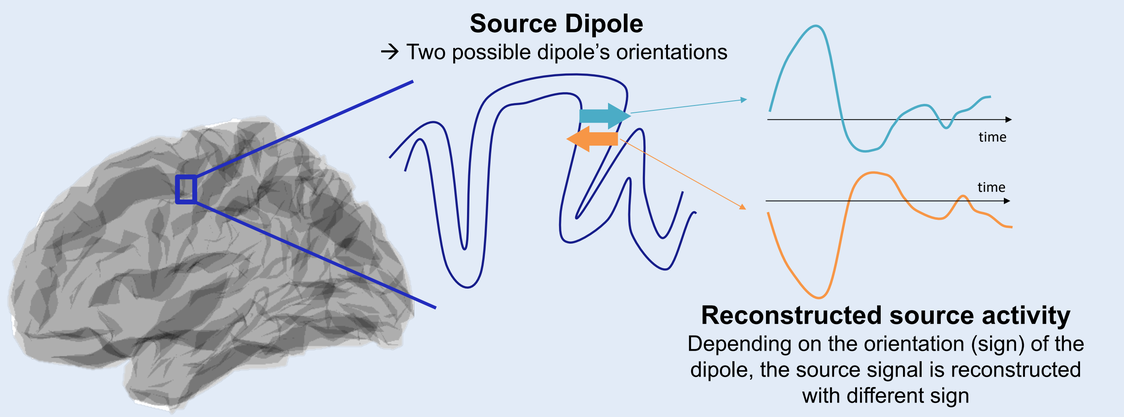
Beamformer – The Sign Ambiguity Issue

- The beamformer is a widely used technique to reconstruct magnetoencephalographic (MEG) data[1].
- This method models the sources as dipoles and applies a spatial filter to extract the contribution of each sensor to the source signal[1].
- Because the detected magnetic field does not carry information about the sign of the source dipole, the sign of the reconstructed dipole is arbitrarily assigned, and it can differ between MEG sessions[2].
- This **sign ambiguity issue hinders the analysis across sessions and across regions**.



Two Methods to tackle the Sign Ambiguity

1. **Absolute value**: this traditional approach consists in taking the absolute value of each epoch before running analysis across subjects. This method highlights the amplitude effects but neglects the temporal oscillation of the signal.
2. **Sign Flipping[4]**: this algorithm allows to preserve the sign of the original signal. It consists in finding the permutation of channels' signs that maximizes the sum of the covariance matrix across all pairs of channels and sessions (subjects).

38 MEG Healthy Subjects (n-back task)
Task: press a button when a target letter is shown; the target is the n-th letter before if n = 1, 2, or letter X if n = 0.

OSL preprocessing[3]
- MEG-MRI coregistration (Rhino)
- Downsampling to 250 Hz
- Filtering (notch 50Hz and band-pass filter 1-45 Hz)
- Artefacts Rejection
- Sensor normalization
- BEAMFORMER – source reconstruction
- 42 ROI parcellation & zero-lag correction

→ Event-related fields (ERFs) → **Absolute Value**

→ **Sign Flipping** → Event-related fields (ERFs)

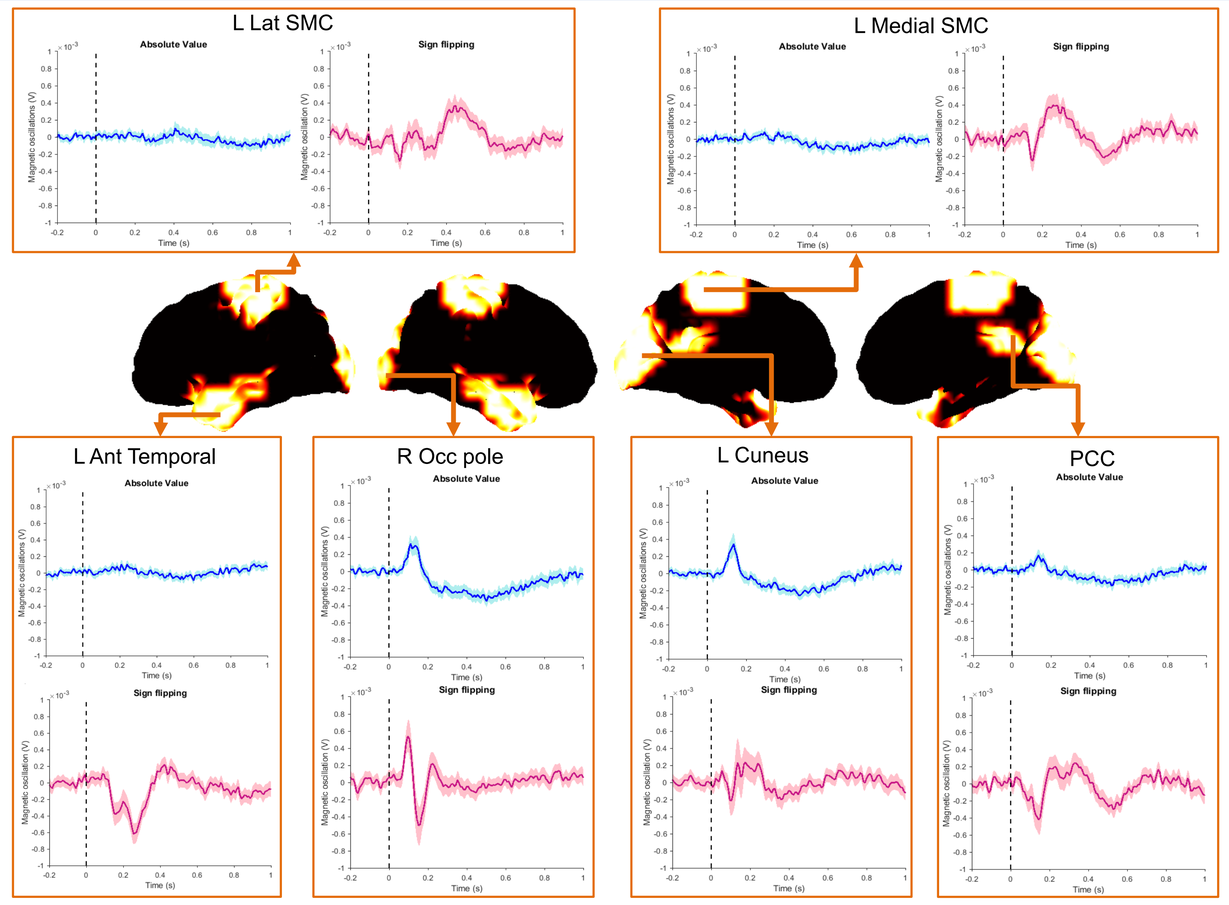
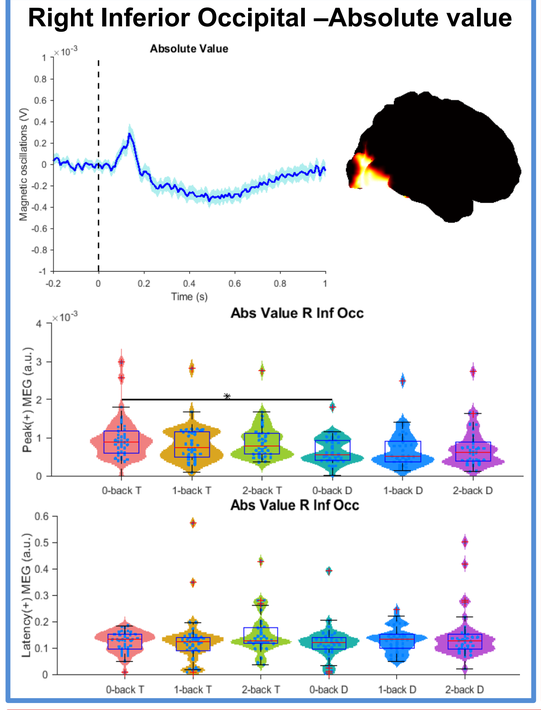


Figure 1 – The plots on the right present the average MEG signal and the 95% CI across subjects and trials for 6 regions resulting from the absolute value (blue) and sign flipping (pink) pipelines: left lateral sensorimotor cortex (L Lat SMC), left medial sensorimotor cortex (L Medial SMC), right anterior temporal (R Ant Temporal), right, occipital pole (R Occ pole), posterior cingulate cortex (PCC), left cuneus.

The sign flipping method seems to uncover a richer brain dynamics as compared to the absolute value approach - which one is best likely depends on the question/paradigm at hand.

Right Inferior Occipital –Absolute value



Right Inferior Occipital – Sign Flipping

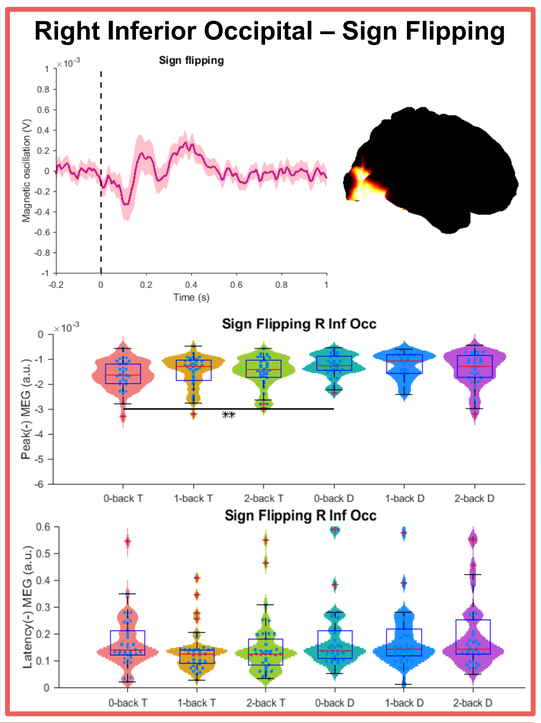
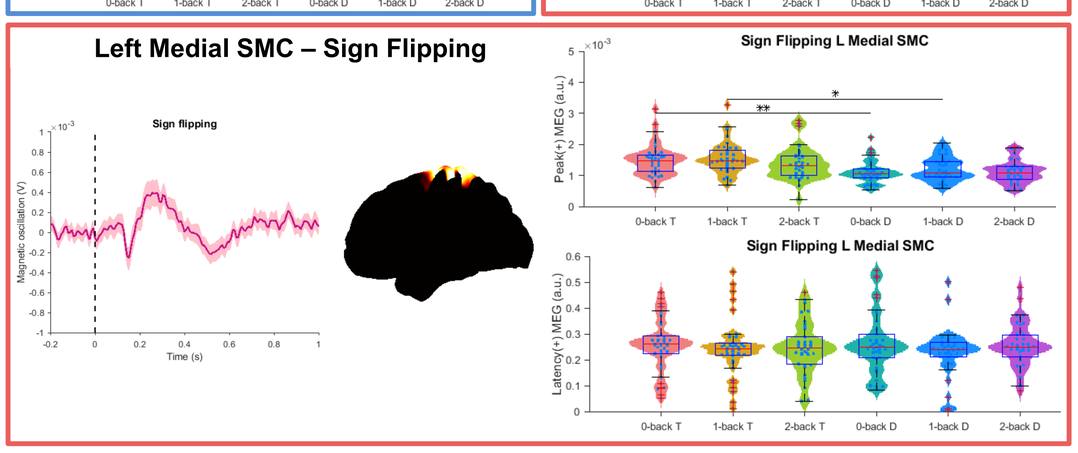


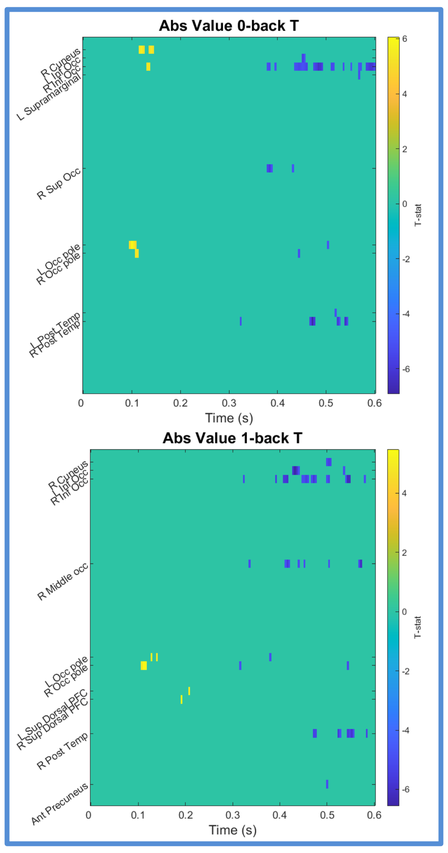
Figure 2 (left), 3 (right), and 4 (bottom) - We extracted the ERF peaks and their latencies for each region and paradigm condition, and we ran a ranksum test to observe changes in peaks' amplitude and latencies across paradigm conditions. The p-values are corrected for multiple comparisons using the FDR algorithm[5]. ***p_value < .05 ** p_value < .005**

Left Medial SMC – Sign Flipping



Right Inferior Occipital – This region appears to be significantly activated or deactivated both in absolute value results and in sign flipping results. However, the ERFs extracted from the two pipelines differ substantially.

Left Medial SMC – The sign flipping approach reveals a clear ERF wave, whereas the absolute value results show a flat ERF - Figure 1. The peak analysis shows a significantly lower peaks' amplitude in distractor trials than in target trials, for the 0 and 1 back conditions. This result is consistent with the activation of the SMC during motor response.



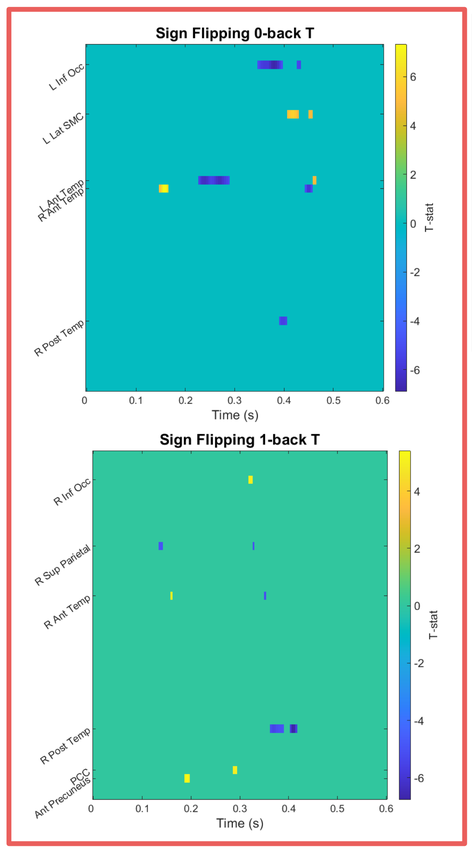


Figure 5 – These images plot the time points where each region is significantly activated or deactivated (permutation test N = 1000); the multiple comparisons problem was addressed using the maximum statistics approach. We report only the 0 (top row) and 1 (bottom row) target conditions for the absolute value (blue rectangle) and sign flipping (red rectangle) methods. Only the significant t-stats and the related regions are displayed.

Conclusions and Future work

- The two approaches reveal consistent traits of the occipital response. The sign flipping method seems to better unravel the temporal dynamics over the epoch and across brain regions, although with higher inter-subjects variability.
- Traditional (abs value) studies have not yet identified the M300 wave4, and this exploratory analysis presents new features of the MEG ERF data to explore further.
- The next step consists in implementing a time-frequency analysis to observe the signal's spectrogram resulting from the two methods.

References
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Contact: chiara.rossi@vub.be

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