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Volume conduction effects in tDCS using a 1mm geometry-adapted hexahedral finite element head model

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Introduction

Transcranial direct current stimulation is a non-invasive brain stimulation technique that can induce transient excitability changes in the stimulated cortex (Nitsche and Paulus, 2000).

Methods

Despite of the recent progress, the knowledge about the underlying mechanisms behind tDCS is still limited. In order to gain insight in the sophisticated interplay of stimulation, volume conduction and resulting cortical current density distribution, we follow an effect-by-effect approach. We start our investigations with a homogenized isotropic three compartment (skin, skull, brain) head model, where results are still rather obvious. In each consecutive step, we then extent our head model by one additional effect, which is either a tissue layer or an anisotropic instead of a homogenized isotropic tissue compartment. For each additional effect, the resulting changes in the current density distribution are deeply investigated. Our most realistic volume conductor contains six tissue compartments and brain anisotropy (Olesch et al., 2010; Wolters et al., 2006; Wagner, 2011).

Results

Major findings of our study include (1) channeling effects of the skin, the skull spongiosa and the cerebrospinal fluid (CSF) compartments and resulting current density vector field orientation and magnitude changes in the cortical compartment of more than 60 degrees and 300%, respectively; (2) current vectors in lower-conducting regions tend to be oriented towards the closest higher conducting region; (3) anisotropic white matter conductivity causes current flow in directions more parallel to the white matter fiber tracts; (4) highest cortical current magnitudes are not only found close to the side of stimulation.

Conclusion

An accurate modeling of the volume conduction effects using highly-realistic multi-compartment anisotropic head models is important for the understanding of tDCS and the guidance of its application in experiments. Finally, by means of Helmholtz' principle of reciprocity, our results are also relevant for EEG and MEG source analysis.

Literature

[1] Nitsche, M.A., Paulus W., Excitability changes induced in the human motor cortex by transcranial direct current stimulation, J physiol., 527(3), pp.633-639, (2000).
[2] Olesch, J., Ruthotto, L., Kugel, H., Fischer, B. and Wolters, C.H., A variational approach for the correction of field-inhomogeneities in EPI sequences, Proc. SPIE Medical Imaging, San Diego, USA, pp.1-8, Feb.2010.
[3] Wagner, S., An adjoint FEM approach for the EEG forward problem, Diploma Thesis (Mathematics), Institute for Biomagnetism and Biosignalanalysis and Institute for Computational and Applied Mathematics, University of Muenster, (2011).
[4] Wolters, C.H., Anwander, A., Tricoche, X., Weinstein, D., Koch, M.A. and McLeod, R.S.,Influence of tissue conductivity anisotropy on EEG/MEG field and return current computation in a realistic head model: A simulation and visualization study using high-resolution finite element modelling Neuroimage, Vol.30(3), pp.813-826, (2006).