Westfälische Wilhelms-Universität Münster

ChiLDBrain
ADVANCING BRAIN RESEARCH IN CHILDREN'S DEVELOPMENTAL NEUROCOGNITIVE DISORDERS

IBB Institute for Biomagnetism and Biosignalanalysis

EEG/MEG source reconstruction of electric wrist/Braille-tactile/pneumato-tactile somatosensory stimulation using realistic head volume conductor modeling

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Introduction

For targeted individualized transcranial current stimulation (tES) of the human somatosensory cortex, an accurate source reconstruction, especially with regard to the orientation component, is important (Dmochowski et al., 2013; Wagner et al., 2016)

Here, we investigate differences in source reconstruction of the human somatosensory P20/N20 component with focus on **source orientation**:

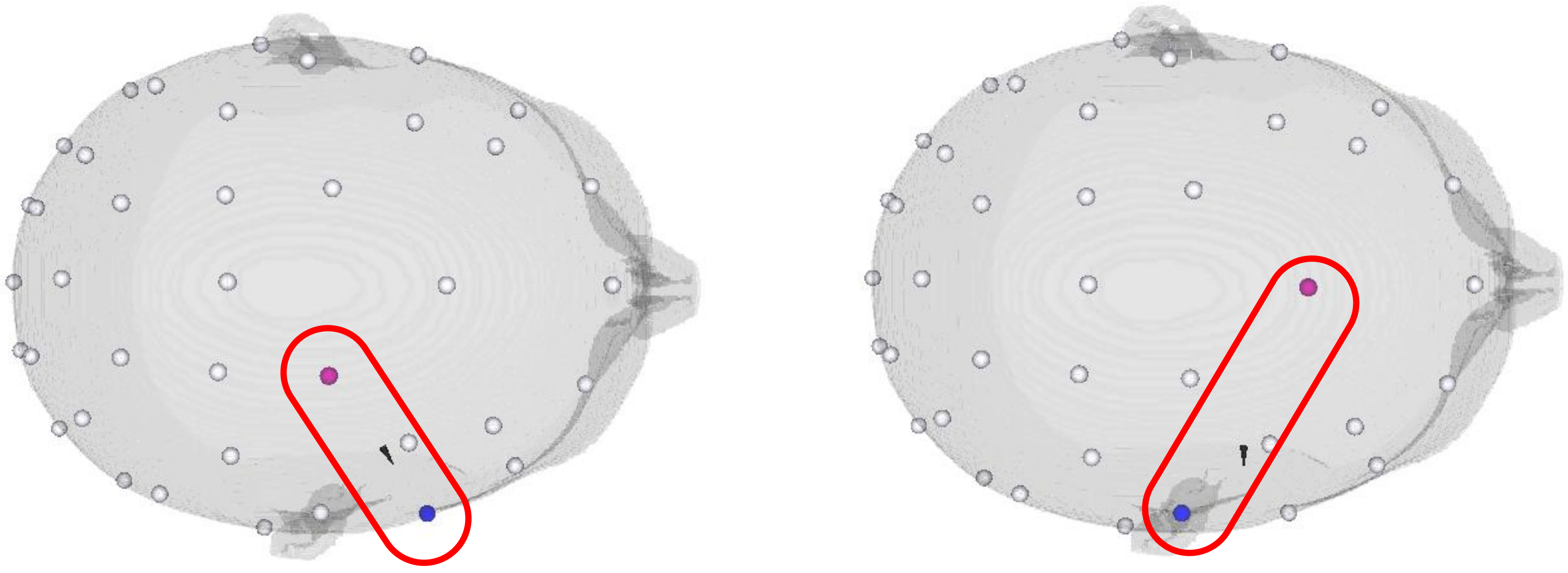
effects of combined EEG/MEG (EMEG) versus single modality EEG or MEG source analysis (Fuchs et al., 1998; Sharon et al., 2007; Aydin et al., 2014)

realistic and calibrated head volume conductor modeling (Aydin et al., 2014)

different kinds of stimulation: electric wrist (EW), Braille-tactile (BT) and pneumato-tactile (PT)

Introduction

If source orientation differs, the electrode configuration of tES will be different

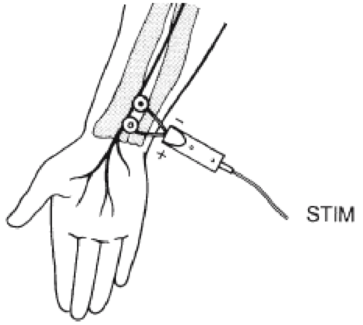


**We used maximum intensity optimization of Dmochowski et al., 2011*

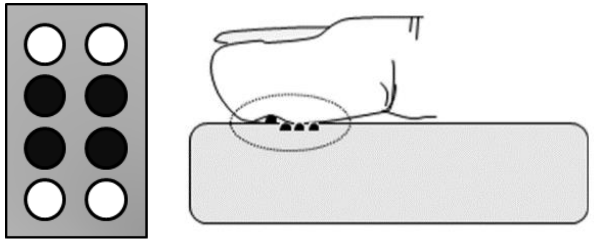
Participants and Procedure

2 right-handed participants

74 channel EEG (plus additional 6 EOG) and 275 channel whole head MEG (plus 29 references to calculate synthetic gradiometers) (CTF, VMS MedTech Ltd.)

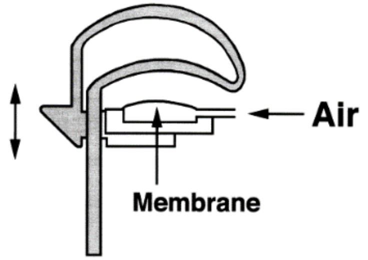


electric wrist stimulation of the median nerve



Braille-tactile stimulation of the index finger

pneumato-tactile stimulation of the index finger



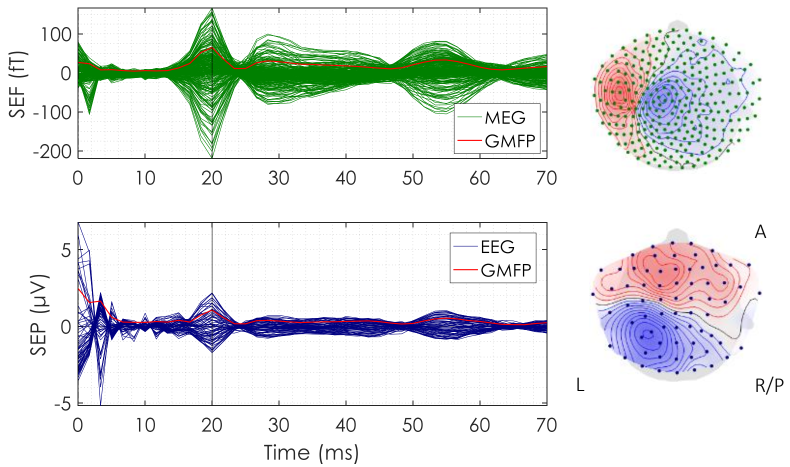
stimulus duration: 200ms, ISI: 350 to 450ms, number of events: ~1000

Scanning of T1w-, T2w- Magnetic Resonance Images (MRI) with voxels of 1 x 1 x 1 mm^3 (MAGNETOM 3.0T Siemens Medical Solutions)

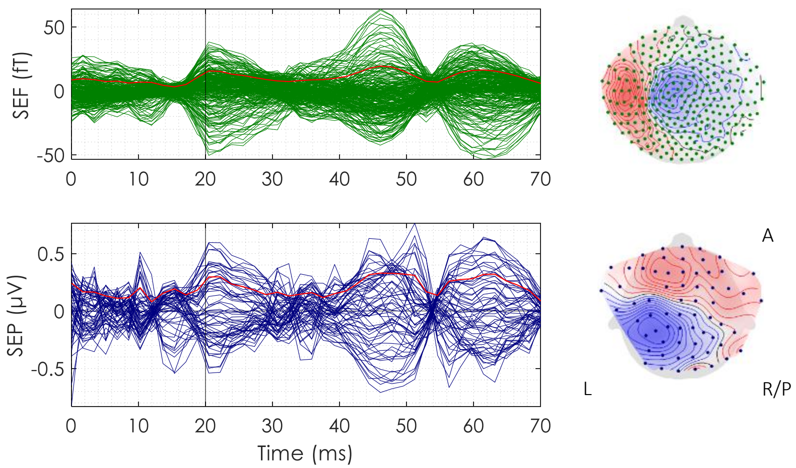
Measuring of diffusion weighted MRI (1.9 mm edge length, one flat diffusion gradient image and 20 volumes with different directions)

Estimation of the P20/N20 component

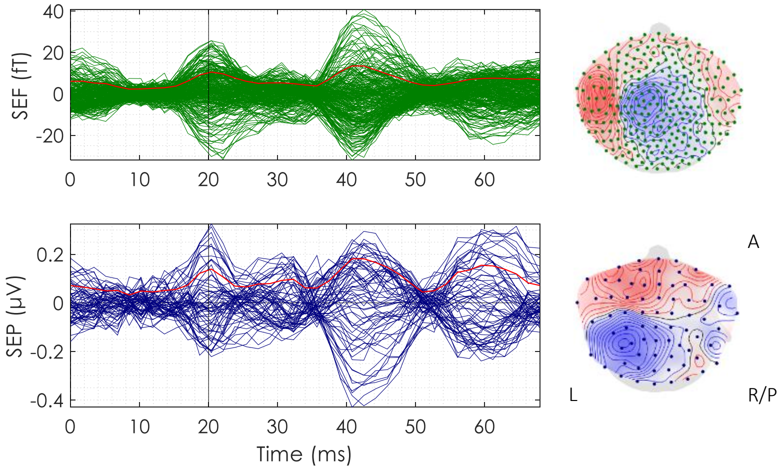
Electric Wrist (EW)



Braille-tactile (BT)



Pneumatic-tactile (PT)



Filtering 20 – 250Hz

Artifact rejection and elimination of the EEG/MEG (Antonakakis et al., 2016, 2017)

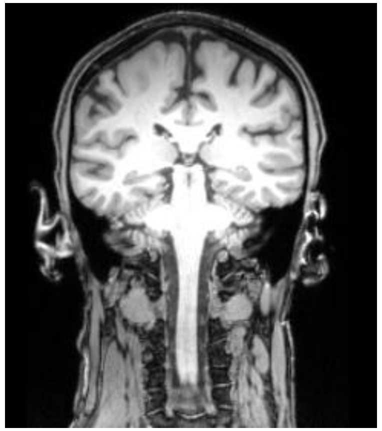
Trial definition: pre-stimulus time, 100ms and post-stimulus time, 200ms

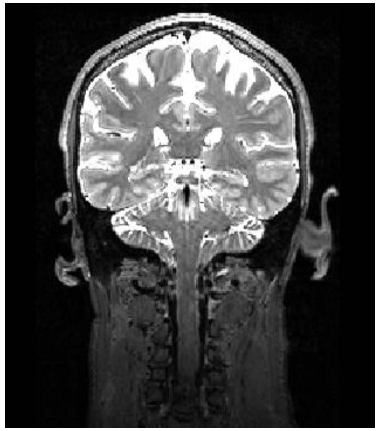
SEP/SEF single trial estimation

Fieldtrip and CURRY8 for functional data preprocessing

Head model construction: Segmentation

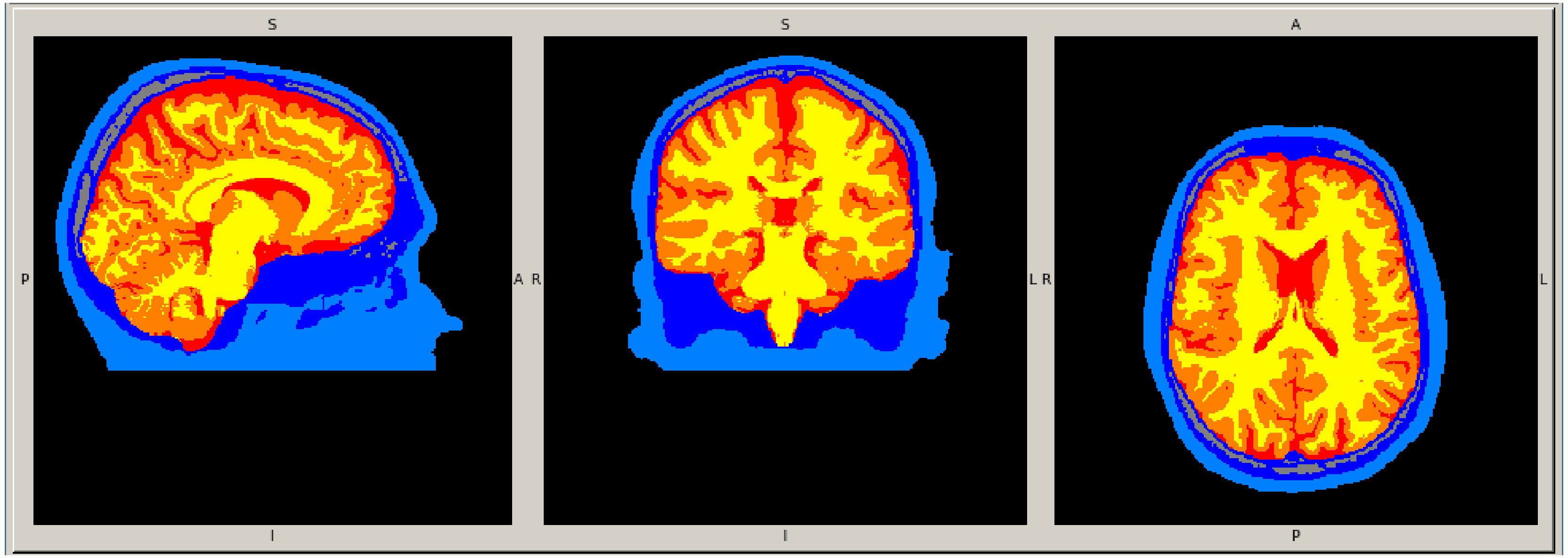
T1w scans



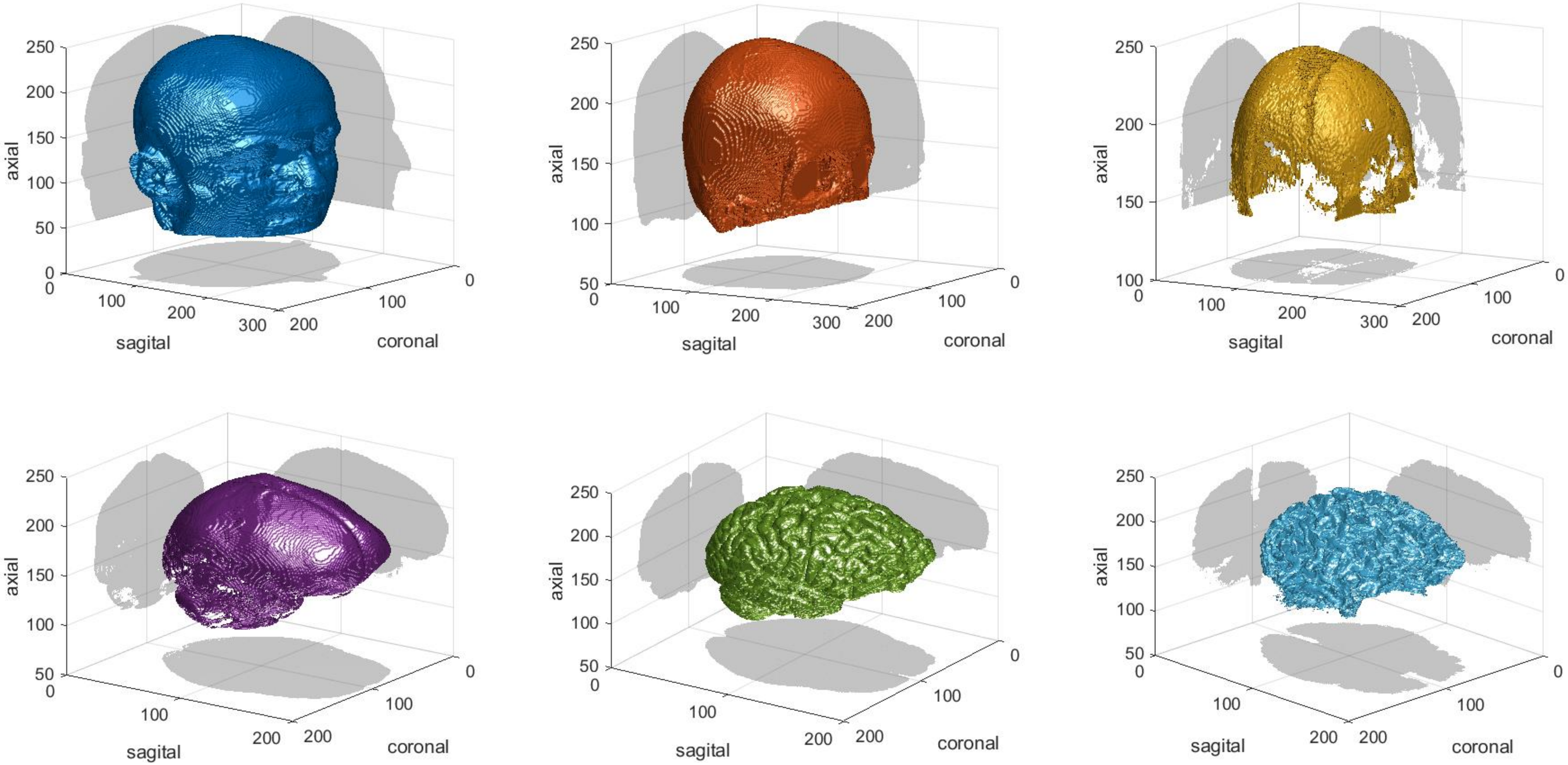


T2w scans

FSL, SPM12, Seg3D, MATLAB



Geometry adapted hexahedral meshes (SimBio-VGRID)

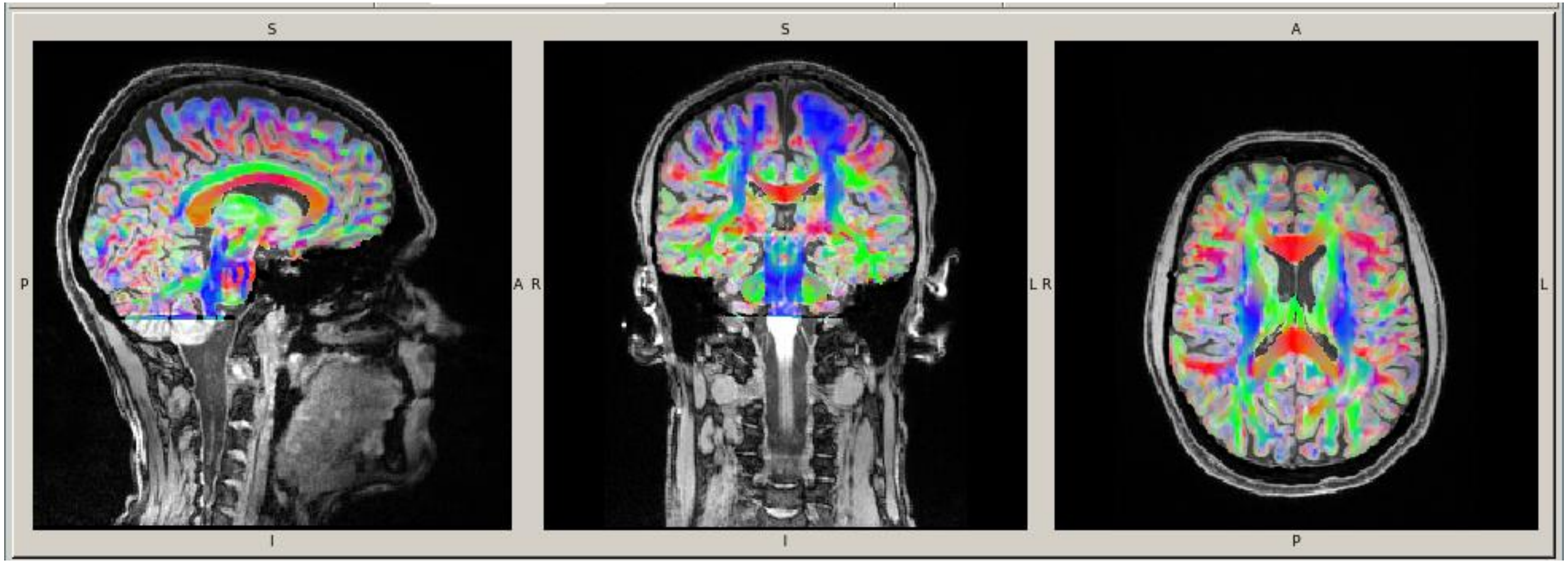


Head model construction: DTI correction

White matter conductivity tensor estimation (Tuch et al., 2001; Rullmann et al., 2009) and embedding into the geometry-adapted hexahedral FE head model

Eddy Current (EC) artifact correction (FLIRT-FSL)

Diffeomorphic approach was applied for nonlinear correction of susceptibility artifacts (SPM, FAIR toolbox, Ruthotto et al. 2012)

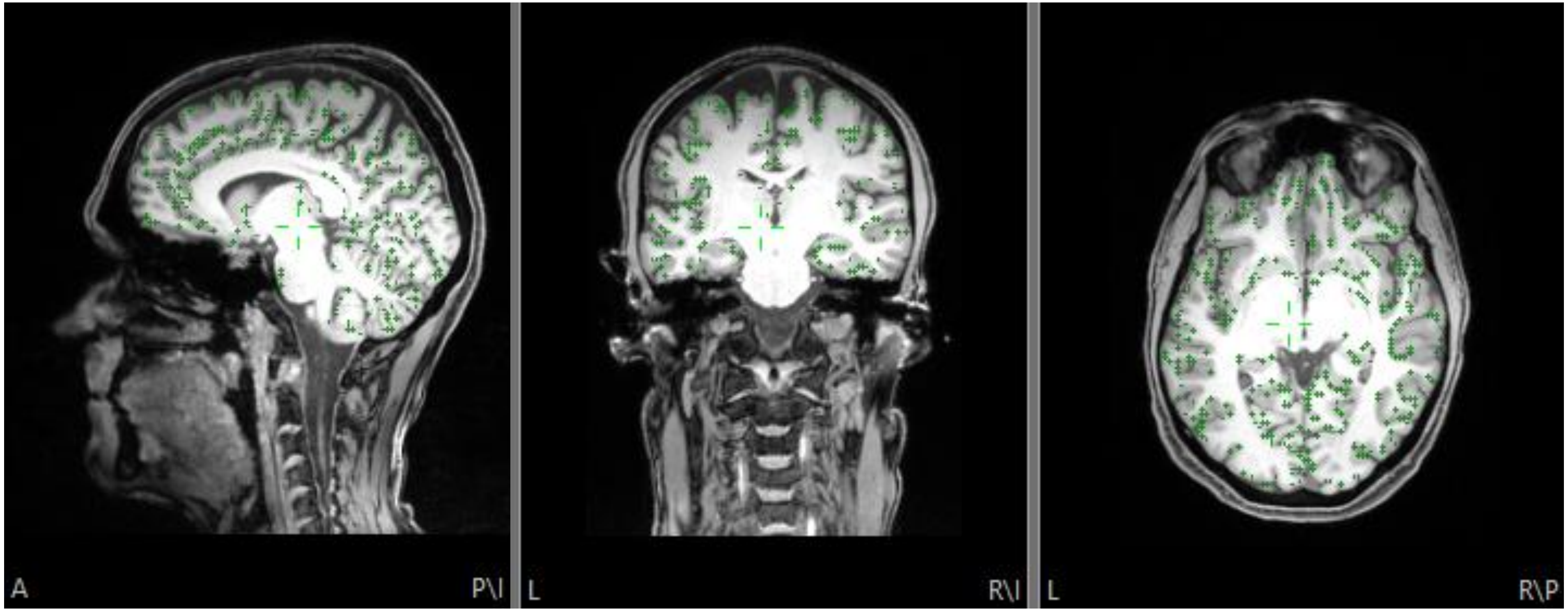


The color indicates the main fiber orientation: red is left-right, green is anterior-posterior and blue is superior-inferior.

SEP/SEF skull conductivity calibration

Source space in gray matter with 2mm resolution fulfilling the *Venant condition* (all the sources inside the gray matter compartment far away from the other tissues - Vorwerk et al., 2014; Fiederer et al., 2016)

Leadfields estimation using FEM – [Venant approach (AMG-CG)- SimBio (Wolters et al., 2004)]



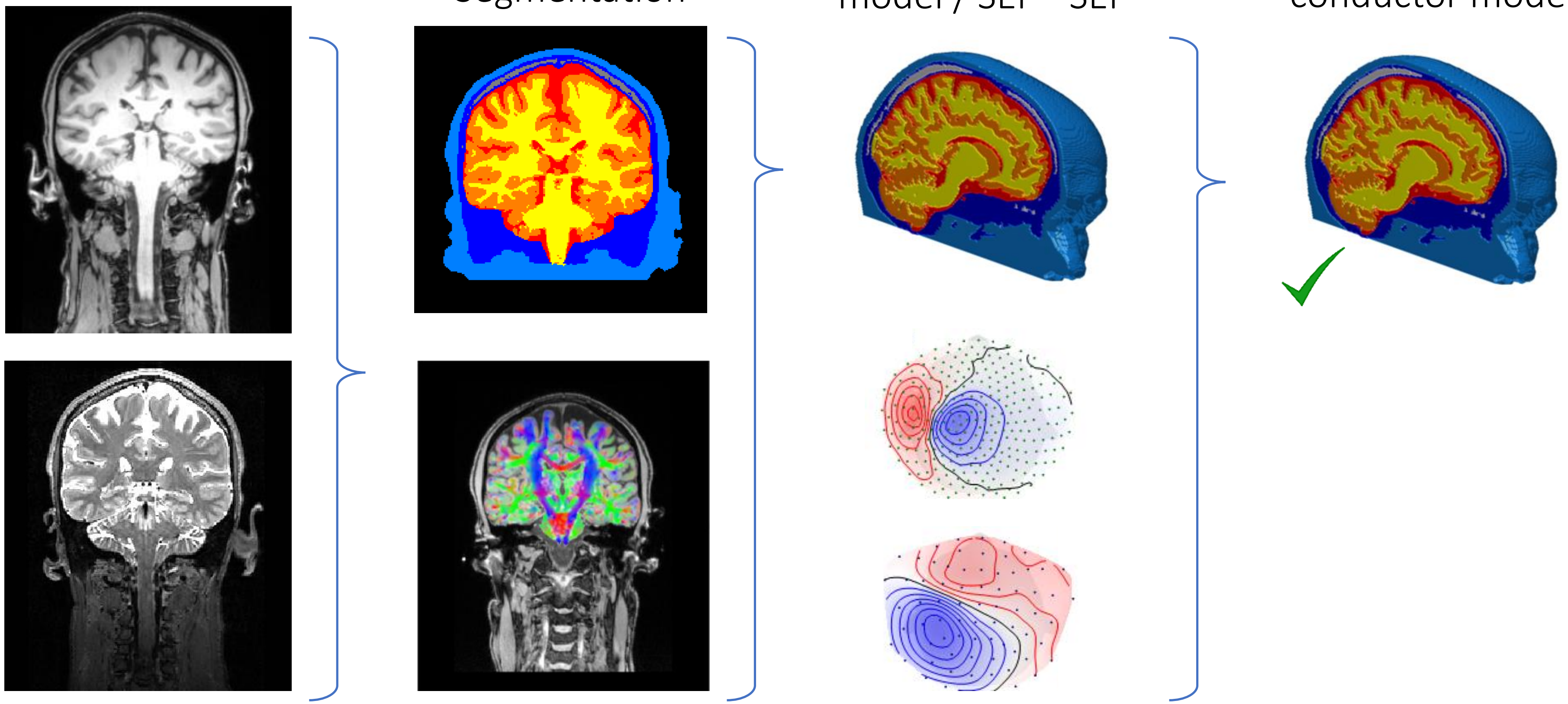
Pipeline for calibrated volume conductor model

MRI measurement

Registration
Segmentation

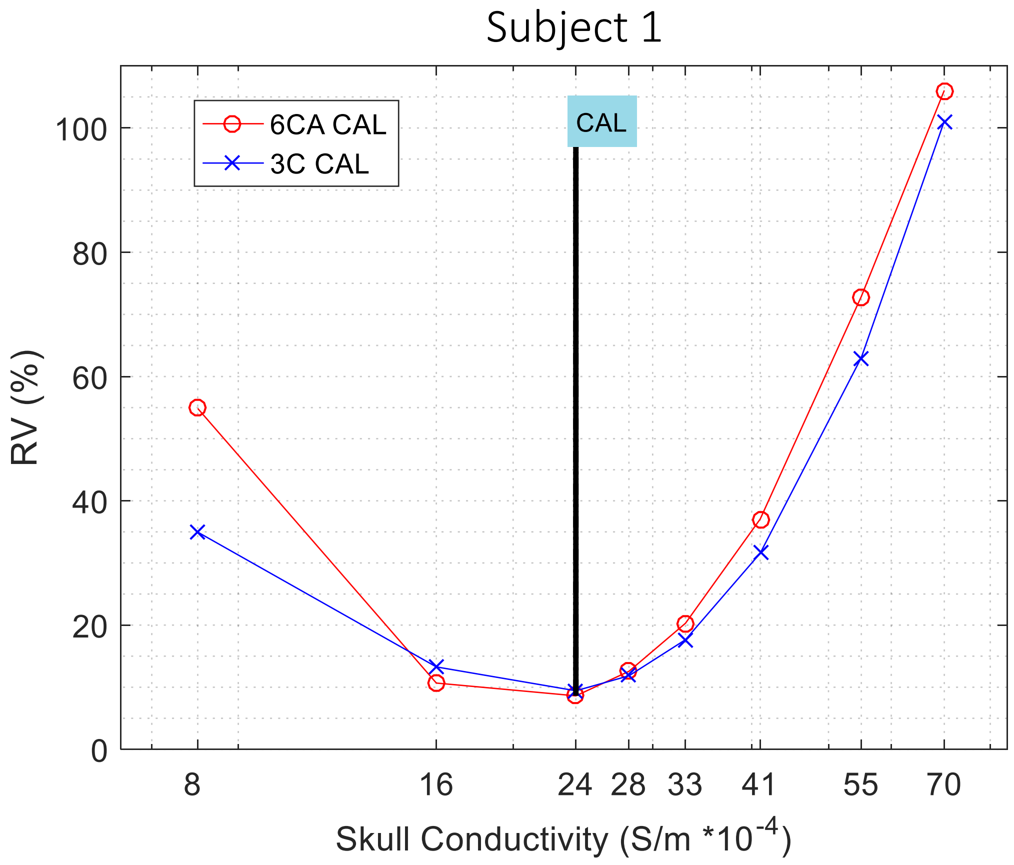
Anisotropic head
model / SEP - SEF

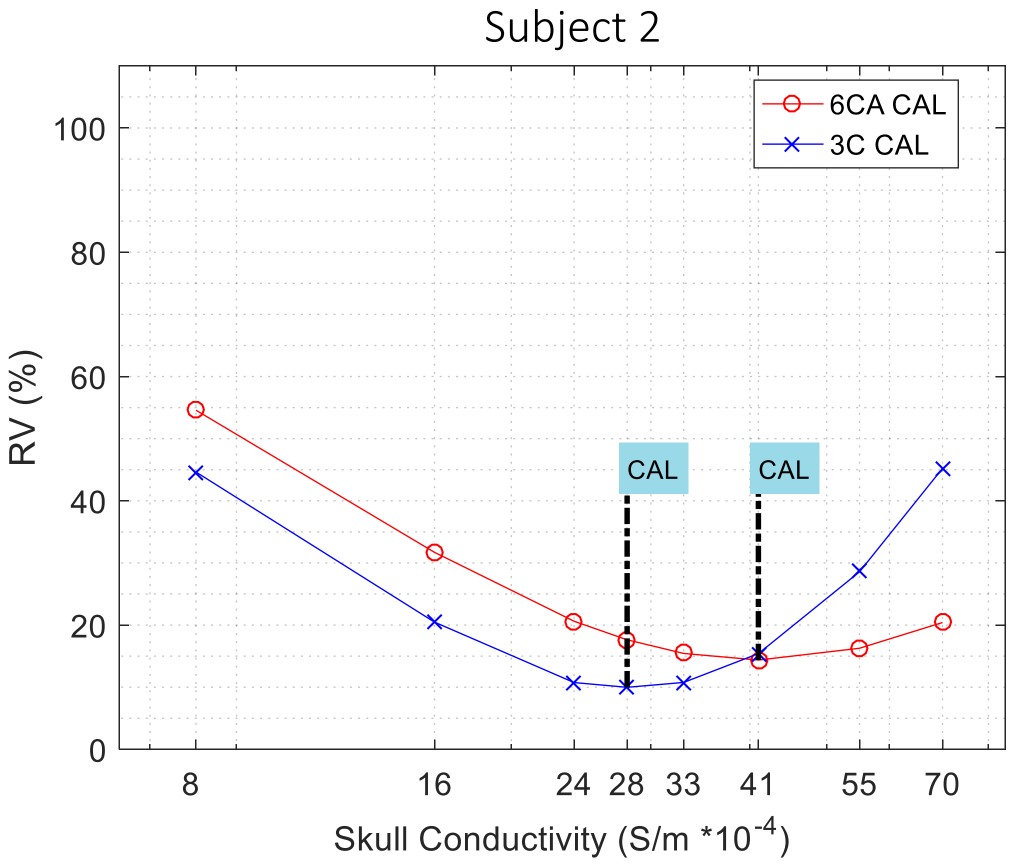
Calibrated volume
conductor model



SEP/SEF Skull Conductivity Calibration

Residual variance (RV) of source reconstruction using SEF and SEP (on y-axis) for a predefined set of skull conductivities (on x-axis)





CA : Compartment Anisotropy

CAL: Calibration point

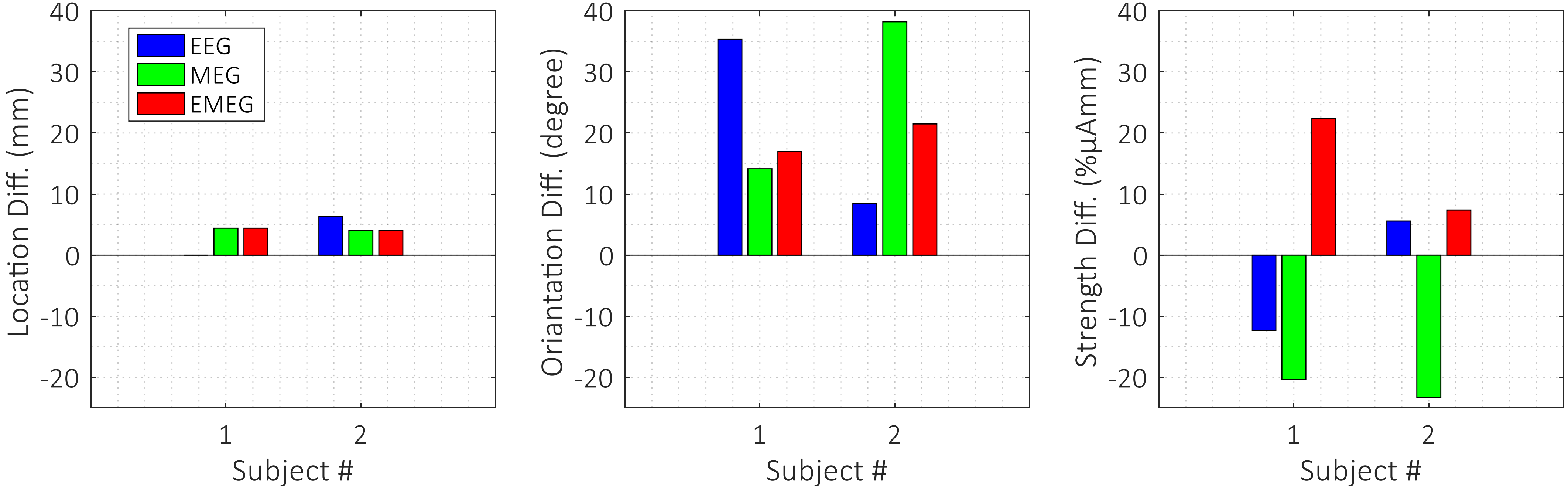
Scanning Dipole Comparison between 6CA CAL and 3C CAL

Selection of peak around 20ms on GMFP for the electrical wrist P20/N20 component

Single Dipole Deviation Scans for source reconstruction

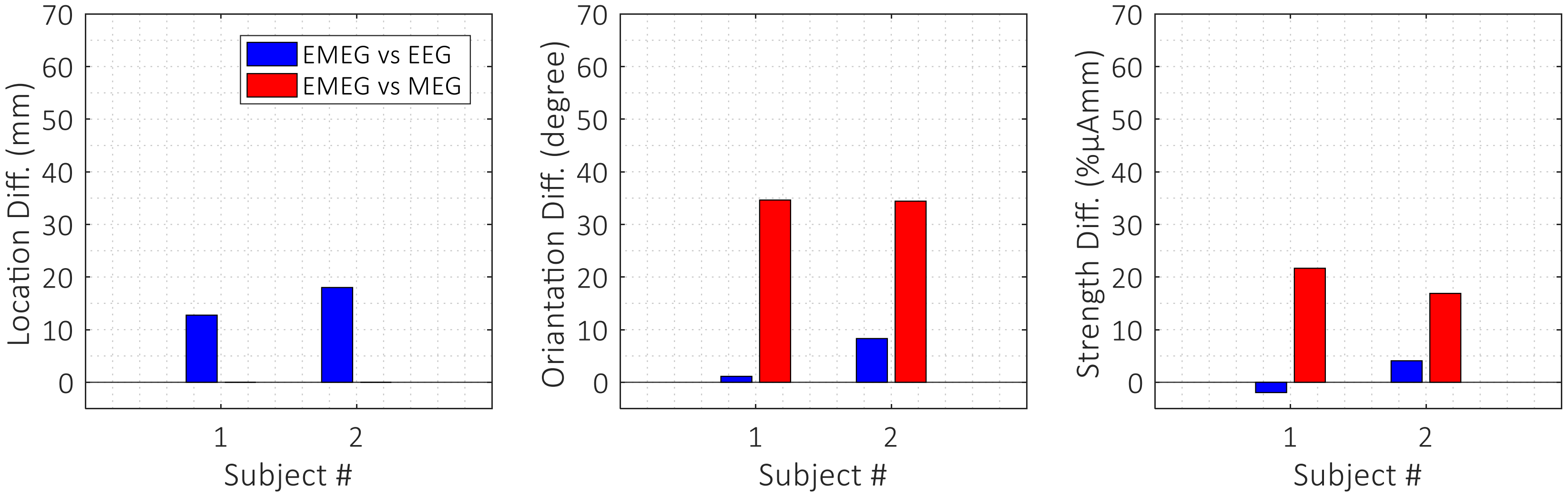
Regularization for MEG by a factor of 1.3

Source differences (6CA CAL vs 3C CAL)

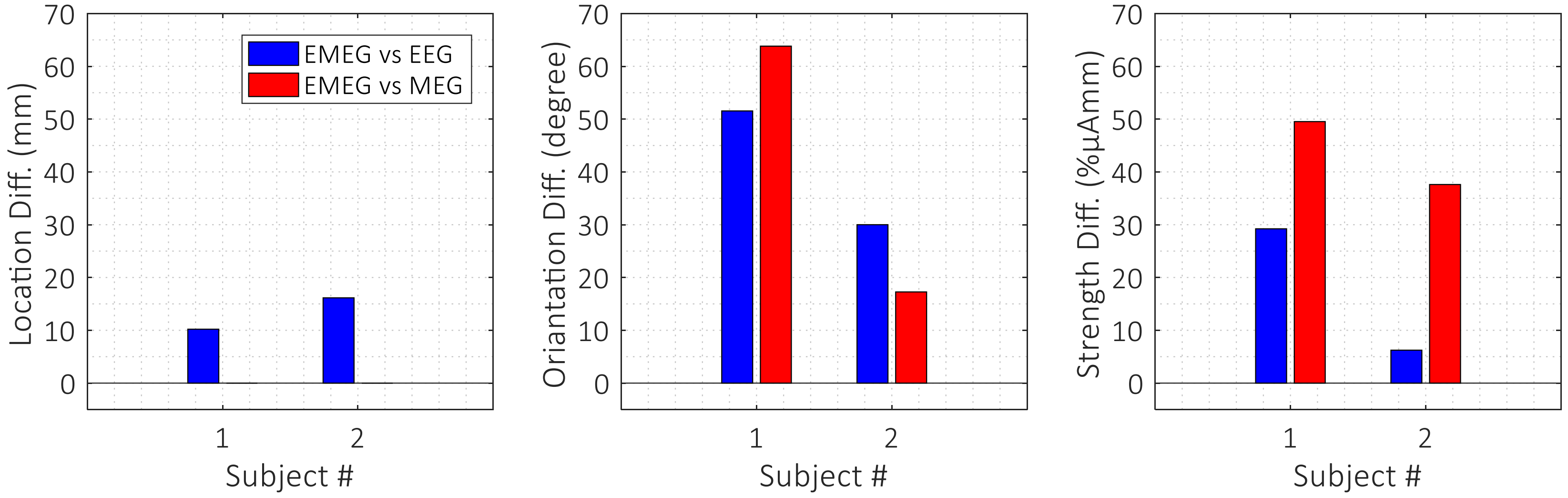


Scanning Dipole Comparison between modalities

Source differences for 3C CAL

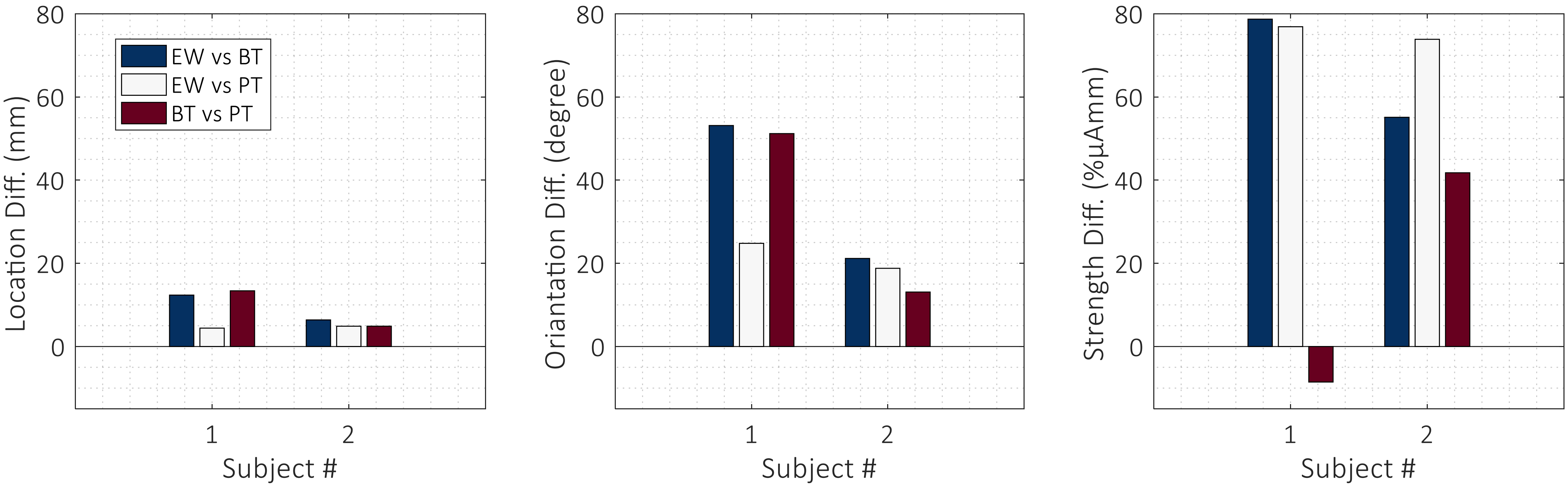


Source differences for 6CA CAL



EMEG scanning dipole comparison between different stimulation approaches of P20/N20 component

Source differences for 6CA CAL and EMEG



EW: Electric Wrist stimulation

BT: Haptic-tactile stimulation

PT: Pneumatic-tactile stimulation

Conclusion

Comparison of 6CA CAL vs 3C CAL FE head model for all the modalities

- Negligible (7mm) localization differences
- In average source orientation differences of 25 degrees
- Higher source strengths for EMEG using 6CA CAL

Conclusion

Comparison source reconstruction of EMEG with EEG and MEG

- Negligible (10mm) localization differences
- Important source orientation differences close to 40 degrees
- High source strength reduction using single modalities

Conclusion

Comparison of EW, BT and PT source reconstruction using 6CA CAL and EMEG

- Small (<12mm) location differences
- Compared to EW, strong amplitude reduction in BT and PT
- Higher orientation changes for BT than PT

Conclusion

Combined EEG/MEG leads to more reliable source reconstruction and especially orientation

6CA CAL realistic head models are needed to determine source orientation

One of the tactile stimulators can be used avoiding any kind of discomfort for long lasting stimulation or application in children

Need of application in more subjects for statistical analysis

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Thank you for your attention!

Any questions ?

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ChildBrain
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MARIE CURIE ACTIONS

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Aydin et al., 2014
MATLAB + CURRY8

SEP/SEF Skull Conductivity Calibration

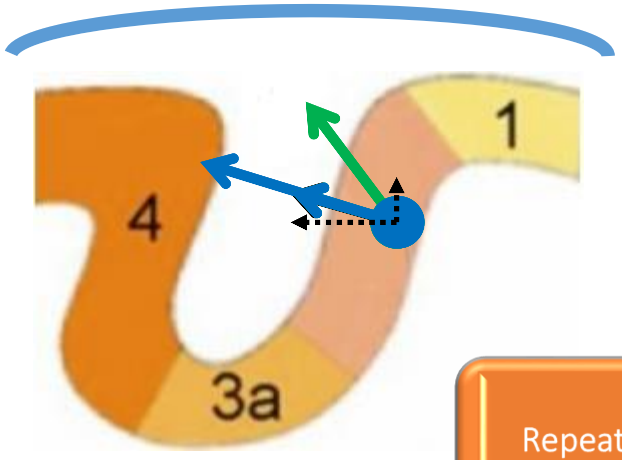
Tissue Conductivity for 6CA

- Skin : 0.43 S/m
- CSF : 1.79 S/m
- GM : 0.14 S/m
- WM : 0.33 S/m
- Ratio C/S: 3.6

Tissue Conductivity for 3C

- Skin : 0.43 S/m
- Skull : 0.0008-0.007 S/m
- Brain: 0.33 S/m

SEP/SEF skull conductivity calibration



Define a set of skull conductivity parameters: $\Sigma=\{\sigma_1,\sigma_2,\ldots,\sigma_n\}$

SEF GFS → location x, orientation o_1 and magnitude m_1.

SEP Least Squares (LS); x fixed → orientation o_2 and magnitude m_2.

SEF LS; *x* and *o_2* fixed → *m_3*

SEP x, o_2 and m_3 → Residual Variance (RV)

Repeat for all predefined conductivities $\{\sigma_1,\sigma_2,\ldots,\sigma_n\}$

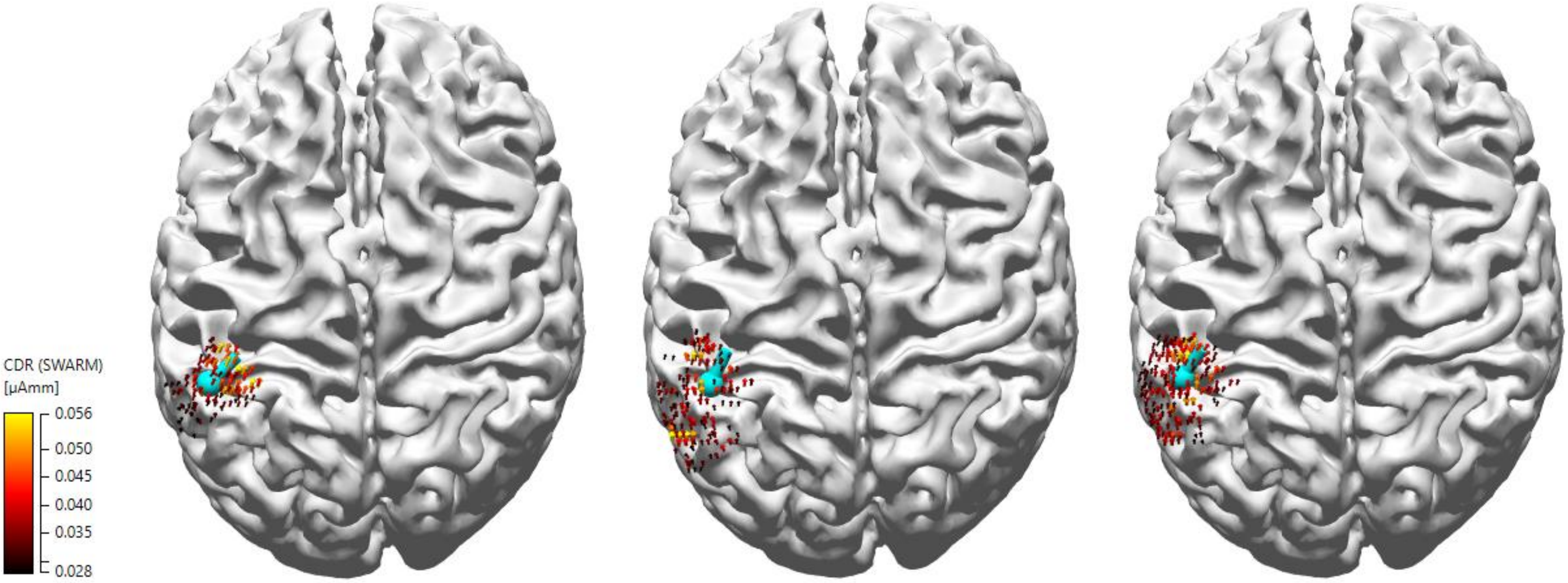
Select the conductivity that gives the lowest RV

Aydin et al., 2014, 2015

MATLAB + CURRY8

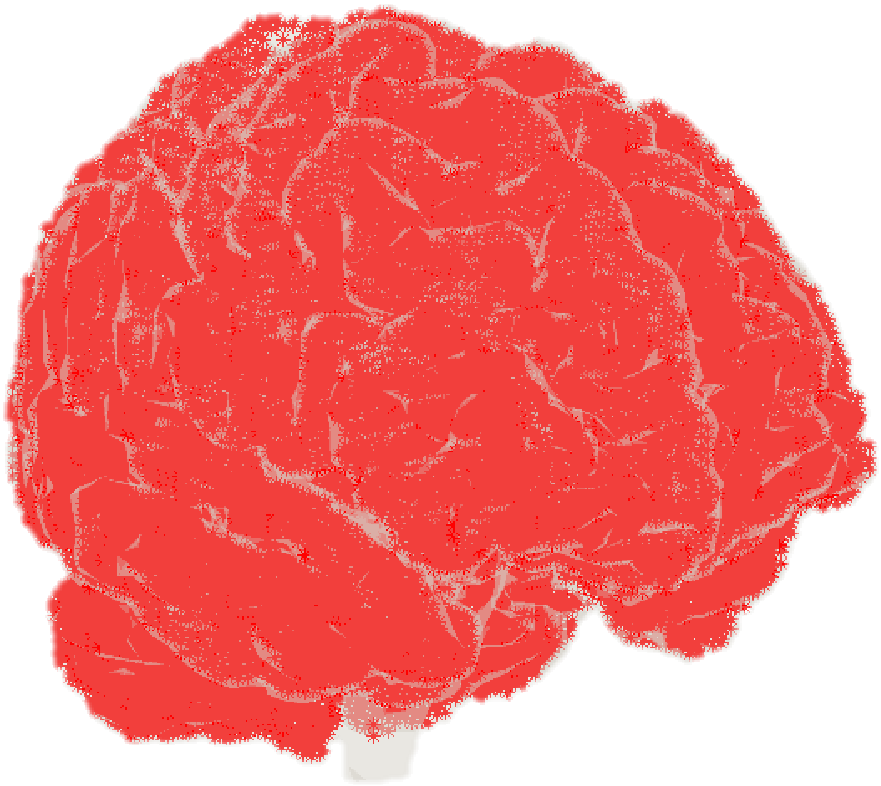
Source reconstruction using goal function scan and sLORETA-weighted accurate minimum norm (SWARM)

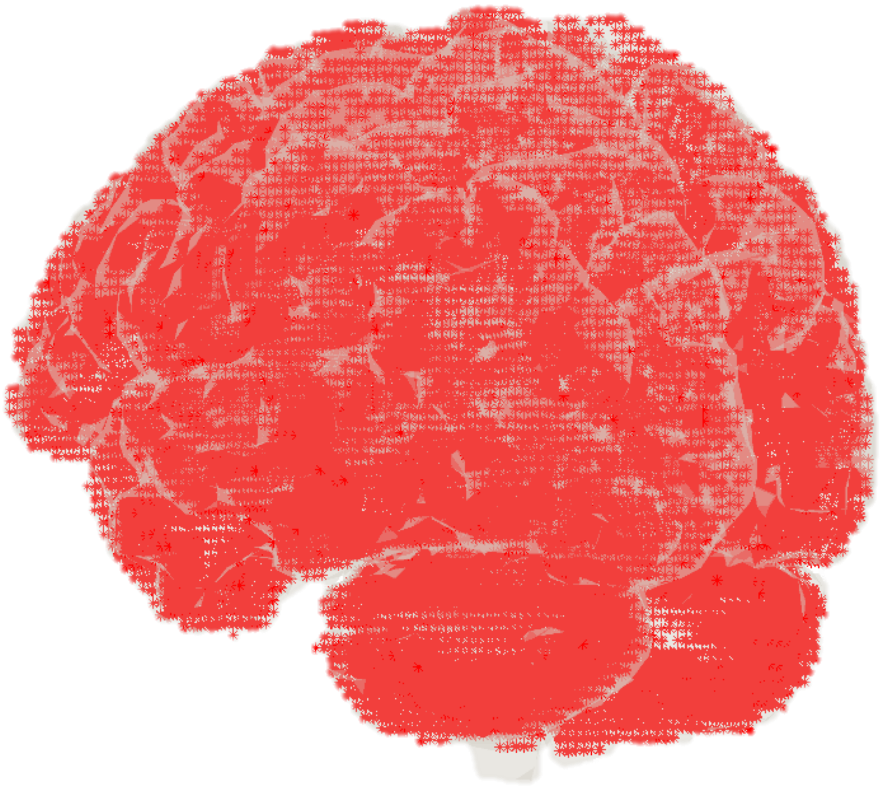
Electric Wrist | Hapto-tactile | Pneumatic-tactile



25ms | 33ms | 82.5ms

Head model construction: DTI correction





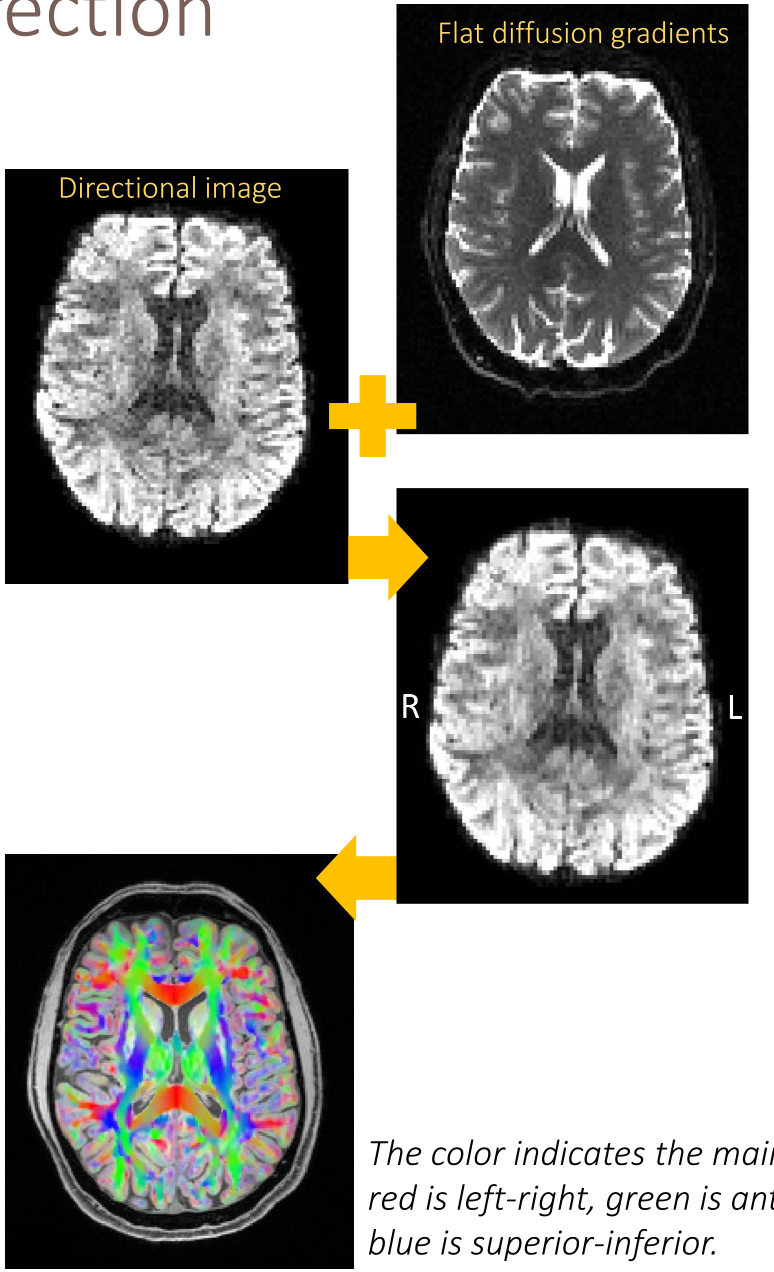
Head model construction: DTI correction

1. Eddy Current (EC) artifact correction by affinely registering directional images to the image with flat diffusion gradients

2. Reorientation of gradient directions using the rotational part of the transformation matrices obtained during step 1

3. Diffeomorphic approach was applied for nonlinear correction of susceptibility artifacts in the DTI dataset (Ruthotto et al. 2012)

4. Registration of the nonlinearly corrected DT images to the T1w image



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