Alexander Opitz (University of Minnesota) will talk about combining electric field modeling with traditional meta-analysis to simulate effects of tDCS. Due to differences in electrode montages and stimulation intensities across studies, results are difficult to aggregate for meta-analytic inferences. A novel meta-analytic method relating behavioral effect sizes to electric field strength was developed to identify brain regions underlying the largest tDCS-induced working-memory improvement.

Maria Vasileiadi (Medical University Vienna) will talk about the application of electric field simulations in pre-surgical language mapping. TMS mapping has been shown to be clinically useful and safe but standard approaches are lacking the accuracy of direct cortical stimulation. She will propose a procedure including fMRI, causal mapping using TMS and improved estimation of effective stimulation targets by combining electric field modeling with high-precision neuronavigation.

INTRODUCTION TO ELECTRIC FIELD MODELING: HOW, WHY, AND WHAT IS STILL MISSING?

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The electric field induced in the brain by non-invasive brain stimulation approaches, such as transcranial magnetic or electric stimulation (TMS/TES), often has a complex spatial distribution shaped by the individual anatomy of a subject (Saturnino et al. 2019, Puonti et al. 2020). Using electric field simulations we can study the magnitude and direction of the induced field in the brain and link its properties to stimulation outcomes, or to plan the stimulation protocol so that the direction and magnitude of the field in a given target is matched for all subjects in a study. In this talk, I will give a basic introduction to electric field modeling: how the simulations are done in practice, why they are useful, and what we are currently still missing. I will cover the different steps in a simulation pipeline, starting from an MRI scan all the way to the electric field estimates, and how the output from such pipeline should be interpreted. To demonstrate how simulations can be exploited, I will present specific examples of how to analyze data that has already been acquired and how to use the simulations in the planning of new studies. In relation to prospective planning, I will also talk about the link between field modeling and personalized stimulation protocols. I will then present results on the validation of the simulations using invasive and non-invasive approaches, and discuss which aspects of the modeling are most crucial for getting accurate electric field estimates. Finally, I will conclude with an outlook for the future developments that are needed to fill the gap between simulation and stimulation.

References:

1. *Saturnino GB, Puonti O, Nielsen JD, Antonenko D, Madsen KH, Thielscher A: SimNIBS 2.1: a comprehensive pipeline for individualized electric field modelling for transcranial brain stimulation. Brain and human body modeling 2019; 3-25*
2. *Puonti O, Van Leemput K, Saturnino GB, Siebner HR, Madsen KH, Thielscher A: Accurate and robust whole-head segmentation from magnetic resonance images for individualized head modeling. NeuroImage. 2020; 219:117044*

DO ELECTRIC FIELD SIMULATIONS HAVE ADDED VALUE FOR DETERMINATING TMS COIL POSITIONS AT THE SCALP FOR OPTIMAL TARGETING?

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Transcranial magnetic stimulation has shown promising results in treatment of depression. Personalized stimulation parameters to improve the clinical efficacy of stimulation is a hot topic. Personalized cortical stimulation targets have been proposed, for example based on the functional connections with the deeper subgenual anterior cingulate cortex. In clinical practice, the coil position is a simple projection above this predefined cortical stimulation target. However, individual gyral folding patterns shape the distribution of the TMS induced electric fields within the brain and hence the projection method might not be optimal to determine the coil position. In line, it has been suggested that electric field simulations can provide added value in determination of the ideal TMS coil position at the scalp (Klooster et al. 2021). However, this has not been investigated in detail.

In this study, we will investigate if the use of electric field simulations can lead to more accurate TMS targeting using data from the human connectome project. A priori knowledge will be used to define the cortical target (MNI - 38, 44, 26 (Fox et al. 2021) mapped to the individual T1-w MRI files). The coil position on the scalp is determined using the projection method. Subsequently, the TMS induced electric field distributions were computed using SimNIBS (Thielscher et al. 2015).

The region of the brain assumed to be affected by the stimulation was defined as the brain areas in which the electric field strength exceeded a threshold. This threshold varies between zero and the maximum induced electric field strength. At the conference, we will show an overview of percentage of subjects in which the predefined cortical target area falls within the stimulated region as a function of threshold derived from the electric field strengths, when the projection method is used for coil positioning. If these percentages are small, electric field simulations might be beneficial.

References:

1. *Fox MD, Buckner RL, White MP, Greicius MD, Pascual-Leone A: Biological Psychiatry 2012; 72:595-603*
2. *Klooster DCW, FergusonMA, Boon PAJM, Baeken C: Biological Psychiatry: Cognitive Neuroscience and Neuroimaging 2021. doi:10.1016/j.bpsc.2021.11.004 (epub ahead of print)*
3. *Thielscher A, Antunes A, Saturnino GB: In IEEE Engineering Medical Biology Society 2015; pp. 2-5*

META-ANALYTIC ELECTRIC FIELD MODELING

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In this presentation, I will talk about our efforts in combining electric field modeling with traditional meta-analysis on the effects of tDCS on working memory. Due to differences in electrode montages and stimulation intensities across different studies, results are difficult to aggregate for meta-analytic inferences. To overcome these limitations, we have developed a novel meta-analytic method relating behavioral effect sizes to electric field strength, to identify brain regions underlying the largest tDCS-induced WM improvement. Simulations on 69 studies targeting left prefrontal cortex showed that tDCS electric field strength in lower dorsolateral prefrontal cortex (Brodmann area 45/47) relates most strongly to improved WM performance. This brain region could be a target area for future tDCS studies. Our metanalytic framework can be applied to other stimulation modalities and behavioral measures.

HIGH-PRECISION LANGUAGE MAPPING THROUGH MULTIMODAL fMRI, TMS AND E-FIELD MODELLING

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Introduction: Neurosurgery requires careful planning to minimize damage to eloquent brain areas. Combining Transcranial Magnetic Stimulation (TMS) with frameless stereotactic neuronavigation and MR imaging allows for image-guided stimulation with high precision. While TMS is increasingly used for preoperative mapping of language areas, standard TMS mapping approaches lack the accuracy of direct cortical stimulation. We propose an optimised procedure for language mapping bringing together fMRI, TMS and improved estimation of effective stimulation targets by combining electrical field (E-field) modelling with precision neuronavigation.

Methods: We evaluated our newly developed multimodal precision mapping in a sample of healthy subjects. An fMRI task was administered to functionally localize language eloquent areas in the brain. For each subject, the fMRI data was used to define a language 'hotspot' in the superior temporal gyrus (STG). TMS-bursts of 10 Hz were applied to a circular grid around this hotspot while subjects performed an object naming task. Images were displayed on a screen and TMS bursts were administered after image onset. The E-fields of coil positions that effectively interfered with speech, i.e. resulted in a speech arrest, were calculated using SIMNIBS.