LIÈGE université
GIGA
CRC In vivo Imaging

“BIDSme, please” +
Electromagnetic head modelling for EEG & tDCS

fnrs
LA LIBERTÉ DE CHERCHER

EOS
THE EXCELLENCE OF SCIENCE

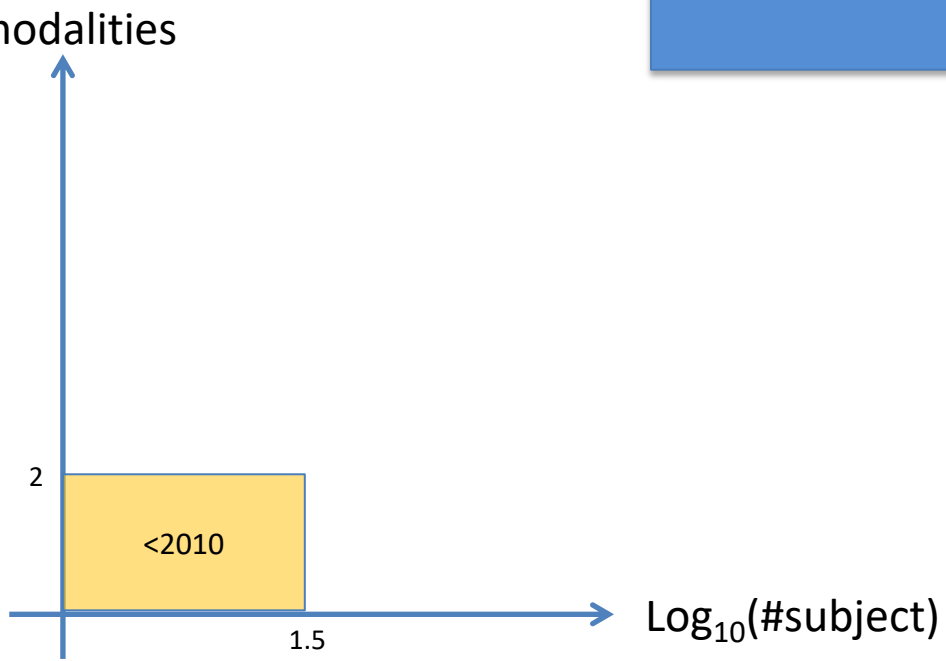
Christophe Phillips
On behalf of Martin Grignard & Nikita Beliy

Data workflow…

Data workflow…

Acquisition:
- #subjects
- #modalities

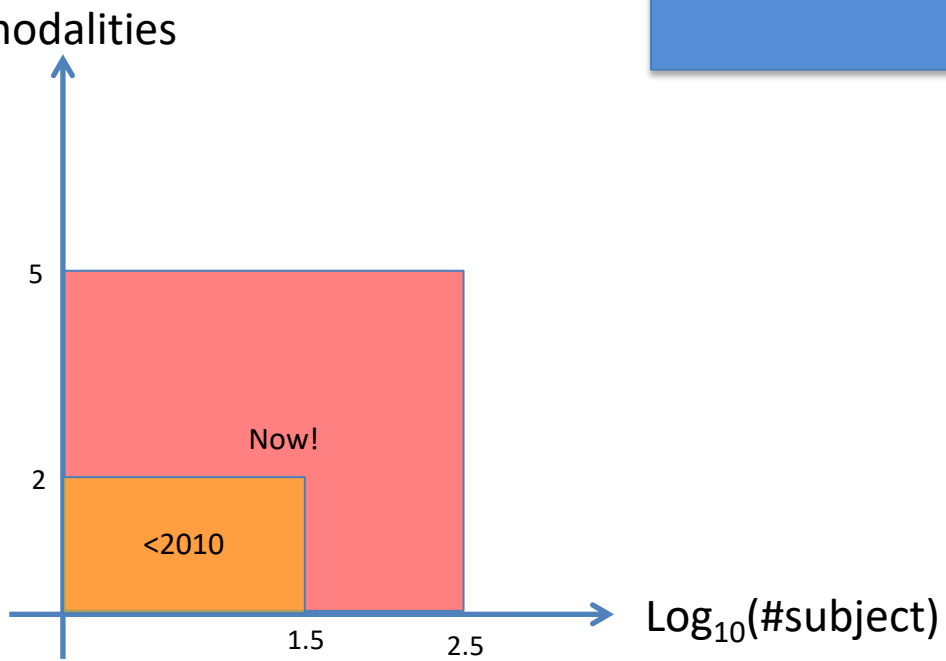
Processing:
- Preprocessing
- Statistical analysis



Data workflow…

Acquisition:
- #subjects
- #modalities

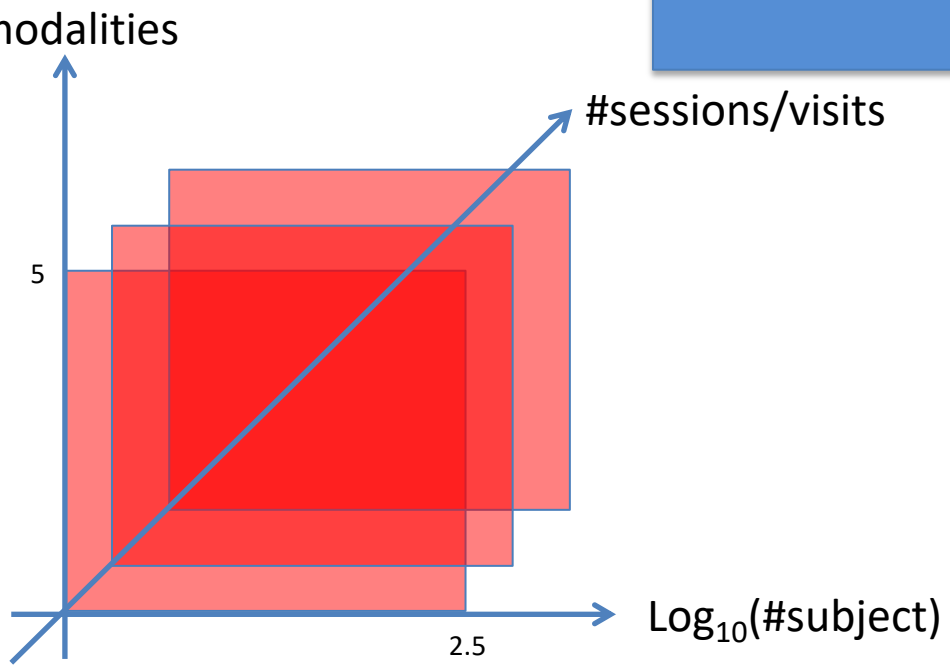
Processing:
- Preprocessing
- Statistical analysis



Data workflow…

Acquisition:
- #subjects
- #modalities
- #sessions/visits

Processing:
- Preprocessing
- Statistical analysis



Data workflow…

"Data complexity" then & now:

- Past "vanilla fMRI & sMRI" : 1.5 x 2 x 1 = 3
- Current "big studies": 2.5 x 5 x 2 = 25

$\Rightarrow$ Multiplied by ~10

"DIY manual" handling of data not possible anymore…

Data workflow…

"Data complexity" then & now:

- Past "vanilla fMRI & sMRI" : 1.5 x 2 x 1 = 3
- Current "big studies": 2.5 x 5 x 2 = 25

⇒ Multiplied by ~10

"DIY manual" handling of data not possible anymore…

Data curation & safe storage are now critical !!!

Brain Imaging Data Structure

- Fixed specific file naming
- Fixed specific file organization in subfolders
- Complete representation of data set, incl.
  - Experimental design & project information
  - Subject specific information, data types & acquisition parameters
  - Raw data, intermediate/derivative & final results + processing information

→ understand the whole experiment & data
→ reprocess the whole dataset
→ reuse/share (part of) the data

https://bids.neuroimaging.io/
Gorgolewski *et al.*, https://doi.org/10.1038/sdata.2016.44

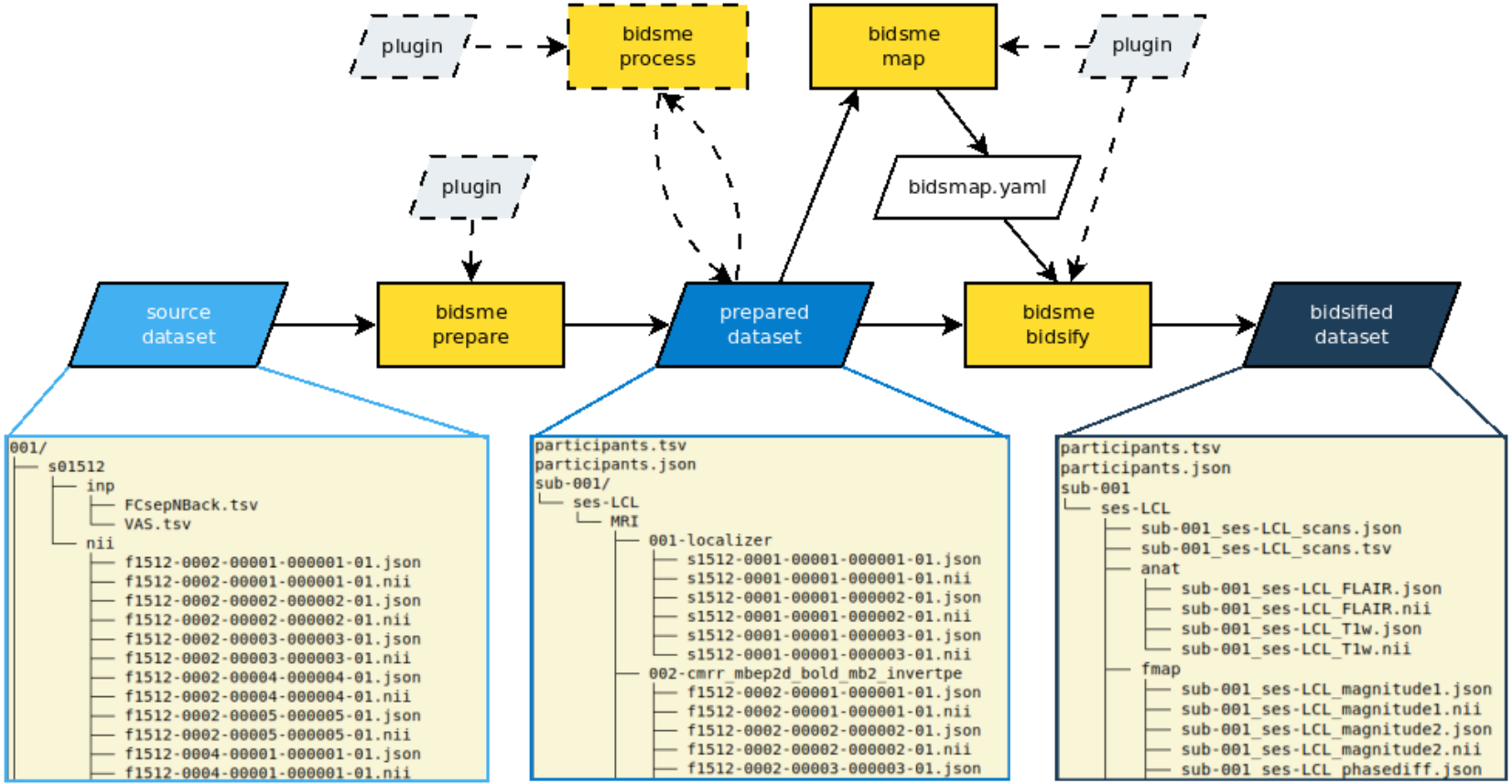
BIDSme to rule them all…

- Python package to BIDSify “any” data type (MRI, EEG, PET,…)
- Fully parameterized through config/schema files
- Supports plugin for data conversion or metadata extraction

0. **map** (once):
   - creates a bidsification schema
1. **prepare**:
   - Put source dataset into standardized folder structure
   - Identifies subjects, sessions, modalities and series
   - (Plugin) Retrieve metadata from exterior sources
2. **process** (optional):
   - Test for various errors and inconsistencies
   - (Plugin) Transform prepared dataset (e.g. 3D to 4D merging)
3. **bidsify**:
   - Bidsifies prepared dataset
   - Manages *participants.tsv* and *scans.tsv*
   - (Plugin) Creates behavioural and derived data

Beliy *et al.*, https://github.com/CyclotronResearchCentre/bidsme

BIDSme to rule them all…



Beliy *et al.*, https://github.com/CyclotronResearchCentre/bidsme

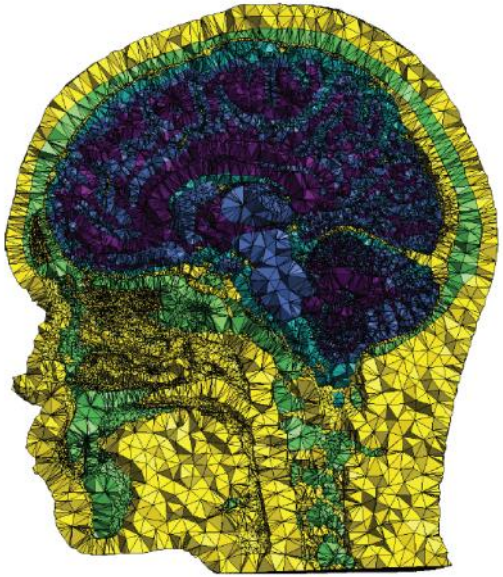
What about the consortium data?

- “The data are available from the corresponding author, upon reasonable request.” ?
- Can we do better?
  - Hosting solutions exist
  - ..need to wrap up curated data
- Any incentive ? More resources (IT & €) available ?

shamo, Stochastic HeAd MOdelling

Calculate forward problem solution for **EEG** and **tDCS**

- build FEM head model(s), based on segmented MRI

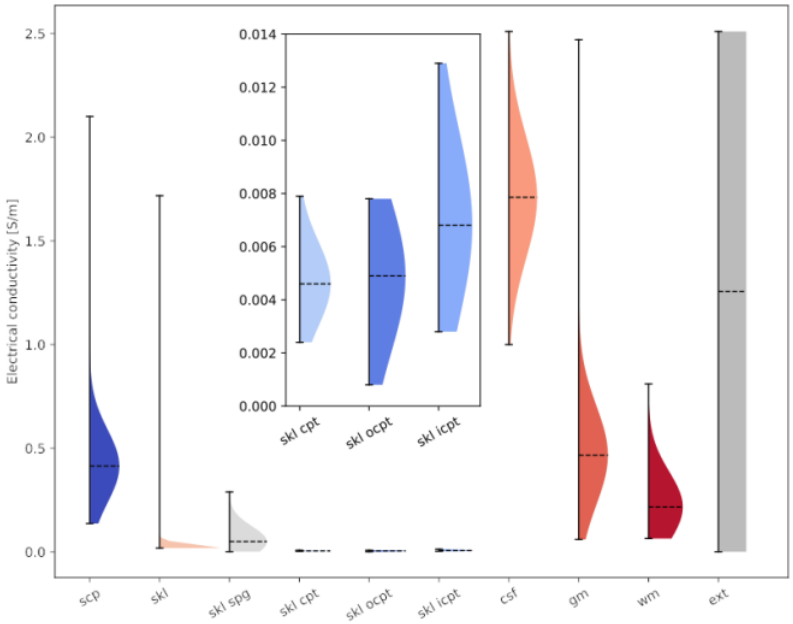


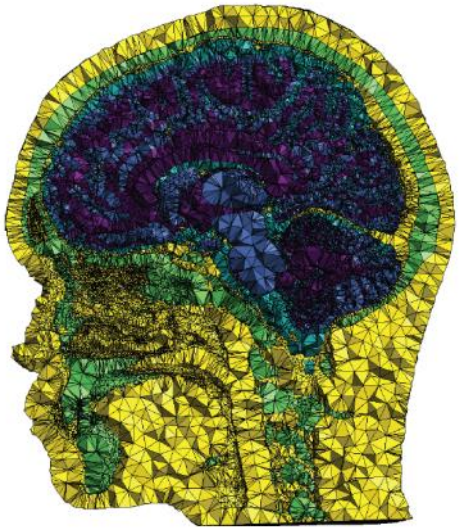
Grignard *et al.*, https://github.com/CyclotronResearchCentre/shamo

shamo, Stochastic HeAd MOdelling

Calculate forward problem solution for **EEG** and **tDCS**

- build FEM head model(s), based on segmented MRI
- tissue conductivity σ? (considered as **stochastic** variable)





Grignard *et al.*, https://github.com/CyclotronResearchCentre/shamo

shamo, Stochastic HeAd MOdelling

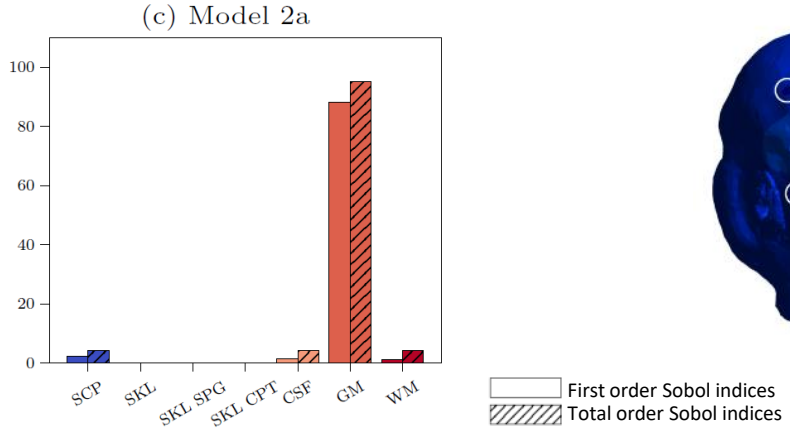
- Use *getDP* to solve the FEM problem, given conductivity values σ
- Build surrogate model to explore the N-D conductivity space.
- Sensitivity analysis with Sobol indices based on scalar $m(\sigma)$

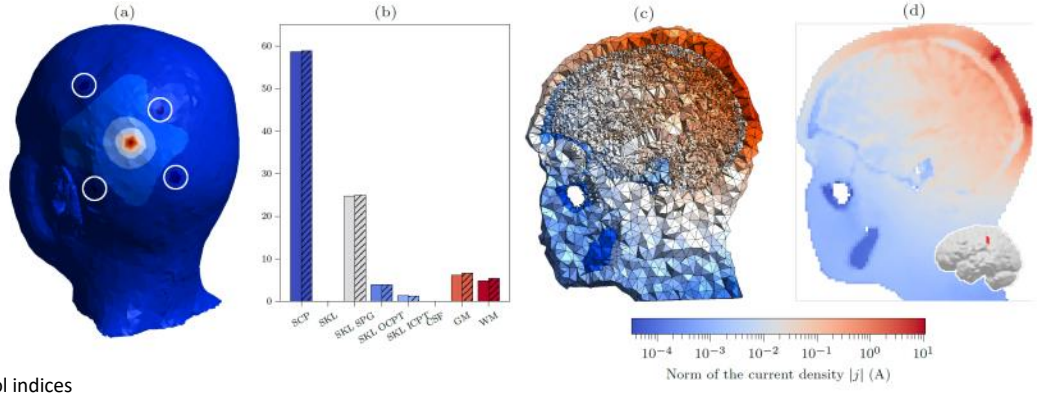
EEG forward solution, sensitivity of the whole leadfield

$$m(\sigma) = \left\| L(\sigma) - L_{\text{ref}} \right\|_F$$

tDCS current density, sensitivity in target region of interest

$$m(\sigma) = \text{mean}(\|j\|_2)_{\text{ROI}}$$





Grignard *et al.*, https://dx.doi.org/10.1007/s12021-022-09574-7

tDCS issues?

Low response rate (~50%) ➔ Potential causes?

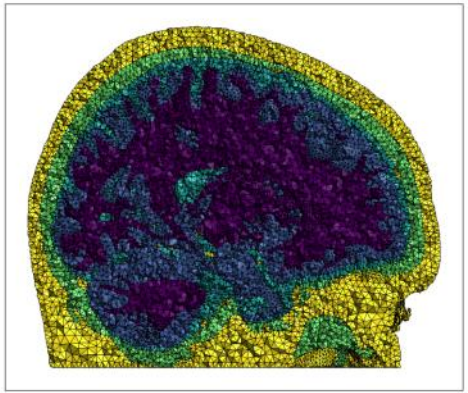
- Subject variability?
  - Function vs. anatomy ? Individual subject's functional organization ?
- Target region actually stimulated?
  - How do we know ? Where does the current flows?
- Head model?
  - subject's anatomy ? Segmentation is not easy…
  - electrodes positioning ? How reliable is the 10-20 system ?
  - **tissue properties ?** Conductivity values and anisotropy ?

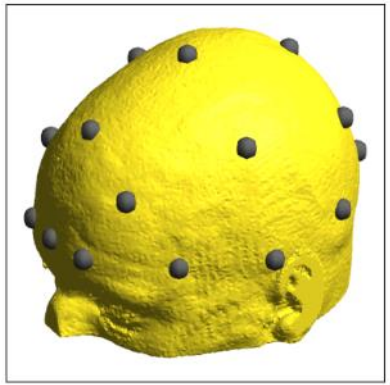
Wiethof *et al.*, https://doi.org/10.1016/j.brs.2014.02.003

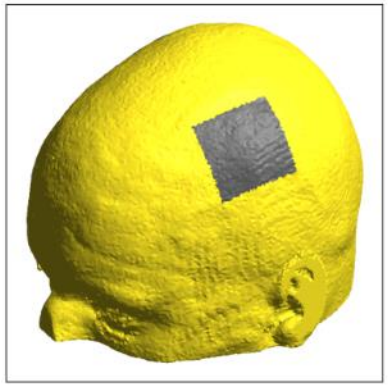
tDCS models

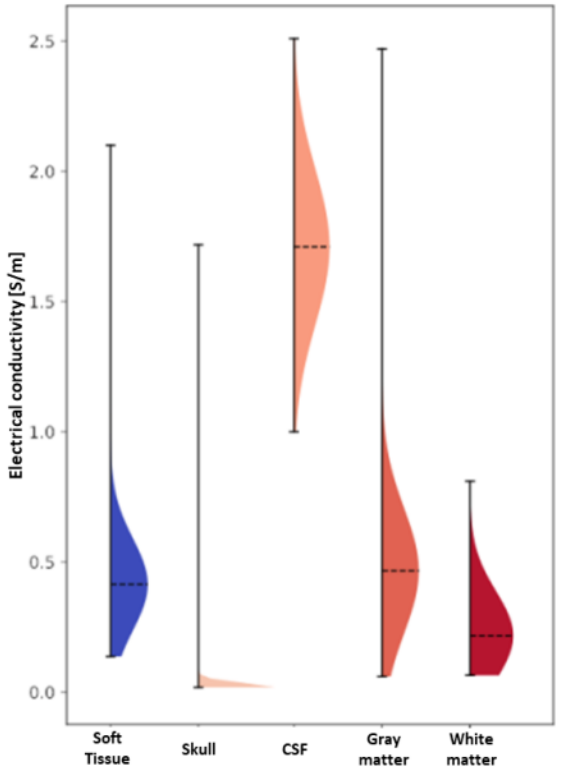
Calculate forward problem solution for **tDCS**

- build FEM head model(s), based on
  - 20 (synthetic) segmented MRI
  - simulated electrode positions
- solve forward problem, based on
  - tissue properties, conductivity value or distribution
  - injected current







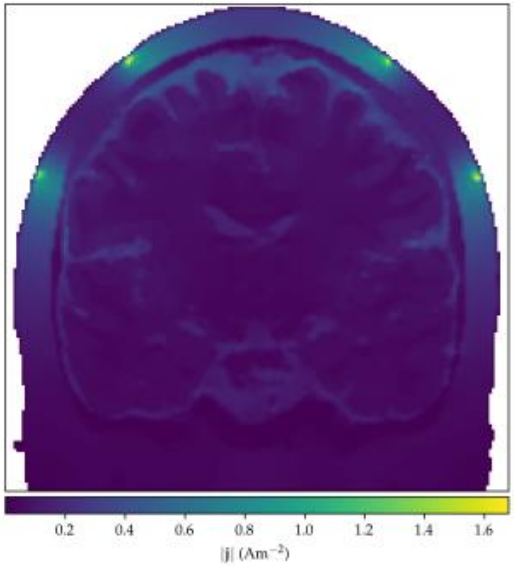


McCann *et al.*, https://doi.org/10.1007/s10548-019-00710-2

Example of simulation

Inject 2 mA at anode,

- "aim" for ROI, e.g. motor cortex with C3-C4 electrode montage
- whole brain current density j (mA/m^2) & electric field e (mV/m)
- Check average absolute values $|e|$ in ROI



Opitz *et al.*, https://doi.org/10.1038/srep31236

Results for 6 simulated montages

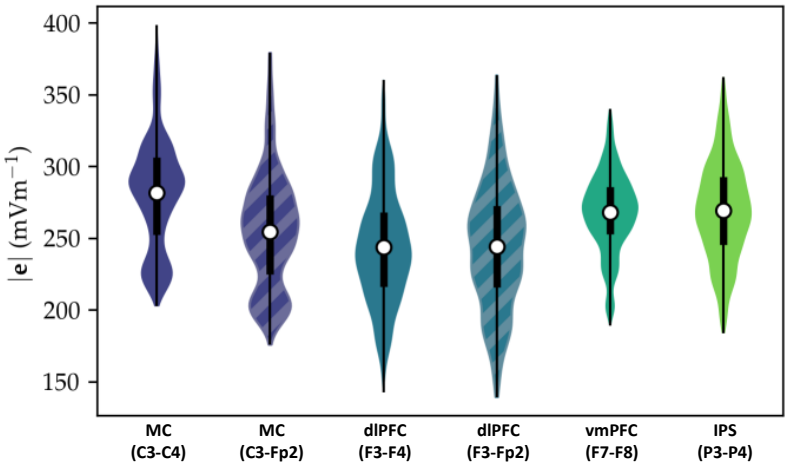
Check source of variability

- "informed" conductivity value distribution
- 20 simulated individuals (slightly different anatomy)
- small electrode position variability

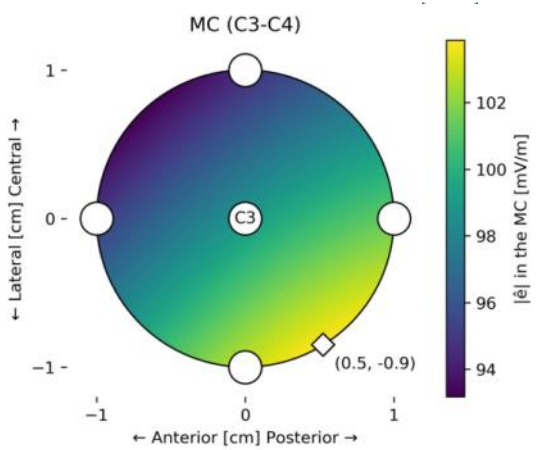
Large range of $|e|$ values!

Note: tDCS effectivity in litterature/models
➔ lower bound ~ 0.5mV/mm = 500mV/m

→ observed values are *"just sufficient to too small!"*



Future…



Optimize individualised setup

- “more accurate” head model
  - anatomy & segmentation,
  - functional localisation
  - tissue anisotropy (from DWI)
- optimize electrode placement & adjust current intensity

- measure (relative) tissue properties, e.g. with “magnetic resonance electric properties tomography” (MR-EPT)

Future…

Acquire preliminary dataset

- full MRI characterization
- precise electrode localization
- standard vs optimized set up
- sham vs active “working memory” stimulation

To be continued…

CRC references

- N. Beliy et al., *BIDSme, a user friendly open-source python toolkit to "bidsify" source-level neuroimaging data-sets to BIDS-conformed*. 2019. https://github.com/CyclotronResearchCentre/bidsme
- N. Beliy et al., *BIDSme,* soon published in "Journal of Open Source Software". 2023(?). https://zenodo.org/records/10185300
- M. Grignard et al., *shamo: A tool for electromagnetic modelling, simulation and sensitivity analysis of the head.* 2021. https://doi.org/10.1007/s12021-022-09574-7 & https://github.com/CyclotronResearchCentre/shamo
- M. Grignard et al., *Why tDCS models cannot be trusted yet? — A simulation study.* 2022. Preprint, https://hdl.handle.net/2268/294662
- M. Sepehr et al., *tDCS optimization, MRI-based (more) precise modelling*. Open dataset + preliminary results, planned for 2024.

LIÈGE université
GIGA

Thank you for your attention!


LIÈGE université
GIGA