TMS field modelling-status and next steps

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In the recent years, an increasing number of studies used geometrically accurate head models and finite element (FEM) or finite difference methods (FDM) to estimate the electric field induced by non-invasive neurostimulation techniques such as transcranial magnetic stimulation (TMS) or transcranial weak current stimulation (tCS; e.g., Datta et al., 2010; Thielischer et al., 2011). A general outcome was that the field estimates based on these more realistic models differ substantially from the results obtained with simpler head models. This suggests that the former models are indeed needed to realistically capture the field distribution in the brain. However, it is unclear how accurate even these more advanced models are and, in particular, to what extent they allow predicting the physiological outcome of stimulation. An experimental validation of the novel methods for field calculation is thus necessary.

Focusing on motor cortex stimulation by TMS, our goal is to explore to which extent the field estimates based on advanced models correlate with the physiological stimulation effects. For example, we aim at testing whether interindividual differences in the field estimates are also reflected in differences in the MEP responses. This would indicate that the field calculations accurately capture the impact of individual macroanatomical features of the head and brain on the induced field distribution, in turn strongly supporting their plausibility.

Our approach is based on the SimNIBS software pipeline (www.simnibs.de) that allows for the automatic creation of accurate head models from structural and diffusion-weighted magnetic resonance images (MRI) (Windhoff et al., 2011). This enables us to perform field calculations for multiple subjects, as required in neuroscientific studies. We substantially improved the software in order to improve its usability in a group analysis. At the moment, we are performing field calculations and are acquiring motor mapping data in a group of subjects for a systematic comparison of both data sets.

I will give an overview on the status of the SimNIBS project. I will start by summarizing the key findings on how the individual brain anatomy shapes the electric field induced by TMS (Thielischer et al., 2011; Opitz, 2011). The putative link between the modeling results and basic physiological TMS effects is highlighted. I will then introduce the novel features of SimNIBS that include the import of coil positions from neuronavigation systems, improved support for diffusion-weighted MRI and transformation of the estimated fields into MNI space for group analysis. Preliminary results on the comparison between field estimates and motor mapping data will be presented.

To summarize, field estimates based on accurate head models have already proven highly useful for a better understanding of the biophysics of non-invasive brain stimulation. The improved software tools now allow for systematic tests of the links between the estimated fields and the physiological effects in multi-subject studies. This will give the knowledge needed, e.g., for a more accurate spatial targeting of specific brain areas by TMS.

References

