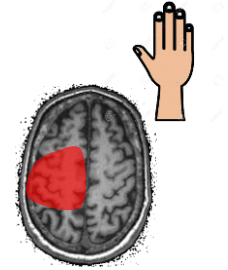


Influence of Morphological and Functional Variability on Surface EEG

Tannaz Mostafid

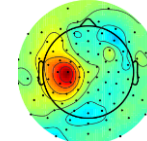
Introduction: Overview

- Performance variabilities in MI-NF and MI-BCI
- Inter-individual anatomical particularities ([Grosse et al., 2013](#))
- MI-NF and MI-BCI approaches based on EEG and ERD
- CSP filters are crucial in using EEG
- Plausible CSP filters enhance individual performances
- No systematic approach for filter selection:
 - Empirically or by heuristic guidelines → Not straightforward!

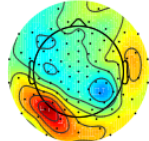


Example of unilateral movement.

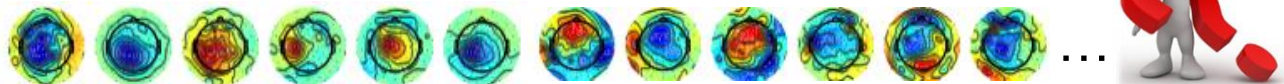
Plausible



Implausible

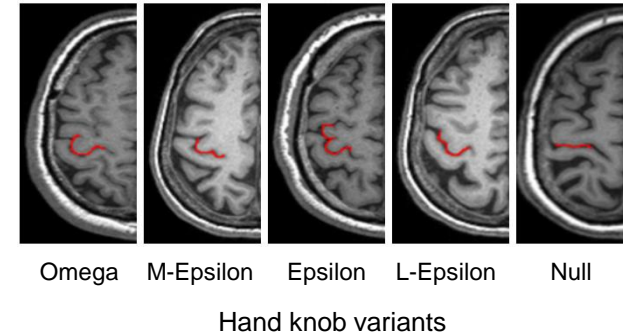
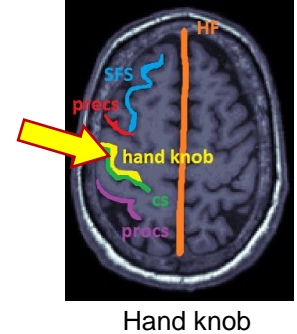


Examples of plausible and implausible CSPs based on Niclas Braun's guideline.



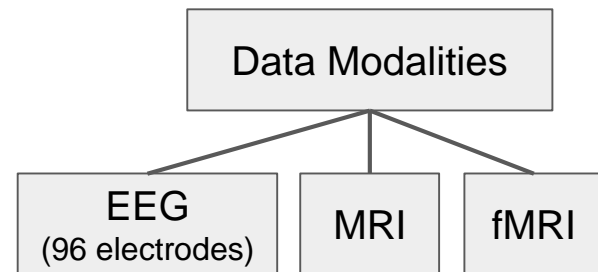
Introduction: Aim of study

- 1) Assess the influences of inter-individual anatomical variabilities on:
 - EEG patterns at the scalp level
 - Selected CSP filters
 - Two CSP selection approaches based on anatomical information
 - Studied anatomical variabilities:
 - Morphological variabilities of hand knob
 - Percentage of hand motor execution lying on gyrus
-
- 2) Exploratory study of the CSP filter plausibility



Methodology: Dataset and Task

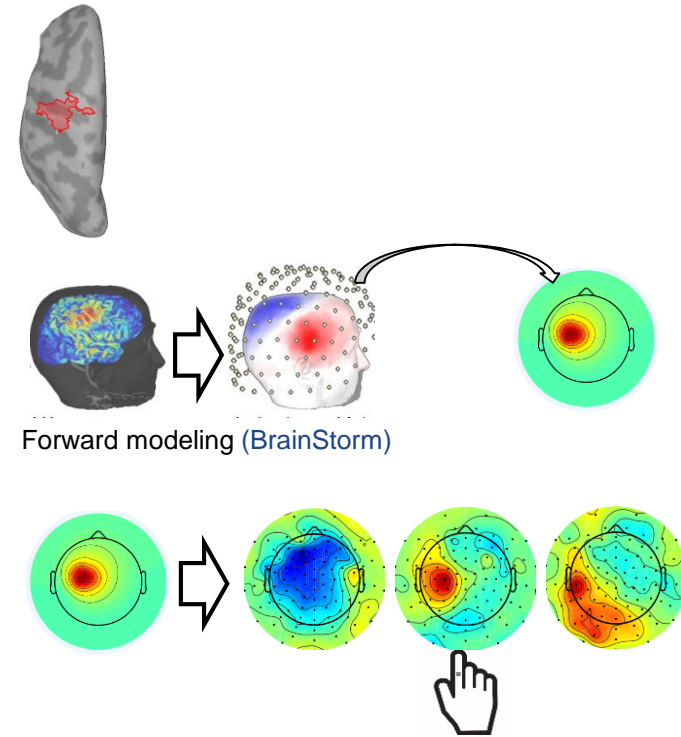
- Re-analyze separately recorded EEG - (f)MRI dataset ([Meekes et al., 2017](#))
- 20 healthy older adults:
 - Mean age 61.4 years (range 48 - 77)
- Hand motor execution task:
 - Closing and opening in pseudo-random order
 - 20 trials per hand:
 - 5-9 s rest; 3 s cue; 5 s execution



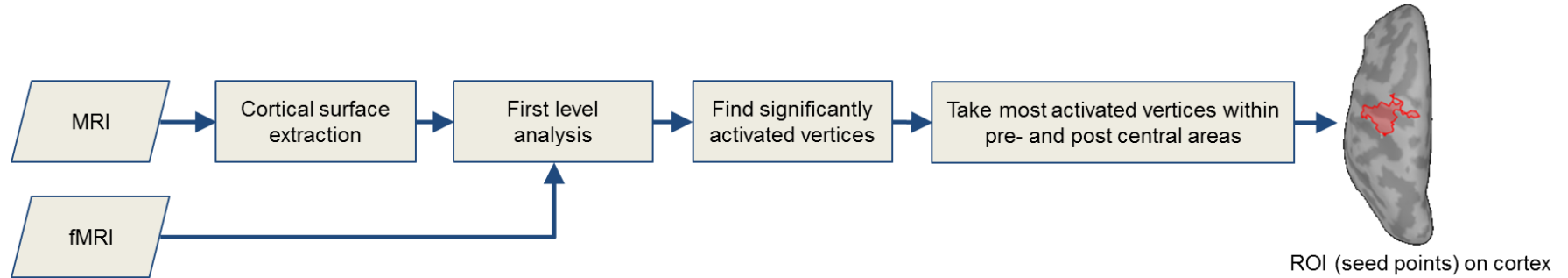
Hand closing and opening, created by Julius Welzel and Mareike Daeglau.

Methodology: Overview

- Define ROI based on individual functional information ..
- Simulate hand motor execution at the scalp level
- Use simulated patterns to select CSPs
- Investigate relationship to the anatomical variabilities

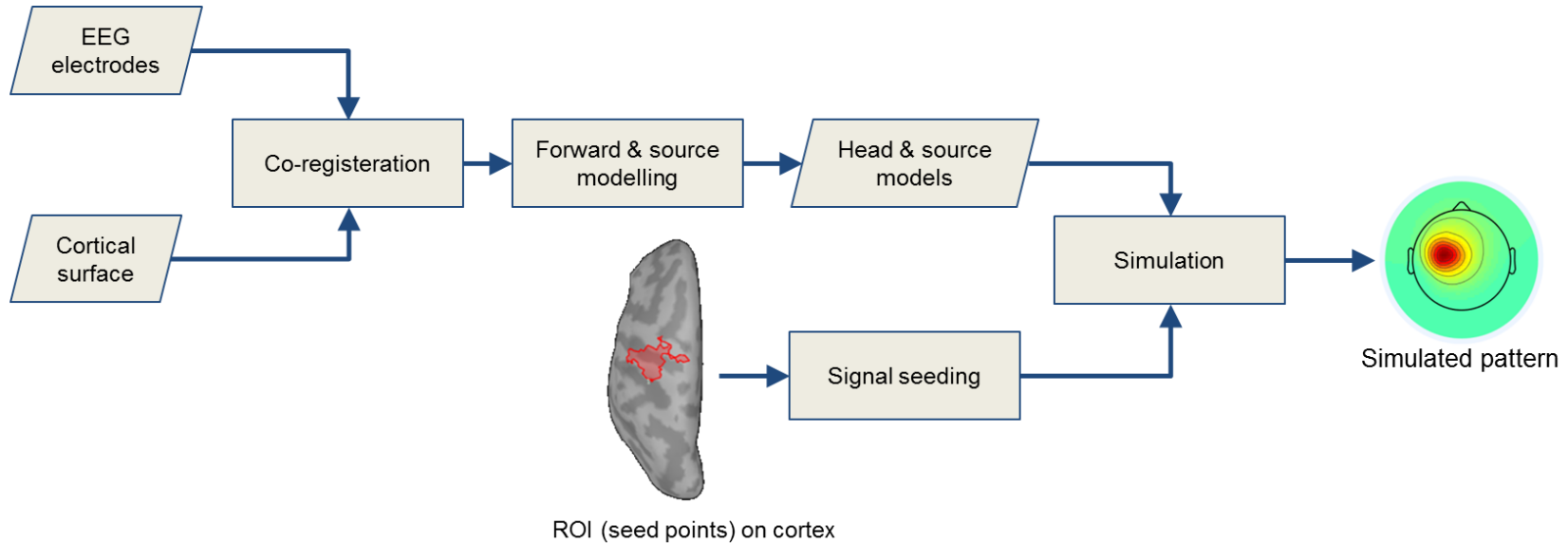


Methodology: Define ROI based on fMRI data



The process chain used for defining ROI (selecting seed points)

Methodology: Simulate EEG patterns



The process chain used for simulating EEG patterns at the scalp level

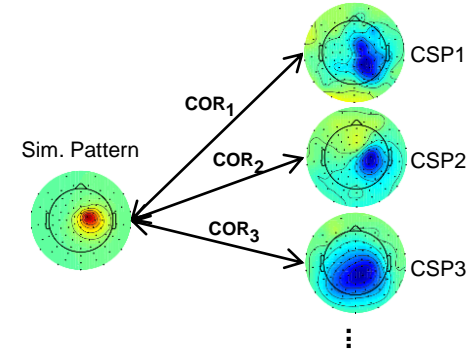
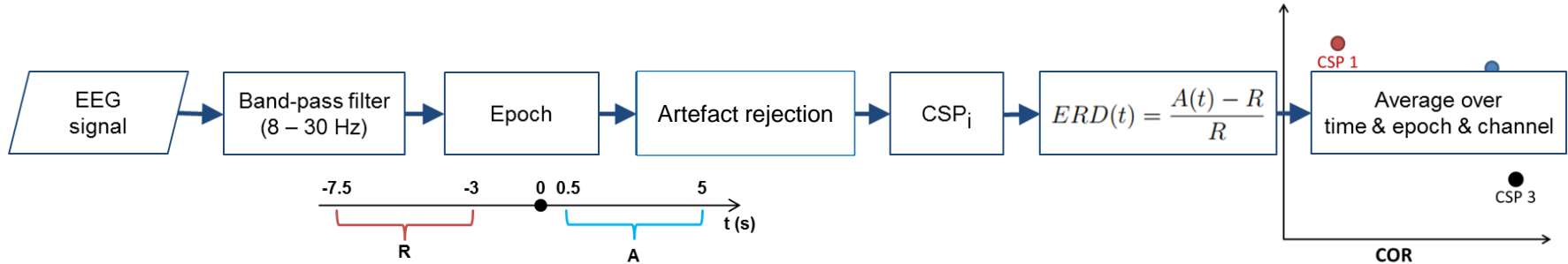
Methodology: CSP selection approaches

1) BCOR: CSP with the largest COR

2) BQS: CSP with **large** COR & **large** ERD → Largest QS

$$QS_i = COR_i * ERD_i; \quad COR_i \in [0, 1], \quad ERD_i \in [0, 1], \quad i = \{1, 2, \dots, 96\}$$

- Compute ERD_i

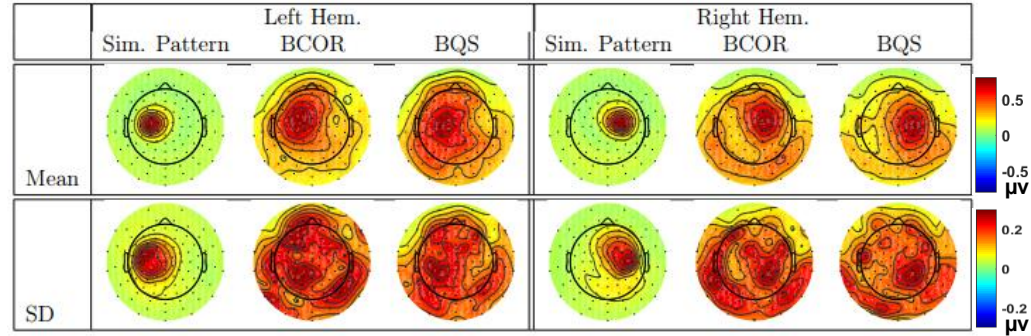


Example of correlations (COR) between simulated pattern and the CSPs of a subject.

Example of how the largest QS looks like.

Results

- Mean and SD summarize the results
- Simulated EEG patterns:
 - Concentrated on sensorimotor area
- Selected CSPs:
 - Represent hand motor activity
 - Largely deviate from the mean



Results: Influence of hand knob variants

- Statistical analysis Omega vs. other hand knob variants
 - Significant difference only for BCOR (right)
 - Effect size (d) < 0.2
- Hand knob variant cannot explain various:
 - Surface pattern are identical
 - Role of hand knob negligible

	Left	Right
Omega	12	14
Others	8	6

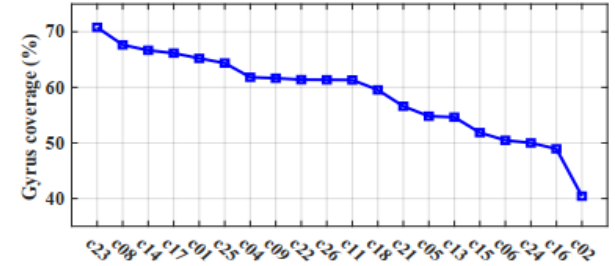
Group sizes.

		Left	Right
Sim. Patterns	Decision	✗	✗
	t -value	0.93	0.38
	P -value	0.35	0.69
	d	0.16	0.08
BCOR	Decision	✗	✓
	t -value	0.82	3.08
	P -value	0.41	0.00
	d	0.13	0.52
BQS	Decision	✗	✗
	t -value	0.36	0.48
	P -value	0.71	0.41
	d	0.05	0.07

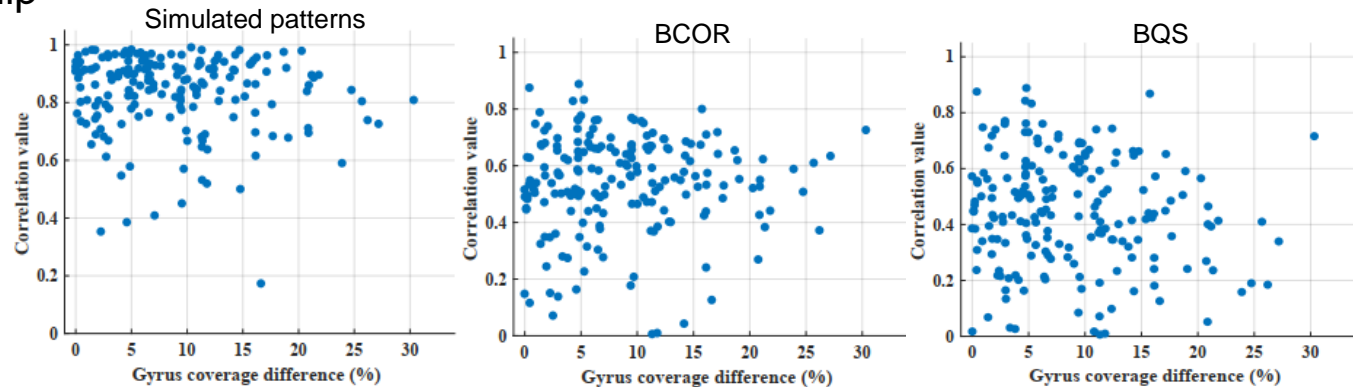
Results of statistical analysis.

Results: Influence of gyral activity

- Order the subjects by percentage of ROIs on gyrus
 - No turning point → cannot group the subjects
- Represent each subject pair by:
 - **Correlation of patterns** and **difference in gyral activity**
- No clear relationship



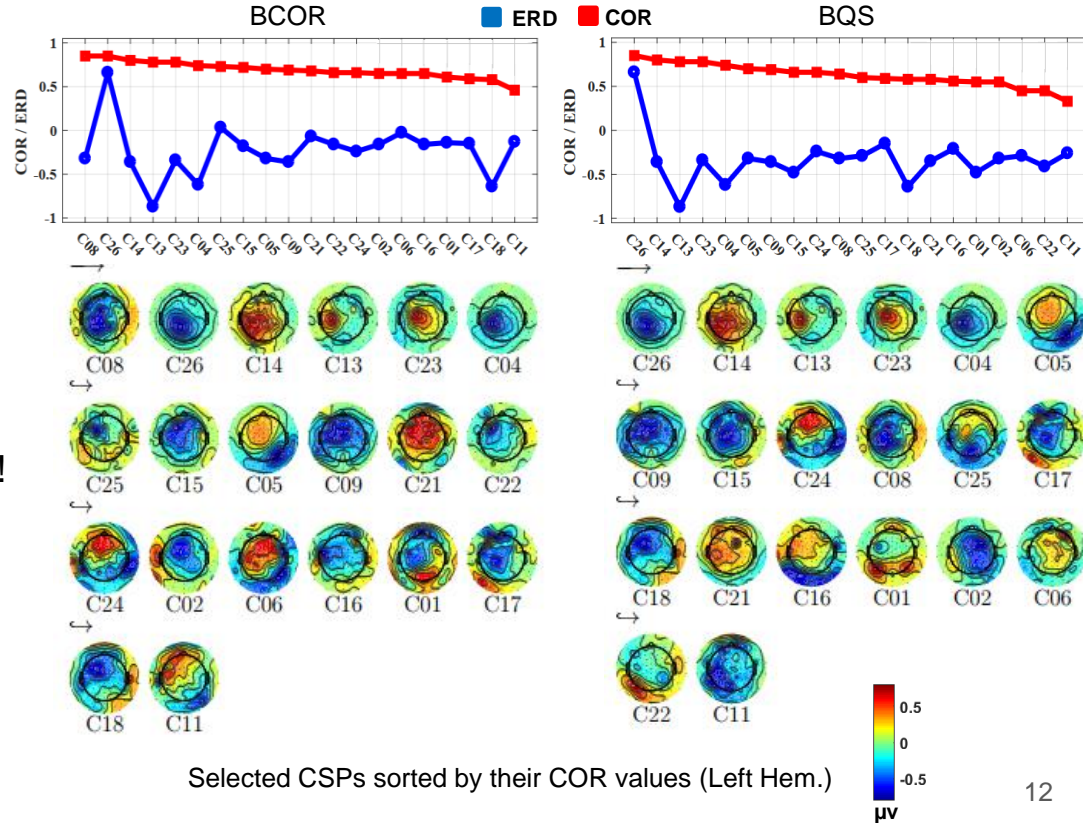
Subject ordering by gyral activities (Left Hem.)



Relationships between correlation of the subject pairs' patterns and the difference between the percentages of their ROI on Gyrus (Left Hem.)











Results: COR, ERD, and Plausibility

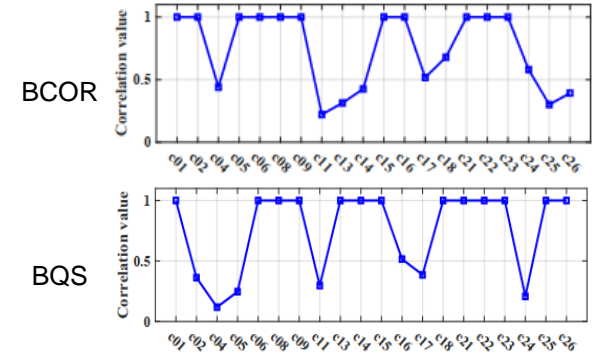
- Sort selected CSPs by COR
- Larger COR → more plausible:
 - **Not** always!
- Larger COR → larger ERD:
 - **Not** always!
- Implausible CSPs → small ERDs:
 - Other way around **does not** hold!
- No consistent relationship:
 - COR, ERD, and plausibility



Results: Average anatomical information for CSP selection

- Large correlation between simulated patterns
- Similar selection by **mean** and **individual** simulated patterns
- Various selection situations:

Situations	Statistics	Examples	
		By Individual	By Mean
Same (plausible)	45%		
Same (implausible)	19%		
Different (implausible by both)	10%		
Different (plausible by mean)	11%		
Different (Plausible by Individual)	15%		



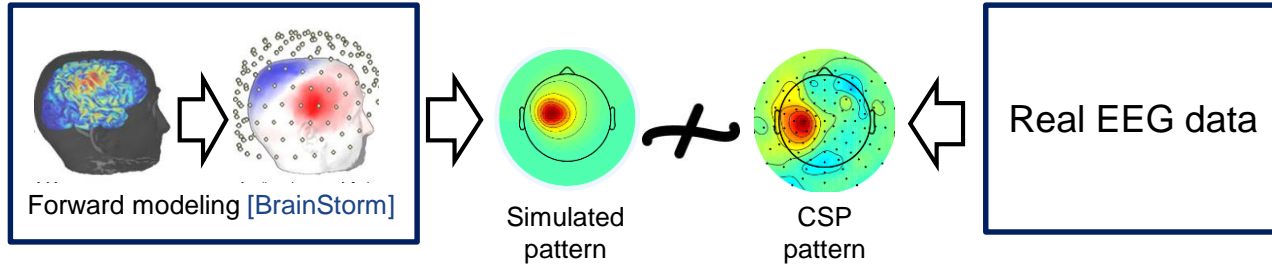
Selected CSPs using mean and individual simulated patterns (Left Hem.)

Discussion: Main hypothesis

- No meaningful relationship between the considered anatomical variabilities and:
 - EEG patterns at the scalp level
 - Selected CSPs

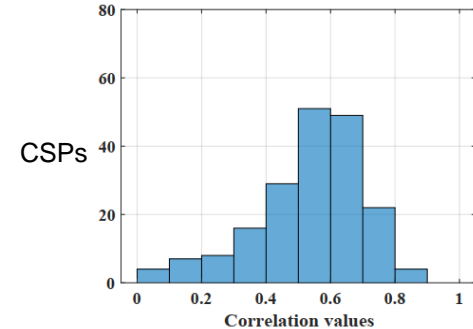
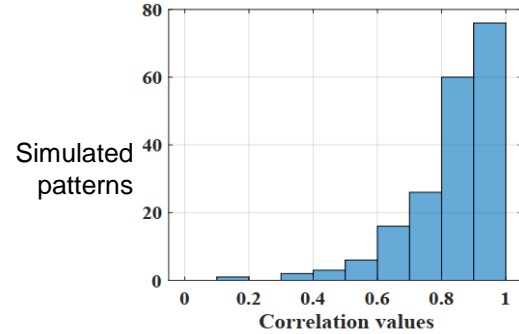
Discussion: Factors influencing the results

- Simulation might be inaccurate:
 - Interpret anatomical variabilities on sensor level



Simulation accuracy:

- Forward modeling errors
- Source modeling errors
- Individual characteristics, e.g., age
- Other (non)cortical activities
- ...



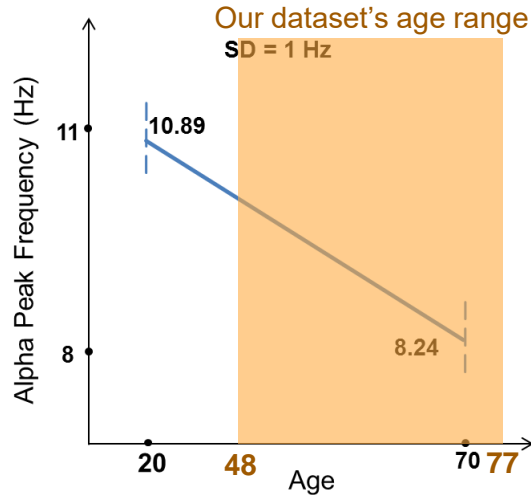
Histograms of the correlations between the subjects' simulated patterns and CSPs (Left Hem.)

Discussion: Factors influencing the results

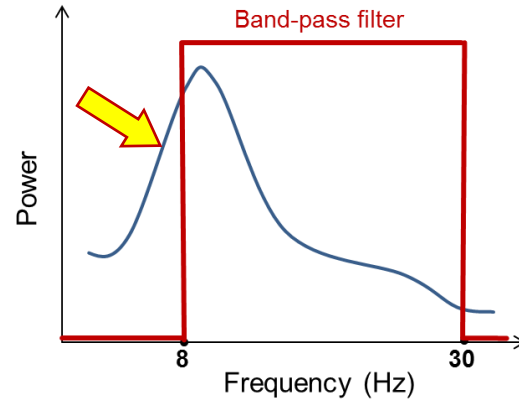
- Separate recording of EEG and fMRI:
 - Different conditions → Different cortical activities
 - Different source location → Inaccurate comparison of simulated patterns to CSPs
 - Remedies:
 - Simultaneous recording ([Huster et al., 2012](#))
 - EEG source localization

Discussion: Factors influencing the results

- Band-pass filter with a fixed frequency window:
 - Remove large portion of alpha power
 - Diversity of the subjects age
 - Influence CSPs and ERDs



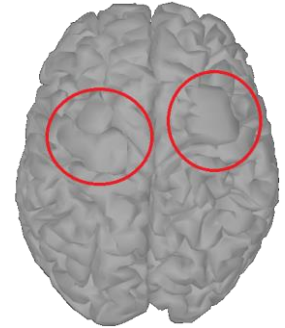
Alpha peak frequency vs. age, based on (Klimesch, 1997).



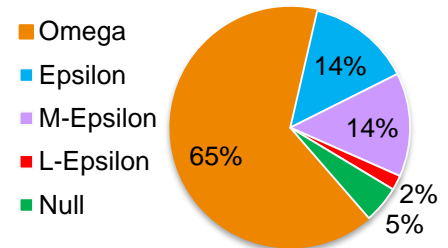
Example of alpha activity and band-pass filter application.

Discussion: Factors influencing the results

- Mean and variance of ages:
 - More widespread and symmetric patterns in older adults ([Kaiser et al., 2011](#))
 - Affect CSPs and ERDs
- Imperfection of extracted cortical surface:
 - Influence the source space and simulation results
 - Displace current dipoles from their true positions
 - Accuracy of forward model → source space
- Unbalance and limited diversity of hand knob variants



Handles and bumps on a cortical surface.



Discussion: Exploring CSP plausibility

- Plausible CSP filters are crucial:
 - Boost lateralization and motor function recovery ([Zich, 2017](#))
- Exploring plausibility of the selected CSPs
- COR and ERD are important for plausibility:
 - Large COR → following simulated patterns
 - Large ERD → strong lateralization
- Importances of COR and ERD vary by:
 - Inter-individual particularities
 - Quality of EEG signals

BCOR	BQS
✓	✓
✗	✓
✓	✗
✗	✗

Different plausibility situations of the selected CSPs by the two approaches.

Discussion: Exploring CSP plausibility

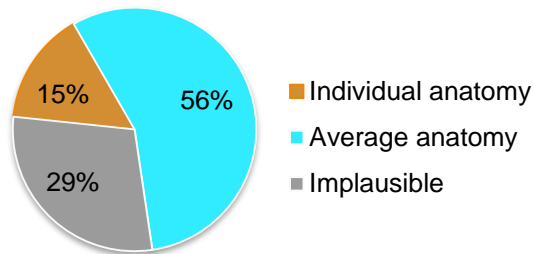
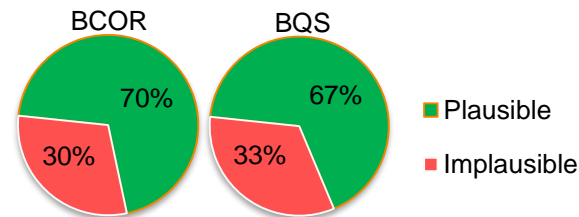
- COR is significant measure of plausibility
- ERD cannot be always relied:
 - Influenced by some factors, e.g.:
 - Irrelevant activities suppressing mu rhythm
 - Inter-individuals differences in resting state SMR ([Blankertz et al., 2010](#))

Summary

- Hypothesis: Anatomical variabilities help explaining the variabilities of:
 - EEG patterns at the scalp level
 - CSP patterns
- Select ROI
- Simulate cortical activities
- Select CSPs based on simulated patterns
- Explore the plausibility of the selected CSPs
- Select CSPs by average anatomical information

Conclusion

- No correspondence between anatomical variabilities and:
 - EEG patterns
 - Selected CSPs
- Plausible CSPs by BCOR and BQS:
- COR and ERD:
 - Important for plausible CSPs
 - Vary by inter-individual particularities and EEG signal
- Implausible CSPs come with poor ERD
- Plausible CSP selection:



References

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- Blankertz, B., et al. (2010). Neurophysiological predictor of SMR-based BCI performance. *Neuroimage*, 51(4):1303-1309.
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- Zich, C. (2017). Characterizing signatures of motor imagery in younger and older adults using multimodal neuroimaging. PhD thesis, Carl von Ossietzky Universität Oldenburg.

Thank you for your attention!