FS4E.5

RETROSPECTIVE AND PROSPECTIVE MODELLING OF ELECTRICAL FIELD TO INDIVIDUALIZE TDCS DOSE: NEUROPHYSIOLOGICAL EVIDENCE FROM TMS-EEG

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Symposium title
Tailoring tES: innovative strategies for protocol individualization to enhance neuromodulation outcomes

Abstract
Inconsistent outcomes hinder tDCS efficacy across studies, as the within-study share of non-responders can reach over 50% of the experimental sample. This variability partly stems from brain and head morphological differences, altering Electrical Field (EF) distribution and inconsistently stimulating brain regions. This holds for our previous studies assessing anodal and cathodal tDCS neurophysiological effects through TMS-EEG recordings on healthy participants.
Here, we aimed to retrospectively and prospectively examine EF variability and its impact on individuals' neurophysiological responses to tDCS.
First, I will re-visit data from our previous studies (Romero Lauro et al., 2014; Varoli et al., 2018) where participants underwent 15minutes of anodal or cathodal stimulation of the right PPC. Neurophysiological response to tDCS was assessed through pre and post-tDCS TMS-EEG recordings by computing TMS-Evoked Potentials (TEPs). We computed the % of TEPs increase from pre to post-tDCS recordings as an index of individual responsivity to the applied protocol. Then, we created a high-resolution EF model for each participant. EF distributions over the cortex were quantified and used to cluster participants according to their EF intensity and neuromodulation on TEP amplitude. Responders and non-responders were identified, anatomically characterized, and we estimated an EF cutoff value between groups at the cortical hotspot.
Secondly, I will present how this computational approach is being applied prospectively in an individualized tDCS protocol to estimate the needed stimulator output to reach the critical EF cutoff value at the cortical hotspot. The computational modeling pipeline and the experimental protocol will be illustrated as well as preliminary TMS-EEG data.
Taken together, our results consolidate the evidence of the impact of dose on the neurophysiological modulations induced by the electrical stimulation, suggesting that tailored protocols based on individual anatomy may enhance the consistency and reliability of tDCS effects across and within studies.
Research Category and Technology and Methods
Basic Research: 9. Transcranial Direct Current Stimulation (tDCS)
Keywords
tDCS, TMS-EEG, Computational Modelling, Individualization

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A COMPUTATIONAL APPROACH TO TUNE TDCS STIMULATION INTENSITY BASED ON ANATOMICAL FEATURES

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Symposium title
Tailoring tES: innovative strategies for protocol individualization to enhance neuromodulation outcomes

Abstract
Transcranial direct current stimulation (tDCS) is a promising tool for treating neurological and psychological disorders, but its effectiveness is limited by inter-subject variability in aftereffects. Traditional fixed-dose approaches indeed do not account for differences in anthropometric characteristics, age, and gender, leading to inconsistent outcomes.
This study explores the potential of incorporating anatomical characteristics—such as cerebrospinal fluid (CSF) volume, skull thickness, and the proportions of white and grey matter—into a personalized dosing approach to enhance cortical excitability during tDCS sessions.
A computational method was used to estimate the electric field distribution across the brain tissues of 23 head models derived from MRI scans. The results demonstrated a strong and significant correlation ($p<0.05$) between the peak electric field and several of the aforementioned anatomical factors, underscoring the importance of considering these variables to reduce variability in electric field distribution. Furthermore, the findings indicate that the spread of the electric field is a critical factor influencing cortical excitability, here evaluated in terms of TMS evoked potentials (TEPs).
Ultimately, the study proposes multiple regression models as a valuable tool for individually targeting cortical regions, predicting subject responsiveness, and adjusting stimulation intensity based on anatomical features, thereby individualizing tDCS protocols and reducing variability in tDCS after-effects.
Research Category and Technology and Methods
Clinical Research: 9. Transcranial Direct Current Stimulation (tDCS)
Keywords
tDCS, Computational modeling, dose individualization, neuromodulation

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ANATOMY-DRIVEN VARIABILITY IN TDCS: EFFECTS OF INDIVIDUAL ELECTRIC FIELDS ON MOTOR CORTICAL EXCITABILITY

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Symposium title
Tailoring tES: innovative strategies for protocol individualization to enhance neuromodulation outcomes

Abstract
The outcomes of transcranial direct current stimulation (tDCS) are highly variable between individuals, which poses a challenge for its clinical application and interpretation of research findings. In the research settings, tDCS variability has been investigated in the motor cortex, by observing the sizes of motor evoked potential (MEP) signals. Both computational and experimental work have sought to find the underlying causes of the variability, investigating the effects of individual anatomical differences and the resulting electric fields in the brain.
Computational models have demonstrated that individual differences in head and brain anatomy, such as cerebrospinal fluid thickness, significantly influence the distribution and strength of the electric fields during tDCS. For instance, thicker cerebrospinal fluid reduces the electric field strength in the motor cortex, leading to variability in the tDCS dose across individuals. The electric field variability is also affected by the electrode montage. High definition (HD) tDCS montages increase the focality of stimulation but can increase inter-individual variability due to anatomical differences. Large variability in the modeled electric fields suggests that personalized approaches may be required to reduce variability and improve tDCS efficacy.
However, attempts to correlate the modeled electric fields with physiological outcomes, such as changes in MEP sizes, have provided mixed results. The overall effects of tDCS are influenced by a combination of individual-specific factors beyond the electric field alone and the sensitivity of the brain to the electric field may vary between individuals. Therefore, despite robust effects observed in modeling studies, the value of electric field modeling on predicting tDCS effects in a new subject or patient may still be limited. This talk will review our latest research on connecting electric field variability to MEP variability, with focus on limitations, open issues, and needs for further research.
Research Category and Technology and Methods
Basic Research: 9. Transcranial Direct Current Stimulation (tDCS)
Keywords
tDCS, Motor Evoked Potentials, Electic Field, Individual Variability

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