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Auditory Functional Mapping. Validation by simultaneous depth and MEG recordings

C. Zielinski^a, A. Trébuchon^{b,c}, S. Chen^b, P. Marquis^b, F. Bartolomei^{b,c}, R. Carron^{b,d}, C. Bénar^b, C. Liégeois-Chauvel^b, J.M. Badier^{b,*}

^a Aix-Marseille Université, Institute of Language, Communication and the Brain (Aix-en-Provence, France) ^b Aix-Marseille Université and INSERM, Institut de Neurosciences des Systèmes (Marseille, France) ^c AP-HM, La Timone, Neurophysiologie Clinique (Marseille, France) ^d AP-HM, La Timone, Neurochirurgie Fonctionnelle et Stéréotaxique (Marseille, France)
* Corresponding author { jean-michel.badier@univ-amu.fr }



Introduction

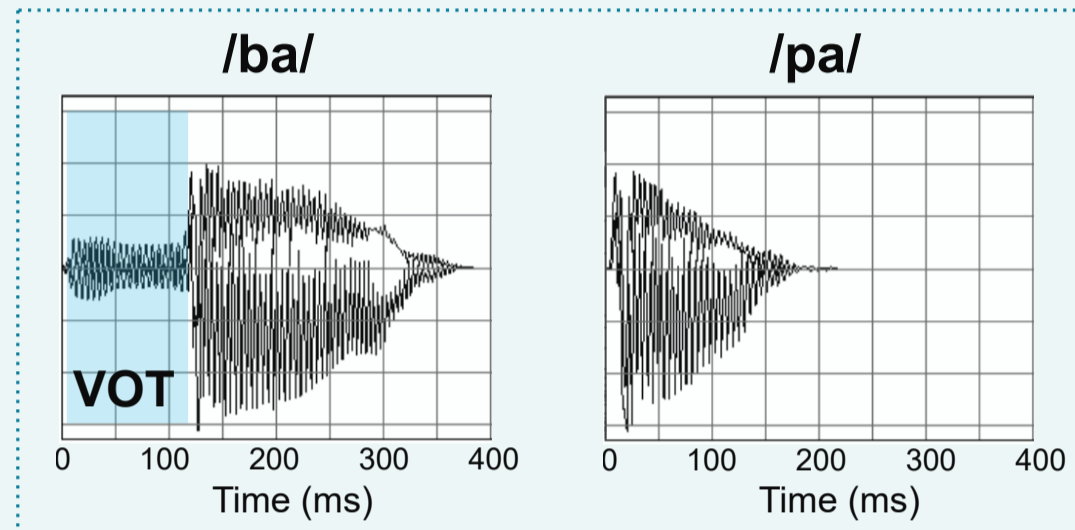
Epilepsy surgery requires the functional mapping of brain functions that might be affected. Recordings of evoked potentials during pre-surgical exploration by intracerebral electrodes give a very accurate information. These activities can also be obtained from non-invasive measurements (EEG or MEG). However, reconstructing the activity of a given cortical region requires the use of methods and models that are still discussed.

In this study, we recorded simultaneously from intracerebral electrodes and MEG sensors the activities evoked at the level of the auditory cortex in response to verbal sounds /ba/ and /pa/, electrophysiological index of hemispherical lateralisation (Liegeois-Chauvel et al. 1999^[1], Trébuchon et al. 2005^[2]). We used a spatial filtering technique to obtain, from the MEG measurements, the temporal time course of the evoked activities at the level of virtual electrodes defined at the location of the contacts of the intracerebral electrodes - thus allowing the comparison between these reconstructed responses and those coming from the intracerebral measurements.

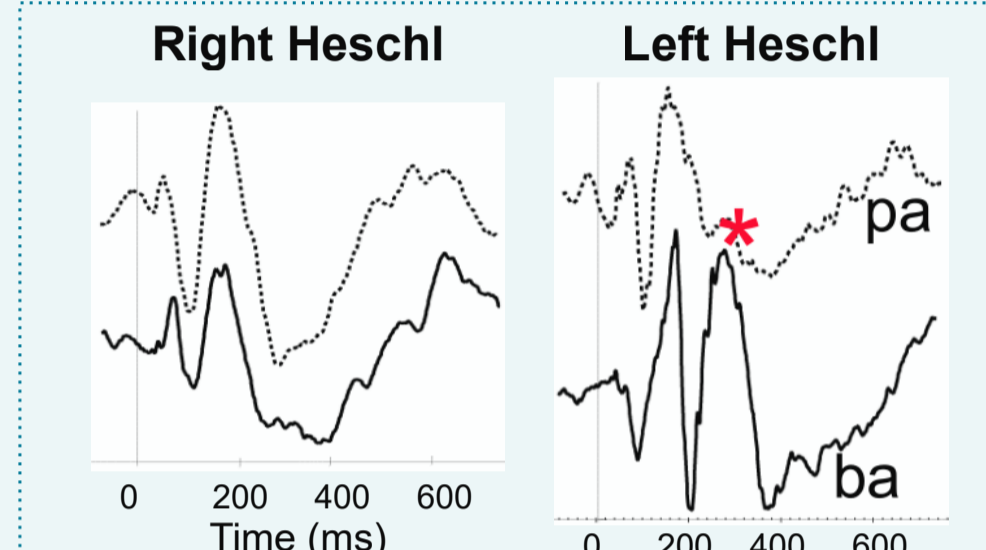
Determining hemispheric dominance for language

Important information in case of epilepsy surgery for the prediction of the risks of language deficit but also of verbal memory. Several types of tasks tested in MEG, based on differences of evoked responses between the left and right hemispheres at the temporo-parietal region of the cortex: listening and word recognition^[3,4], verbal production^[5,6,7], semantic decision^[8].
Bapa protocol: passive listening, not requiring the cooperation of patients and/or children

Acoustic signal



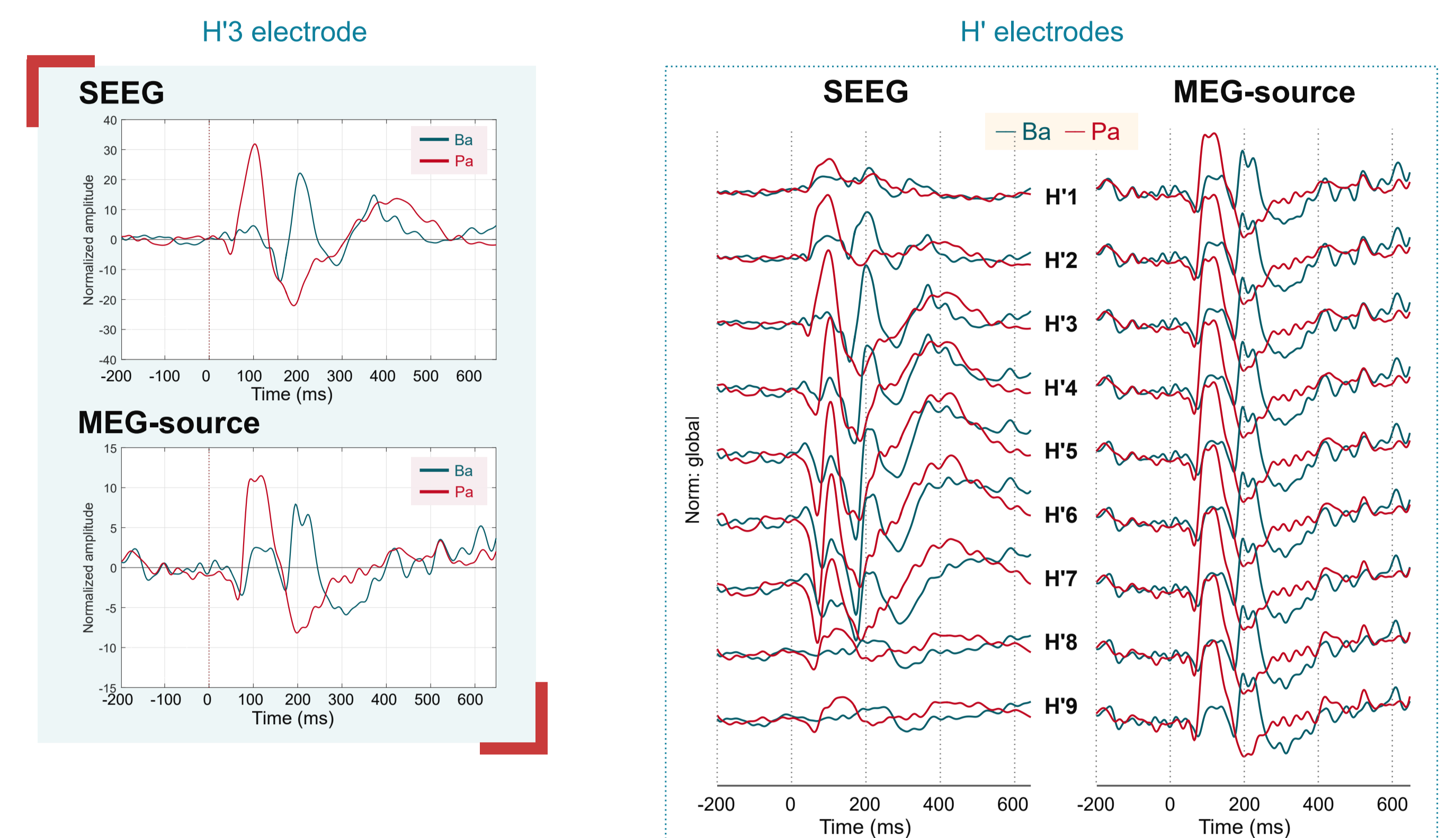
Evoked response for SEEG



Component ~300 ms for /ba/

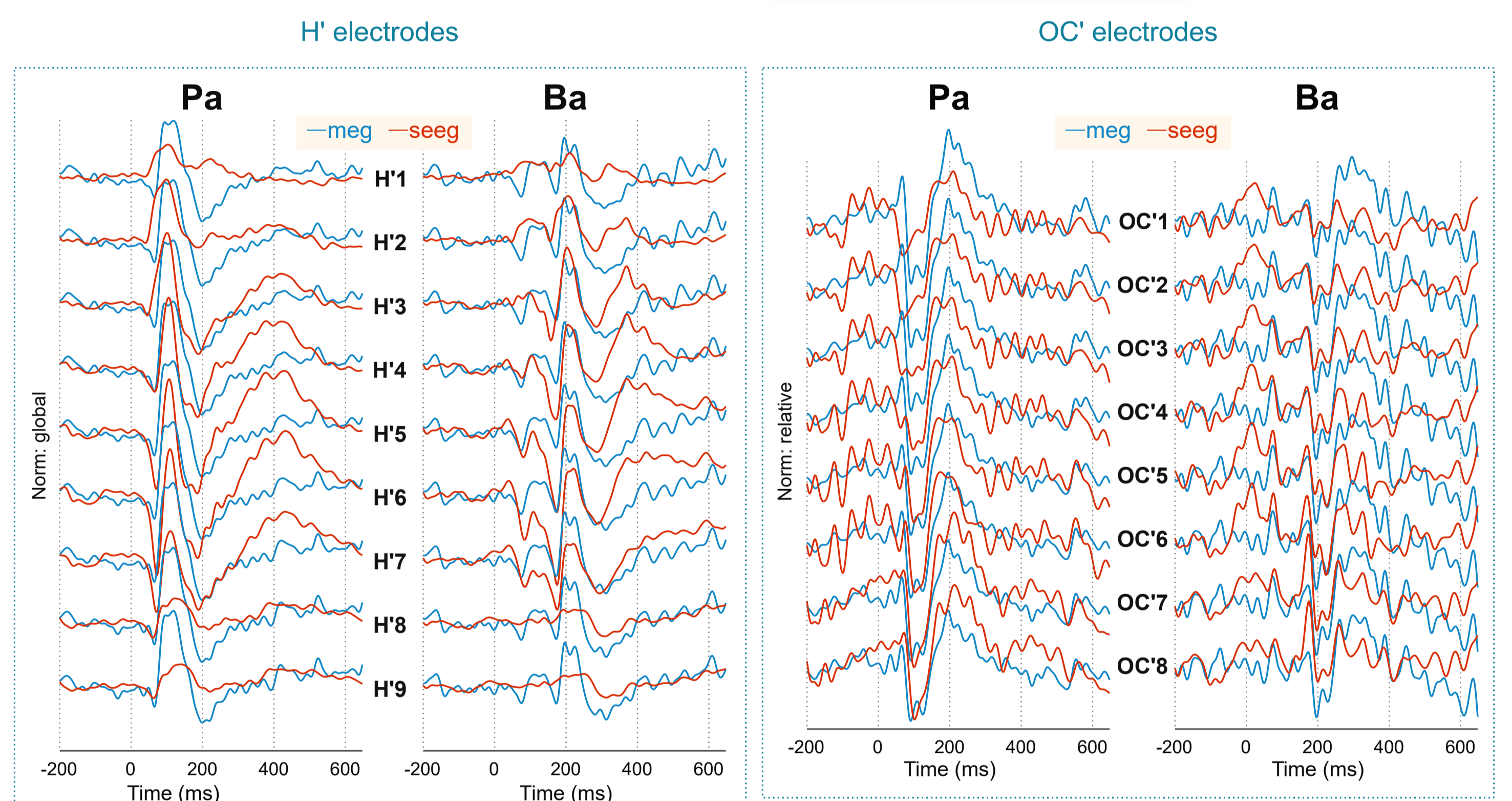
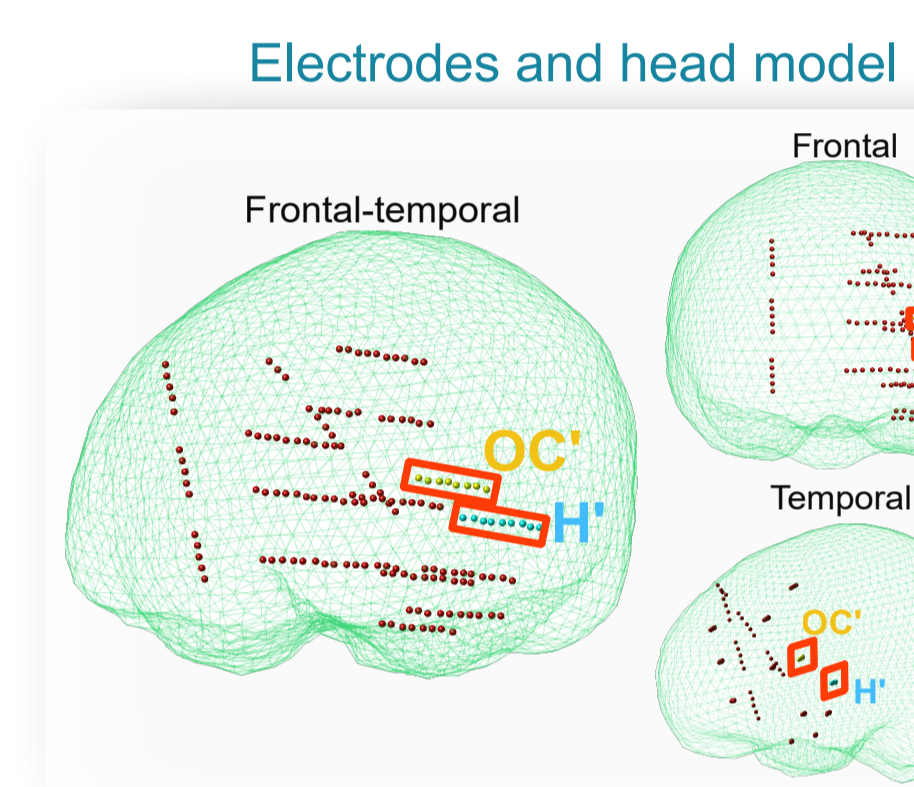
Results and discussion

Ba vs Pa



SEEG vs MEG virtual electrode reconstructions

For comparison purpose a normalization based on the maximum amplitude for each modality have been performed.



The temporal responses of the virtual sources obtained by spatial filtering of MEG data are similar to those obtained by SEEG data both in the primary auditory cortex region and for more distant regions.

The responses obtained in SEEG remain more focused than those obtained in MEG, which confirms the phenomenon of "source leakage" which tends to show a less punctual localization than expected and is due to the properties of the gain matrix.

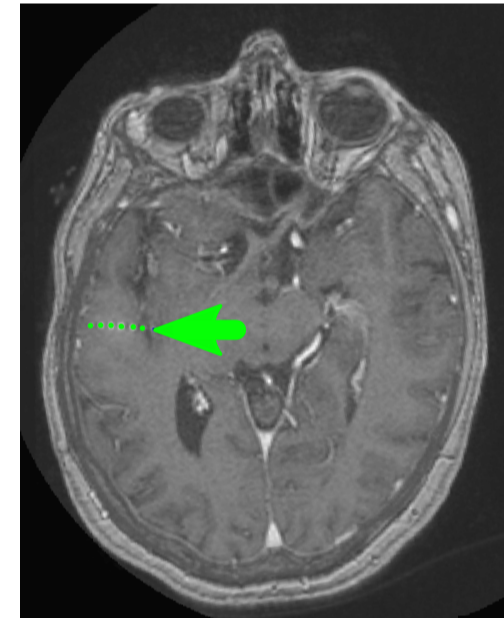
The answers obtained in MEG are able to allow a functional mapping of the auditory cortex areas. It is possible to obtain close results without the contribution of the MRI of the patient (cf. supplementary analysis)

Methods

Patient

- Women 43 years old suffering for a left frontal lobe epilepsy
- SEEG: 13 electrodes in the left frontal and temporal lobes. 1 electrode in the right frontal lobe. The reconstructions are given here for the two electrodes exploring the left auditory cortical areas (electrode H').

H' implantation



Acquisition

- Simultaneous MEG/SEEG: detail protocol in Dubabarry et al., 2014^[9] and Badier et al., 2017^[10]
- MEG: 248 full magnetometer system (3600WH 4D Neuroimaging). Sampling frequency 2034.51 Hz
- SEEG : 219 channels (BrainAmp[®]). Sampling frequency 2500 Hz.
- MEG and SEEG are synchronized through the stimulation triggers.
- /ba/ and /pa/ displayed in random order, N=250 each, ISI 0.8-1.2 s, two-sided earphones

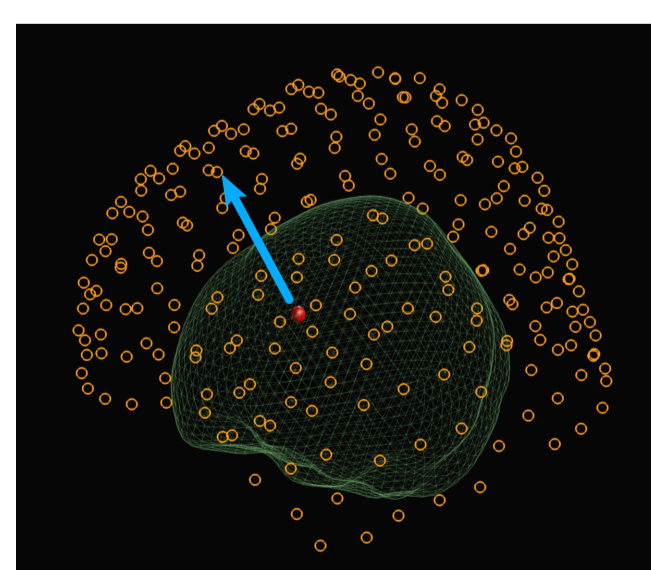
Data analysis

- Software: Anywave^[11] for visualization and preprocessing. Fieldtrip^[12] for preprocessing and source reconstruction.
- Preprocessing (MEG & SEEG)
 - filtering 0.5 - 40 Hz
 - resampling 400 Hz
 - epoching -200 to 650 ms
 - averaging for MEG sensors and SEEG recording

MEG source reconstruction

- Head model
 - anatomical registration between MEG and MRI by fiducial points and head surface matching
 - determination of the SEEG contact coordinates (EpiTools^[13])
 - segmentation of the patient head for construction of a realistic model of the head^[14]
- Estimation of the gain matrix (MEG forward solution) from the calculation of the magnetic field from one single source to each of the MEG sensor
- Source reconstruction (inverse solution) by spatial filtering (LCMV^[15])
 - filter coefficients estimated from the variance of all trials and the gain matrix
 - optimal orientation of the sources calculated from a singular value decomposition
 - normalization of the temporal course of the virtual electrode by pseudo Z transformation using the baseline [-200 to 0 ms]

Forward model

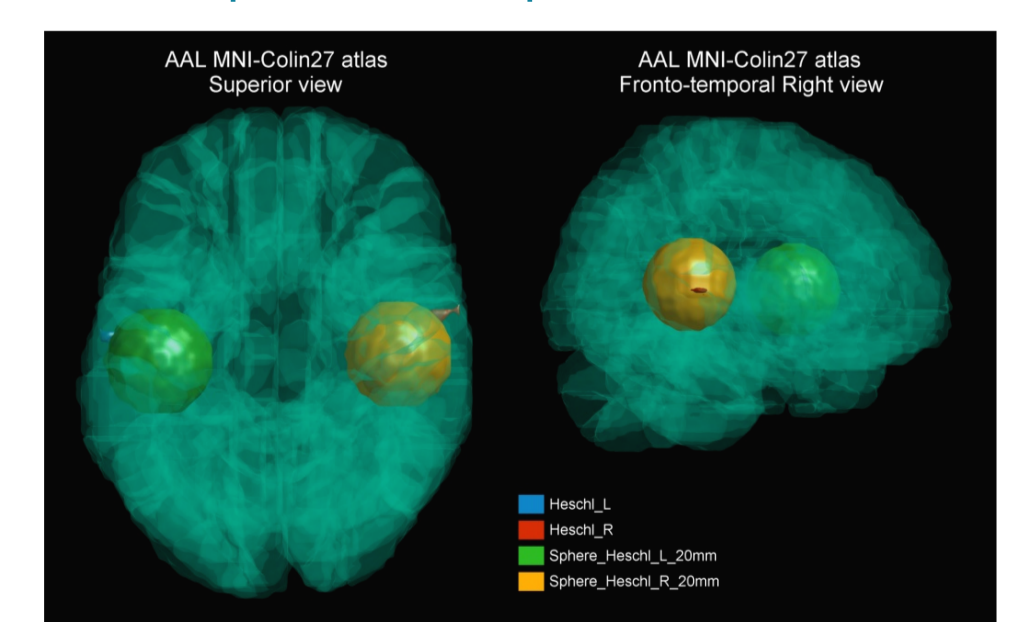


Spatial filter provides the evoked response estimated for each SEEG contact from the MEG recordings: virtual electrode

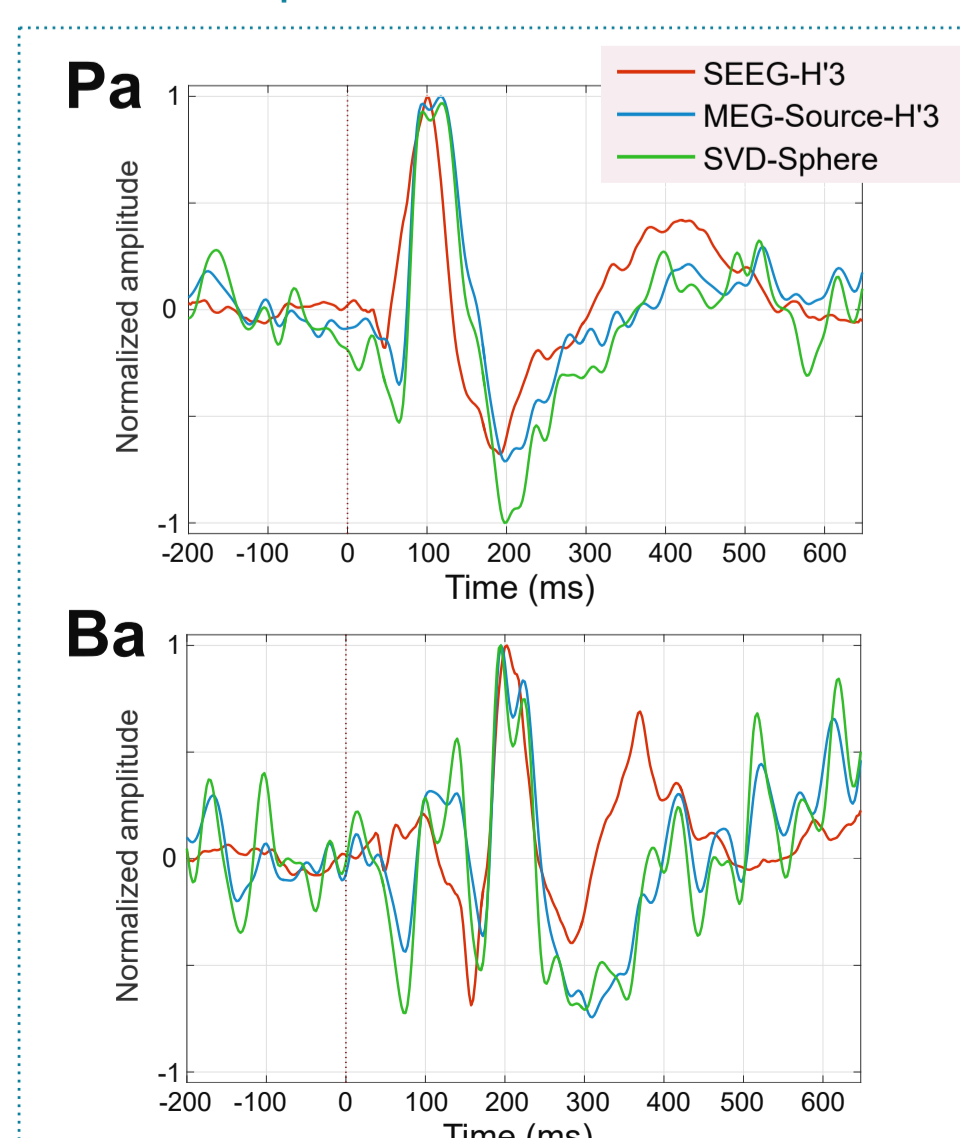
Supplementary analysis

- Head model: template (Colin 27)
- Source model: 3D grid of dipole uniformly spaces of 10 mm. The dipole retains are the one contained on a sphere (one for each side) centered around Heschl gyrus (104 dipoles).
- The first component of the resulting singular value decomposition (SVD) of the 104 dipoles is taken as the reconstruction.

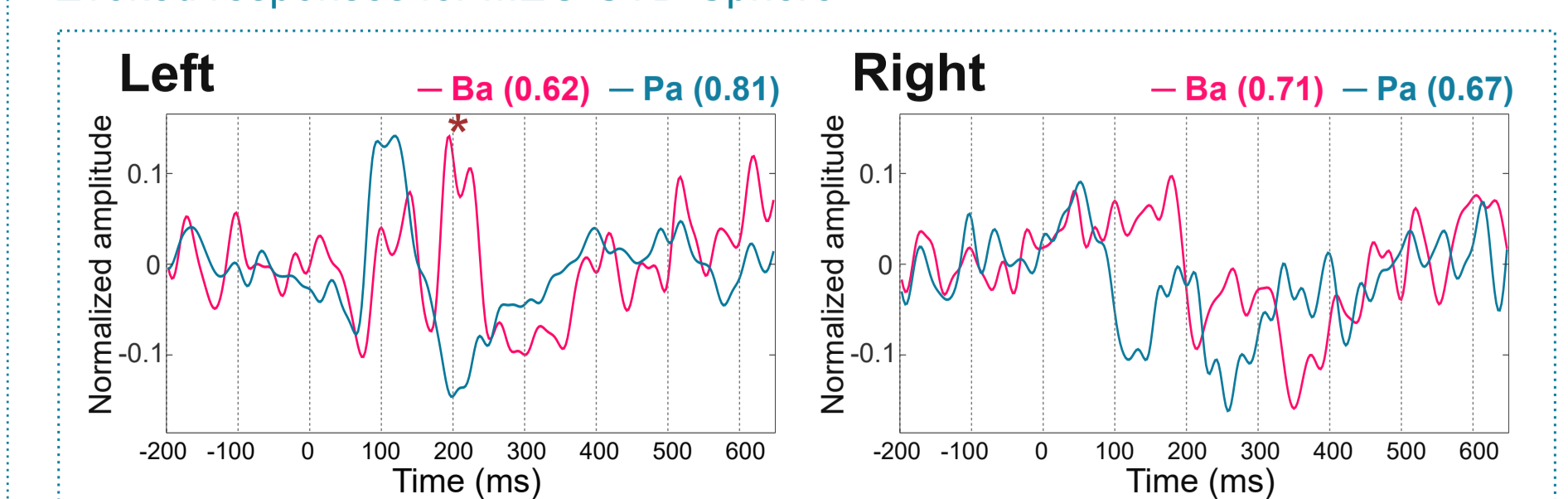
Spheres for dipole selection



Evoked response for the different modalities



Evoked responses for MEG-SVD-Sphere



Reconstruction for MEG at virtual electrode H'3 similar to the SVD-sphere estimation. Note the supplementary responses corresponding to the voice onset time on the left side.

[1] Specialization of left auditory cortex for speech perception in man depends on temporal coding [10.1093/cercor/9.5.484](https://doi.org/10.1093/cercor/9.5.484) [2] Hemispheric lateralization of voice onset time (VOT) comparison between depth and scalp EEG recordings [10.1016/j.neuroimage.2004.12.06](https://doi.org/10.1016/j.neuroimage.2004.12.06) [3] Papanicolaou et al., 2004 [10.3171/jns.2004.100.5.0867](https://doi.org/10.3171/jns.2004.100.5.0867) [4] Kim & Chung, 2008 [10.1016/j.neuroimage.2008.06.001](https://doi.org/10.1016/j.neuroimage.2008.06.001) [5] Bowyer et al., 2005 [10.1016/j.yebeh.2004.12.002](https://doi.org/10.1016/j.yebeh.2004.12.002) [6] Findlay et al., 2012 [10.1002/ana.23530](https://doi.org/10.1002/ana.23530) [7] Pirmoradi et al., 2016 [10.1016/j.eplepsyres.2015.11.015](https://doi.org/10.1016/j.eplepsyres.2015.11.015) [8] Tanaka et al., 2013 [10.3174/janr.A3233](https://doi.org/10.3174/janr.A3233) [9] Simultaneous recording of MEG, EEG and intracerebral EEG during visual stimulation: from feasibility to single-trial analysis [10.1016/j.neuroimage.2014.05.055](https://doi.org/10.1016/j.neuroimage.2014.05.055) [10] Technical solutions for simultaneous MEG and SEEG recordings: towards routine clinical use [10.1088/1361-6579/aa7655](https://doi.org/10.1088/1361-6579/aa7655) [11] Colombet et al., 2015. AnyWave: a cross-platform and modular software for visualizing and processing electrophysiological signals [10.1016/j.jneumeth.2015.01.017](https://doi.org/10.1016/j.jneumeth.2015.01.017) (http://meg.univ-amu.fr/wiki/AnyWave) [12] Oostenveld et al., 2011 [10.1155/2011/156869](https://doi.org/10.1155/2011/156869) (http://www.rnl.nl/neuroimaging/fieldtrip) [13] Medina et al., 2015. EpiTools, A software suite for presurgical brain mapping in epilepsy: Intracerebral EEG [10.1016/j.jneumeth.2018.03.018](https://doi.org/10.1016/j.jneumeth.2018.03.018) [14] Nolte, 2003 [10.1088/0031-9155/48/2/002](https://doi.org/10.1088/0031-9155/48/2/002) [15] Van Veen et al., 1997 [10.1109/10.623056](https://doi.org/10.1109/10.623056)