Individual targeting and optimization of multi-channel transcranial electric stimulation of the human primary somatosensory cortex

Marios Antonakakis[1], Asad Khan[1], Andreas Wollbrink[1], Michalis Zervakis[2], Walter Paulus[3], Michael Nitsche[4], Rebekka Lencer[5], Sonja Suntrup-Krueger[6], Jens Haueisen[7], Carsten H. Wolters[1]

marios.antonakakis@uni-muenster.de

1. Institute for Biomagnetism and Biosignal Analysis, University of Muenster, Germany
2. School of Electronic & Computer Engineering, Technical University of Crete, Chania, Greece
3. Department of Clinical Neurophysiology, University Medical Center Goettingen, Goettingen, Germany
4. IfADo - Leibniz Research Center for Working Environment and Human Factors, Dortmund, Germany
5. Department of Psychiatry and Psychotherapy and Otto-Creutzfeld Center for Cognitive Neuroscience, University of Muenster, Muenster, Germany
6. Department of Neurology, University Hospital of Muenster, Muenster, Germany
7. Institute for Biomedical Engineering and Informatics, Technical University of Ilmenau, Ilmenau, Germany

Institute for Biomagnetism and Biosignalanalysis

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ChildBrain

ADVANCING BRAIN RESEARCH IN CHILDREN'S DEVELOPMENTAL NEUROCOGNITIVE DISORDERS

Motivation

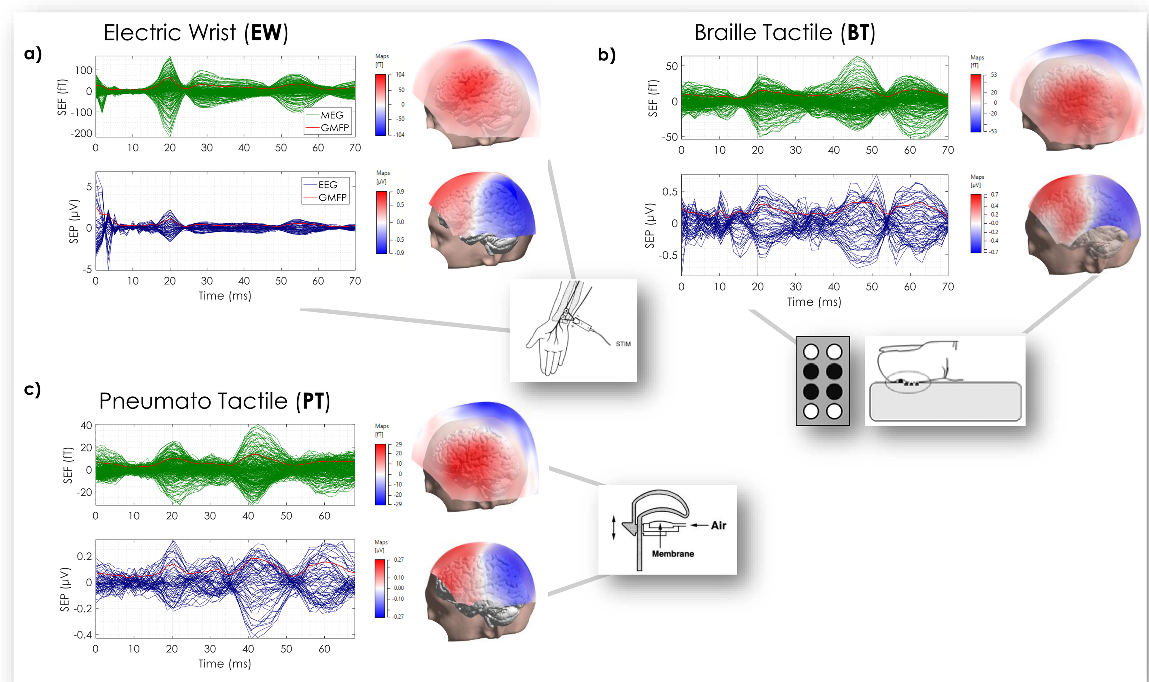
- Individually targeted multi-channel transcranial Electric Stimulation (tES) has been suggested as a promising new approach for manipulation of brain networks[1]
- Our study **aims** at evaluating the contribution of this novel technique in a first experiment using a group of five healthy subjects
- We focus on the human somatosensory system, a well-controlled network that has been deeply investigated over the past decades
- As a first step, for individual targeting, we analyzed the N20/P20 components using combined somatosensory evoked potentials (SEP) and fields (SEF), we then investigated how **the individually determined** targets affect the **optimization of electrode montages** for performing multi-channel tES of the somatosensory cortex.

Head model generation and source analysis

- T1w- and T2w- MRIs were used for the construction of a six compartment (skin, skull compacta, skull spongiosa, CSF, gray and white matter) head model (fig. 1).
  - Registration was performed using FSL[7] and image segmentation conducting SPM12 – Fieldtrip[5] in combination with image processing techniques in MATLAB.
  - Eddy current correction and diffeomorphic approach was applied for nonlinear correction of susceptibility artifacts[6] of the dMRI enabling modeling white matter anisotropy (WMA).
- Adapted hexahedral mesh (node shifting of 0.33) with WMA conductivity tensors[3,7] and source space of 2mm on gray matter far away from neighbour tissues.
- Finite element model simulations using Venant source modeling (AMG-CG, SimBio)[8].
- Use of scanning dipole for source reconstruction of the P20/N20 component[9].
- A calibration procedure[3] was performed for the selection of optimal skull conductivity.

Individual targeting using P20/N20 component

- **SEP/SEF** were elicited by three different types of stimulation (fig. 2) during the acquisition of **EMEG** (combined MEG (275 gradiometers - OMEGA2005, CTF, VSM MedTech Ltd., Canada) and EEG (80 electrodes – EASYCAP GmbH, Herrsching, Germany).
- **Supine position** to reduce head movements and to avoid erroneous cerebrospinal fluid (CSF) effects due to brain shifts when combining **EMEG** and MRI[2,3].
- Runs of 10min with 1200 Hz sampling rate and filtered online with 300 Hz low pass filter.



Preprocessing of EEG/MEG

- Constant baseline correction
- Band-pass filtering at 20 – 250Hz (Notch filtering at 50Hz)
- Artifact rejection and elimination of EEG/MEG using trial SNR-based threshold approaches[3] and visual inspection
- SEP/SEF averaging across trials

Figure 2. SEF/SEP butterfly plots and scalp topographies for **a)** Electric Wrist (EW) stimulation, **b)** Braille Tactile (BT) stimulation and **c)** Pneumato tactile) PT= stimulation. SEF (MEG) is presented using green color and SEP (EEG) is with blue and the correspond GMFP is in red. The single trial amplitude scaling differs from type to type of stimulation. Time axis is according to N20 response. The vertical black line at 20ms represents the highest peak of each stimulation.

Optimized multi-electrode stimulation

- For optimization of the tES stimulation protocols a multi-electrode array of 39 channels (Starstim tDCS system (Neuroelectrics, Barcelona, Spain) is used.
- The optimized stimulation protocols are estimated using a modified version of maximum intensity optimization algorithm[4] achieving better current distribution.
- The total applied current is limited to 2mA fulfilling the safety constraints[1].

Results

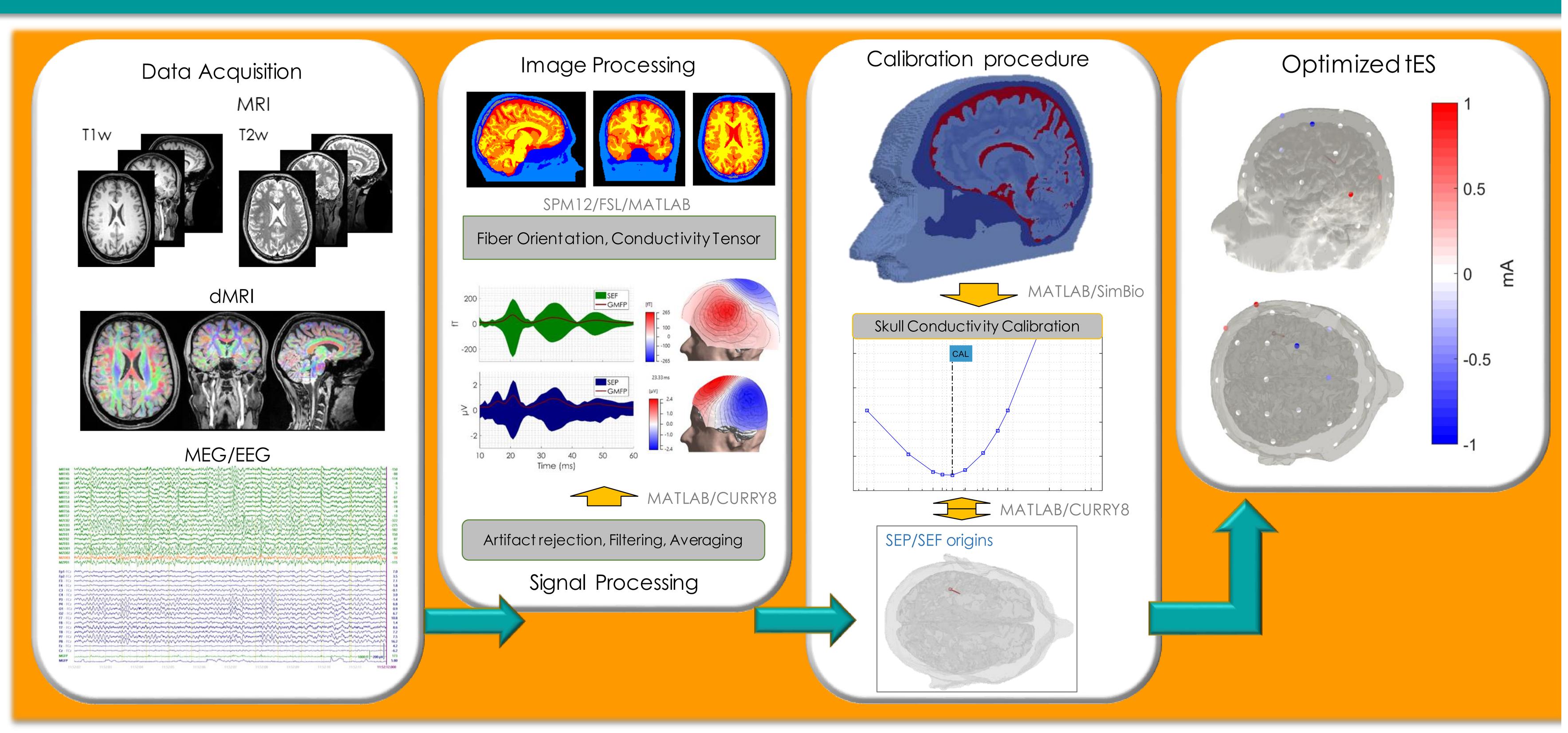


Figure 1. Pipeline for targeted tES using EMEG source analysis. The pipeline starts from the raw data (functional and image), continuous with the preprocessing of both kind of data. Next step is the calibration procedure achieving the optimal skull conductivity value and ends up with an optimal EEG configuration for tES using the target from source analysis of each type of stimulation.

- Figure 1 depicts the pipeline for tES targeted by EMEG source analysis while figure 2 shows the SEP/SEF waveforms together with scalp topographies. Table I presents the source reconstruction difference among the target vectors.
- Figure 3 and table II shows the tES optimization results.

Table I. Target vector differences. EMEG reconstructed brain source (Location and Orientation) comparison is represented between the three stimulators (EW, BT and PT).

	Location Difference (mm)	Orientation Difference (degrees)
EW vs BT	8.4	20.9
EW vs PT	7.5	3.3
BT vs PT	6.9	17.8

Table II. Quantification of optimized current density for all the target vectors. The intensity of the current density in the target area (IT), the averaged intensity of the current density in non-target regions (INT), and the percentage of current intensity of the density that is oriented parallel to the target vector (PAR as DIR/IT, where DIR is the inner product of current density and target vector (DIR), third column) is displayed for evert target (EW, BT and PT).

	IT (Am^{-2})	INT (Am^{-2})	PAR (%)
EW	0.1	0.13	73
BT	0.08	0.1	80
PT	0.11	0.15	75

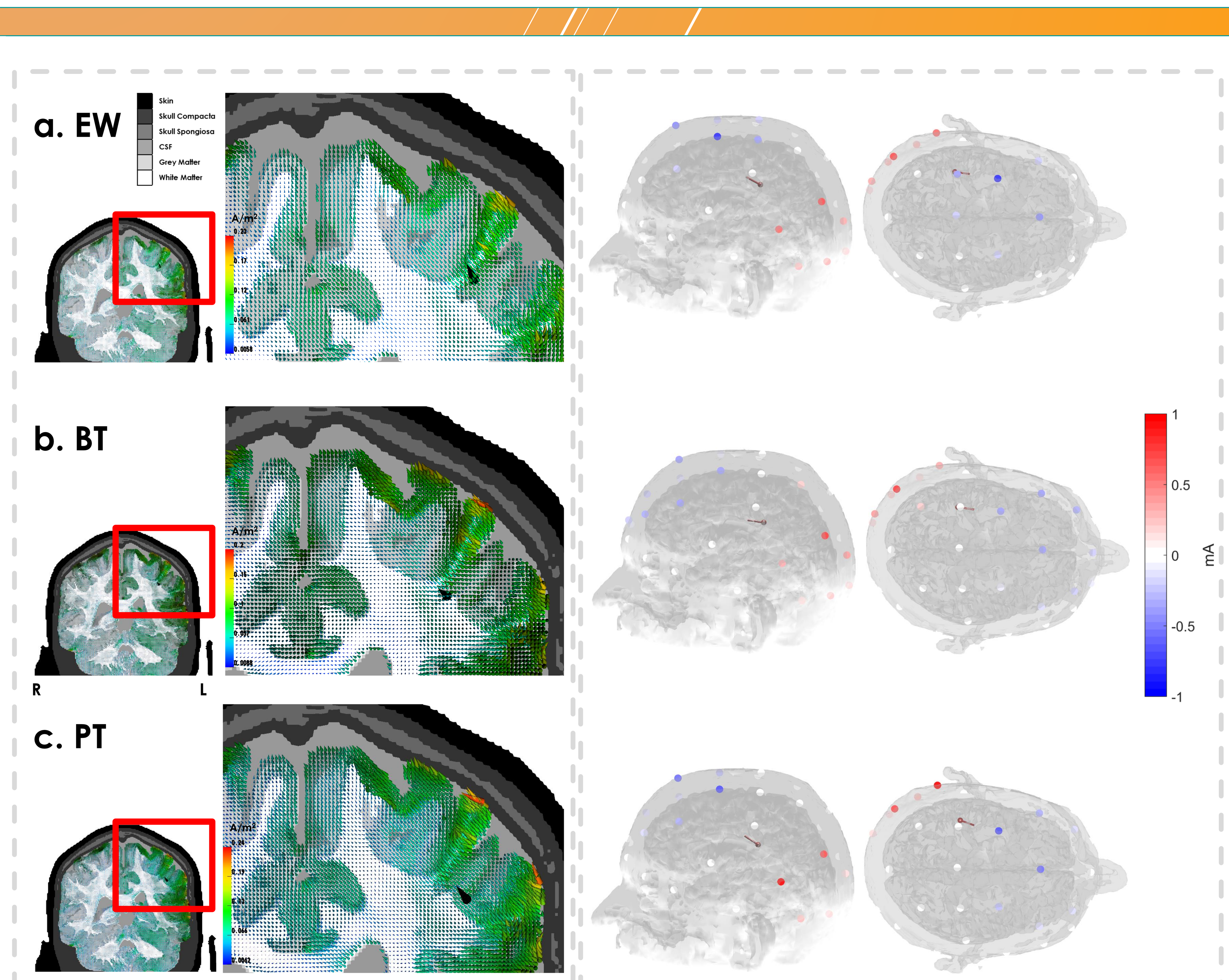


Figure 3. Optimized current intensities in coronal view (left panel) and EEG configurations optimized electrode distribution in left and top view (right panel) for **a)** EW target, **b)** BT target and **c)** PT target. The target is presented by a black cone in case of current intensity visualization and by a dark red dipole for the underlying source of the P20/N20 SEP/SEF component.

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Conclusion and Outlook

- An **individual skull conductivity calibration procedure** as presented here seems **important** for **EMEG** source analysis.
- Using a modified version of maximum intensity optimization algorithm[4], the electrode configuration montages are clearly different with regard to the different stimulations (EW, BT, PT) and resulting P20/N20 sources.
- From the current results (table I, Fig. 3), we conclude that an accurate target determination with regard to both location and orientation is an important prerequisite for an individually optimized multi-channel tES protocol.