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Modelling of electric field distribution of transcranial magnetic stimulation

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non invasive neurostimulation therapies

Background

Transcranial magnetic stimulation (TMS) is a non-invasive form of brain stimulation used for the treatment of a variety of psychiatric and neurological conditions. An electromagnetic coil is placed on the participant's head and current flow through the coil creates a changing magnetic field. This induces an electric field in the conductive brain tissue, influencing the membrane potential of the neurons in the cortex and modulating the neural activity in those brain regions[1].

Due to the high focality of the magnetic fields, the placement of the coil is vital to targeting the desired brain regions. However, the coil is not radially symmetric and so not only the location but also the orientation of the coil influences the induced electric field[2]. This project explored the effect of varied coil orientation and individual anatomical variation on the electric field distribution.

Methods

The modeling software "SimNIBS" (Simulation of Non-Invasive Brain Stimulation)[3] was used to create individualized head models and simulate the electric field of TMS coil placements. For each participant, 4 simulations with constant coil location but varying orientation were completed.

First, the processing pipeline "headreco" was used to segment and reconstruct individualized FEM head models[4] of 5 research participants in a previous study on Treatment Resistant Major Depressive Disorder. This was completed using their anatomical MR images (T1 and T2 weighted). For each TMS simulation, the coil center was then placed over a parietal lobe target with MNI coordinates of [47, -68, 36]. It was repeated for 4 different coil orientation (45-degree steps). Due to the symmetry of the electric field, only angles on one half of a full circle were simulated. All other parameters were kept constant between simulations.

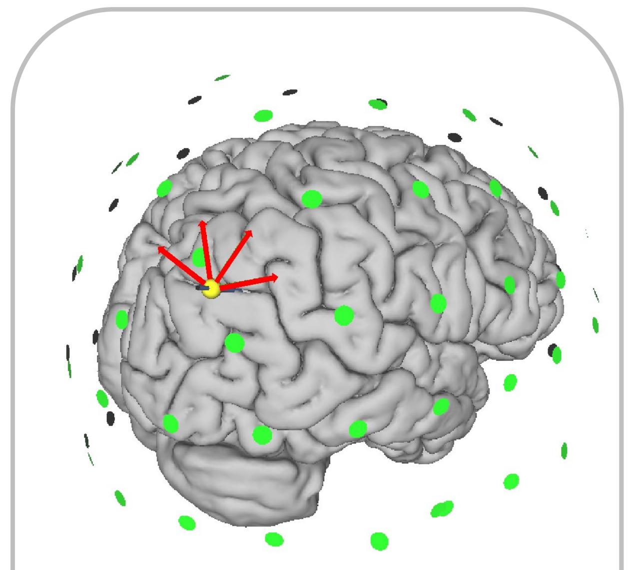

Fig 1. Demonstration of the coil orientations. The yellow sphere indicates the center of the coil, and the red arrows indicate the 4 different coil directions that were simulated for each participant.

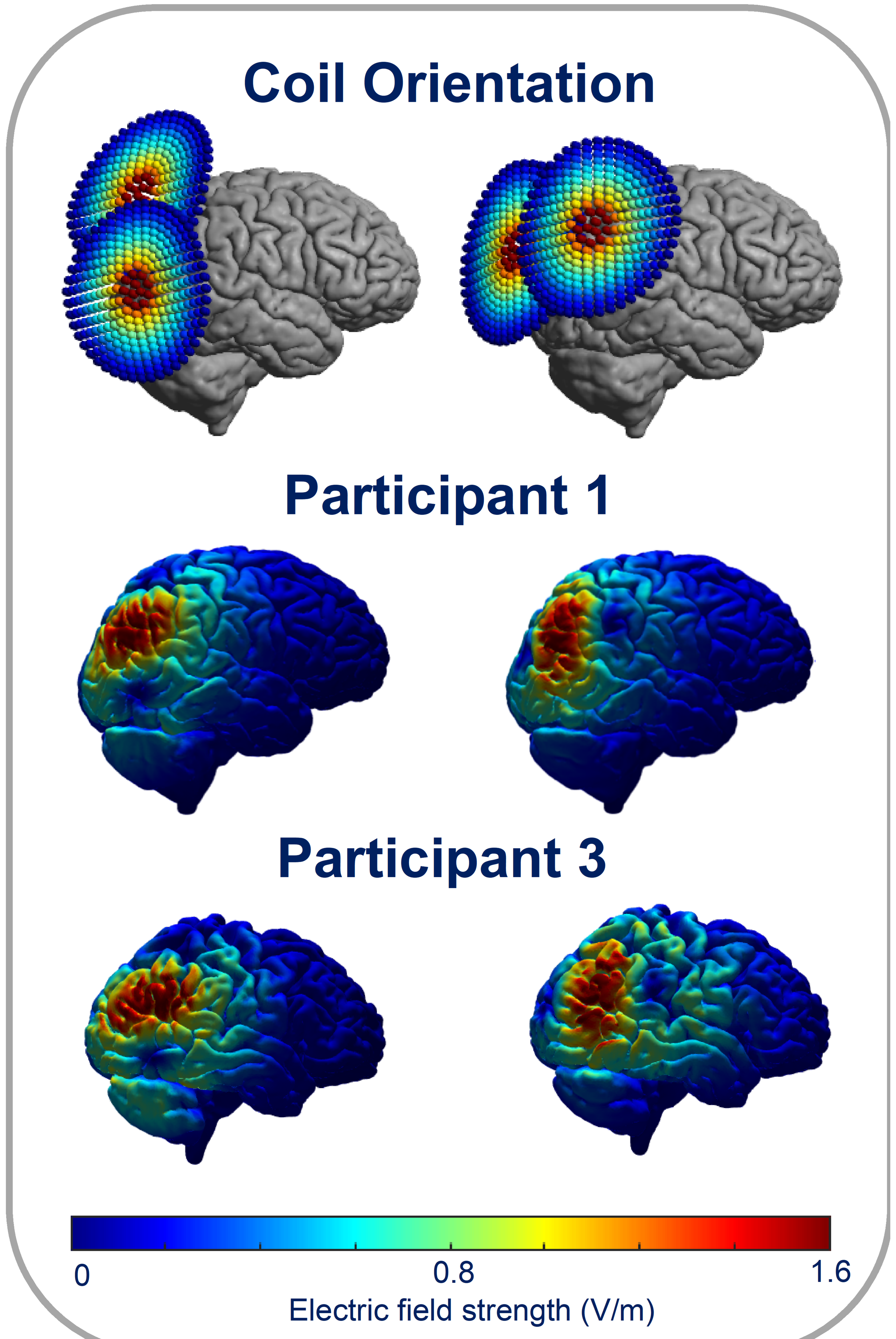

Fig 2. Example coil orientations and their electric field distributions. The first row demonstrates two of the coil orientations (A and C), with the coloured spheres indicating the magnetic dipoles used to represent the TMS coil. The next two rows illustrate the magnitude of the induced electric field in the gray matter head meshes of two different participants.

Results

For each simulation, the magnitude of the electric field in the gray matter was examined. To explore the effects of coil orientation on the targeted brain region, the spherical volume with a radius of 5mm around the target coordinates was analyzed. The mean value and standard deviation for each participant (ID 1-5) and coil orientation (A-D) are shown in the table below.

Mean (SD) magnitude of E-field in 5mm ROI (V/m)

Orientation:	A	B	C	D
ID 1	1.38 (0.22)	1.32 (0.32)	1.27 (0.30)	1.34 (0.20)
ID 2	1.19 (0.19)	1.44 (0.28)	1.47 (0.29)	1.22 (0.22)
ID 3	1.25 (0.34)	1.24 (0.27)	1.29 (0.26)	1.30 (0.34)
ID 4	1.21 (0.25)	1.20 (0.27)	1.22 (0.25)	1.24 (0.22)
ID 5	1.51 (0.22)	1.52 (0.23)	1.52 (0.17)	1.52 (0.15)

These values indicate that although coil orientation influences the electric field magnitude, the individual anatomical variation between individuals appears to be a greater source of e-field variation.

Conclusions

Current clinical targeting methods account for skull size variability however not brain geometry. As this research illustrated, individualized electric field modeling provides the tools to better understand how these anatomical differences affect targeting of TMS treatments. Further research is warranted to explore whether individualized modeling and targeting has an impact on clinical outcomes.

References

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