#2803

Determining the Stimulation Site in TMS: Sensitivities with Respect to Uncertain Model Parameters

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Overview

Background

We proposed a method to determine the cortical site of stimulation by TMS by combining behavioral data with electric field simulations [1]: the congruence factor [2].

Aims

Verify its robustness against uncertain model parameters and measurement uncertainties.

Methods

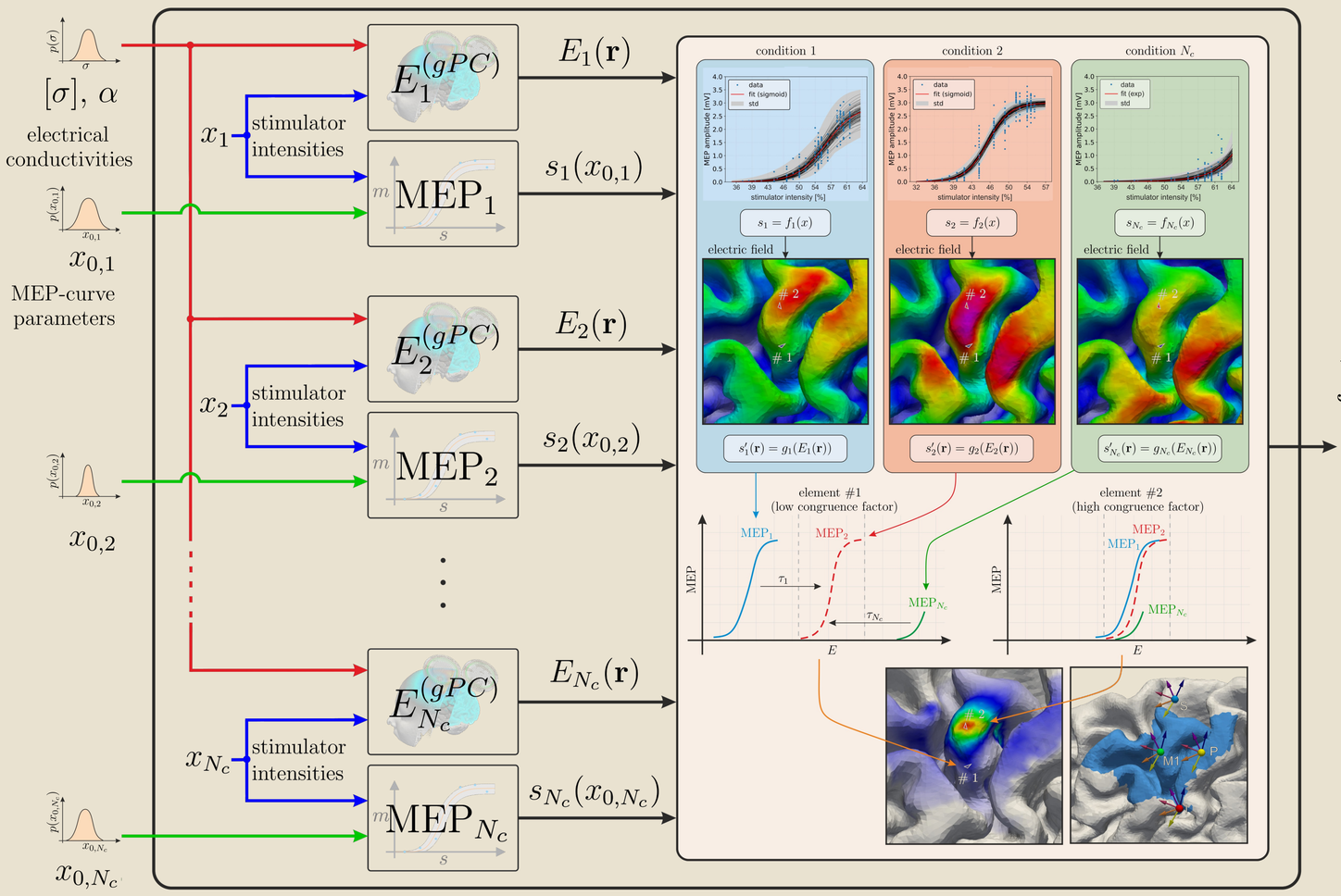
Adaptive generalized polynomial chaos (gPC) [3]:

$$c(r,\xi)=\sum_{\alpha\in A} u_\alpha(r)\,\Psi_\alpha(\xi) \qquad [U]=[\Psi]^{-1}[C]$$

Disentangle the influence of uncertain parameters by Sobol decomposition (ANOVA):

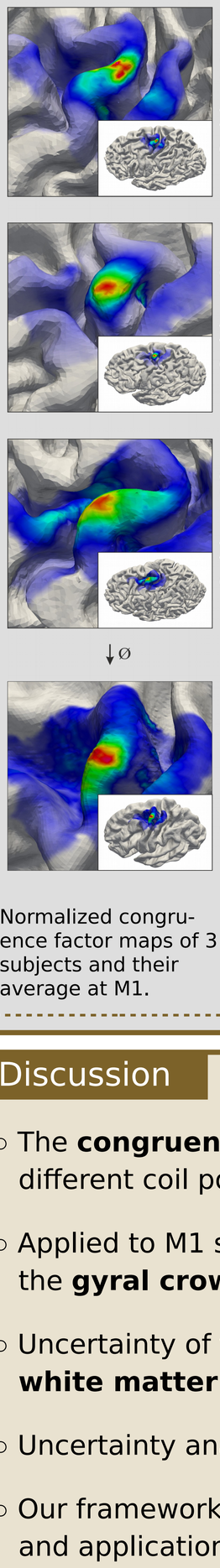
$$S_i(r)=\frac{1}{VAR}\sum_{\alpha\in A_i} u_\alpha^2(r)$$

Here, we applied it to primary motor (M1) stimulation and motor evoked potential (MEP) recordings at FDI.



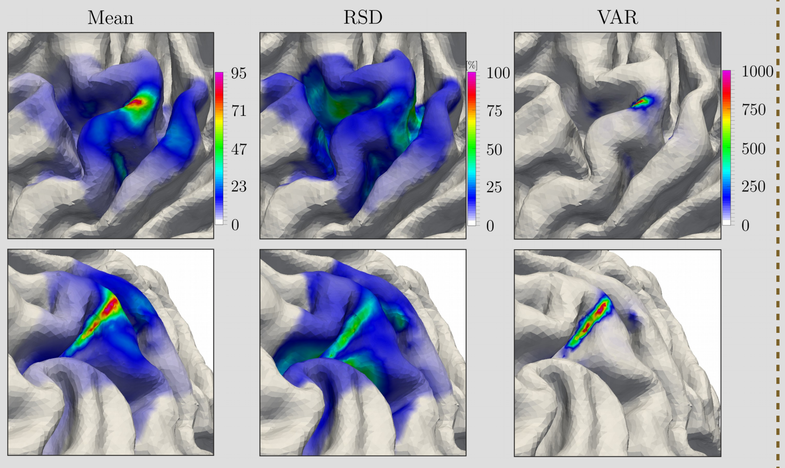
Results

1 Congruence factor



Normalized congruence factor maps of 3 subjects and their average at M1.

2 Statistics



Mean, relative standard deviation (RSD), and variance (VAR) of the congruence factor gPC.

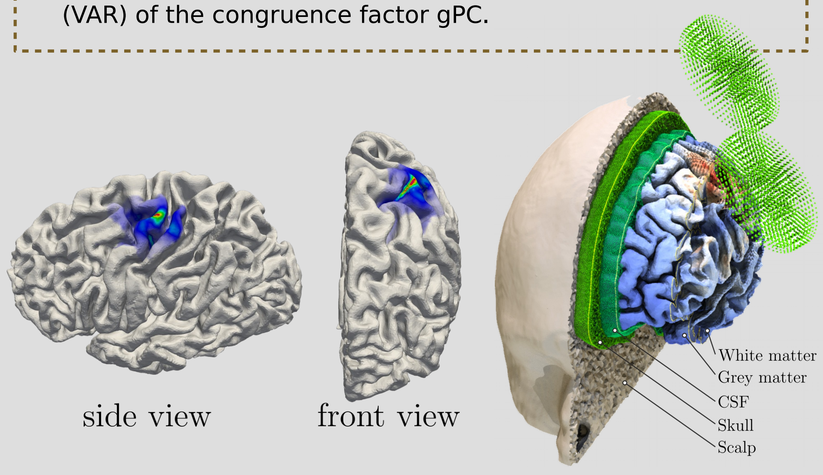
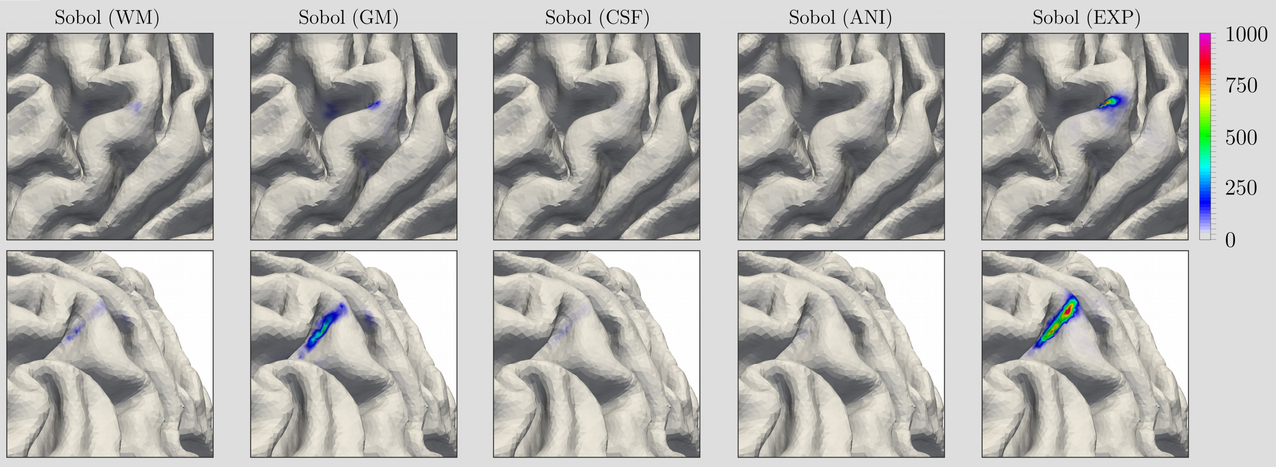


Table 1: Uncertain model parameters.

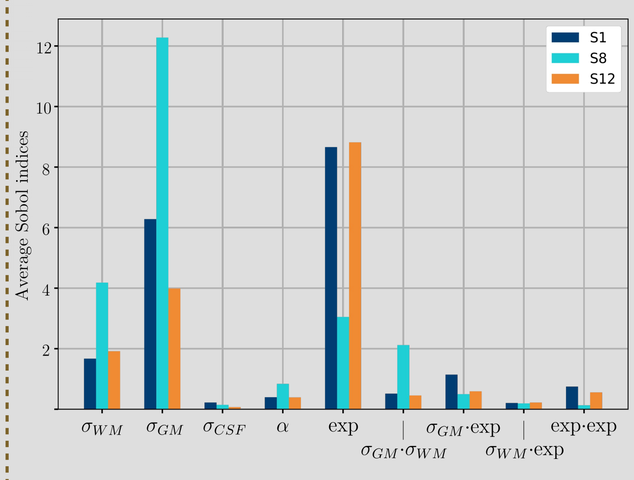
Parameter	Description	Min	Max	p / q
σ_{WM}	White matter (WM)	0.1 S/m	0.4 S/m	3 / 3
σ_{GM}	Grey matter (GM)	0.1 S/m	0.6 S/m	3 / 3
σ_{CSF}	Cerebrospinal fluid (CSF)	1.2 S/m	1.8 S/m	3 / 3
α	Anisotropy scaling	0.4	0.6	3 / 3
Ø(X_0)	6 MEP curves	118.6 A/µs	140.25 A/µs	4 / 4

3 Sensitivity

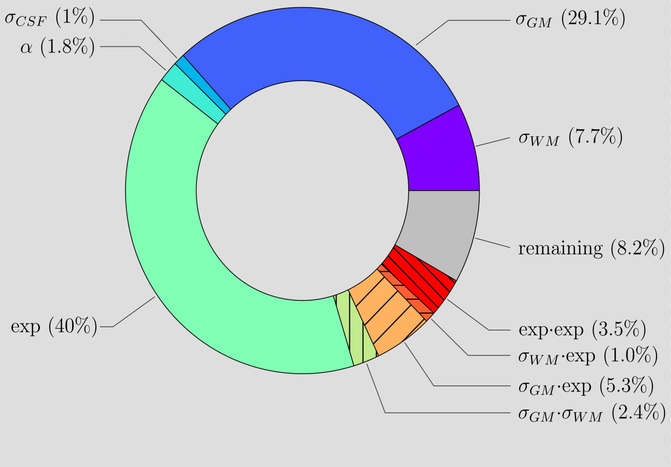


Spatial distributions of the absolute 1st order Sobol indices. Sobol index maps of the individual MEP parameters resulting from uncertainties in the data are summarized into one map "Sobol (EXP)".

4 Average Sobol Indices



Absolute Sobol indices averaged over ROI elements.



Relative Sobol indices averaged over ROI elements.

Discussion

- The **congruence factor** quantifies the interrelation between behavior and electric field over different coil positions and orientations.
- Applied to M1 stimulation, uncertainty and sensitivity analyses confirms **robust hot spots** on the **gyral crowns** extending to sulcal wall rims as supported by other modeling studies [4].
- Uncertainty of the congruence factor is driven by conductivity of **grey matter** (~30%) and **white matter** (~8%), and measured **I/O curves** (~40%).
- Uncertainty analysis confirmed the **absence of further hot spots**.
- Our framework provides a **high level of flexibility** and the possibility to adapt other paradigms and applications such as language mapping.

Our approach robustly localizes the effectively stimulated cortical area by TMS.

References

[1] Thielscher A., et al. (2015). Where does TMS Stimulate the Motor Cortex? Combining Electrophysiological Measurements and Realistic Field Estimates to Reveal the Affected Cortex Position. Conf Proc IEEE Eng Med Biol Soc 222-225.

[2] Weise, K., et al. (2019). A Novel Approach to Localize Cortical TMS Effects. BioRxiv.

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[4] Bungert A., et al. (2017). Where does TMS Stimulate the Motor Cortex? Combining Electrophysiological Measurements and Realistic Field Estimates to Reveal the Affected Cortex Position. Cerebral Cortex 27:5083-5094.

Acknowledgment

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