Visualising a multi-modal neuroimaging dataset

Robin De Haes, Wolf De Wulf, Alexis Verdoodt

May 28, 2022

VRIJE
UNIVERSITEIT
BRUSSEL

DATA FROM THE CENTRAL NERVOUS SYSTEM (CNS)

- Electroencephalography (EEG): measuring neural activity through recording electrical activity originating from the brain
- Magnetoencephalography (MEG): measuring neural activity through recording magnetic fields originiating from the brain
- functional Magnetic Resonance Imaging (fMRI): measuring neural activity through changes in blood flow in the brain
- . . .

DATASET

- **“A multi-subject, multi-modal human neuroimaging dataset”** (Wakeman & Henson, 2015):
  - Freely available
  - EEG, MEG, and fMRI for 19 subjects
  - Multiple runs of hundreds of trials of a simple perceptual task on pictures of familiar, unfamiliar and scrambled faces
  - Through the combination of multiple modalities aim to increase the spatial and temporal resolution above that of any one modality alone

INTENTION

- Focus on EEG and MEG
- Provide a flexible but simple visualisation for inter- and intra-subject comparisons of the EEG and MEG data
- Allow for simple operations such as windowing, averaging, and fourier transforms
- Target users are neurologists who can use it as:
  - Doctor, for diagnosing
  - Student, for learning patterns
  - Teacher, for teaching patterns
  - Domain expert in the context of A.I., for finding and correcting artefacts

APPROACH

PREPROCESSING: FREQUENCY FILTERING

- Oscillating signals originating from the CNS are often divided into frequency bands:

Brainwave	Frequency band	Mental condition
Delta	0 – 4 Hz	State of deep sleep, when there is no focus, the person is totally absent, unconscious.
Theta	4 – 8 Hz	Deep relaxation, internal focus, meditation, intuition access to unconscious material such as imaging, fantasy, dreaming.
Low Alpha	8 – 10 Hz	Wakeful relaxation, consciousness, awareness without attention or concentration, good mood, calmness
High Alpha	10 – 12 Hz	Increased self-awareness and focus, learning of new information.
Low Beta	12 – 18 Hz	Active thinking, active attention, focus towards problem solving, judgment and decision making.
High Beta	18 – 30 Hz	Engagement in mental activity, also alertness and agitation.
Low Gamma	30 – 50 Hz	Cognitive processing, senses, intelligence, compassion, self-control.
High Gamma	50 – 70 Hz	Cognitive tasks: memory, hearing, reading and speaking

Table: CNS signal frequency bands. Data from Kawala-Sterniuk et al. (2021).

APPROACH

PREPROCESSING: FREQUENCY FILTERING

- Often recording devices record more frequencies
- Only interested in 0 to 70 Hz, so we filter out all other frequencies
- Intend to allow for live frequency filtering such that specific frequency bands can be investigated

APPROACH

PREPROCESSING: DOWNSAMPLING

- According to Shannon-Nyquist sampling theorem (Shannon, 1949), sampling frequency should be $> 2\cdot$ upper frequency bound
- Hence, we can downsample to 150Hz ($> 2 \cdot 70$Hz)
- This and dropping other irrelevant data significantly reduces the size of the dataset: 95GB to 6GB

APPROACH

PREPROCESSING: ARTEFACT CORRECTION

- Aside from the activity of interest, a lot of other things are happening in the human body
- These will result in noise in the data, i.e., artefacts, e.g., heartbeat and eye-blinks
- To filter out these artefacts, artefact correction techniques are used, in our case: Independent Component Analysis (ICA; Sun et al., 2005) in combination with 2 Electrooculography (EOG) channels and 1 Electrocardiography (ECG) channel

APPROACH

PREPROCESSING: ARTEFACT CORRECTION

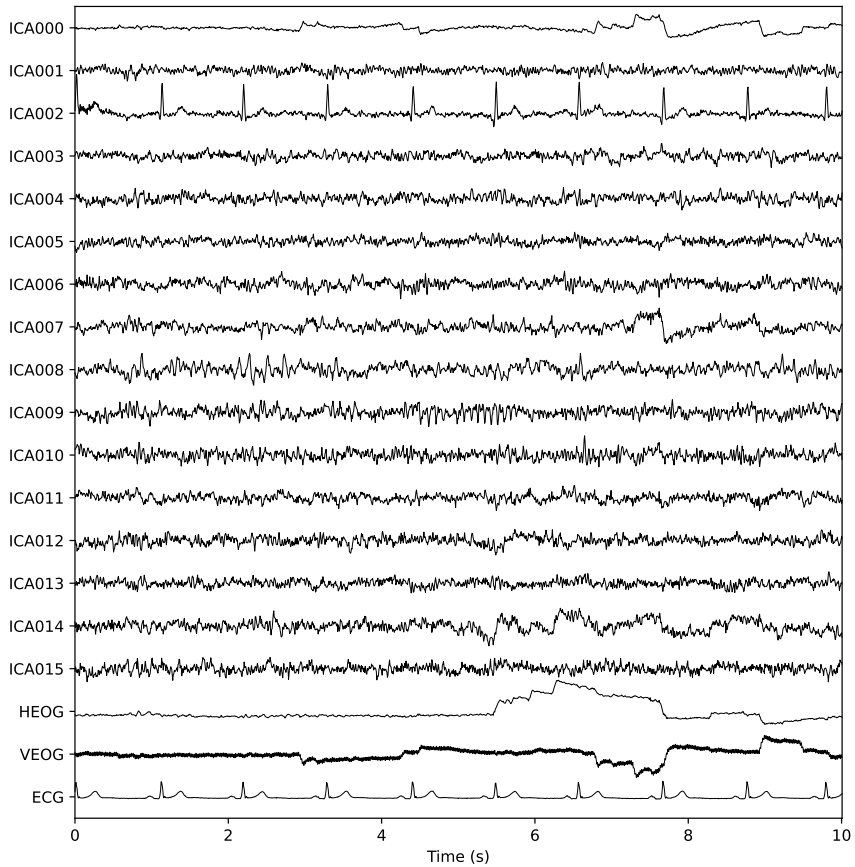


Figure: 10 seconds of 16 ICA components of the data, including EOG and ECG channels.

APPROACH

MOCK-UP: MAIN PAGE

Subject A

Subject A

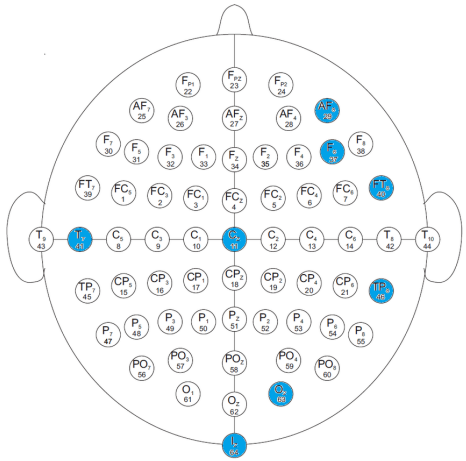
Subject A

Subject A

Subject A

- Sex: Female
- Age: 22
- ...

EEG

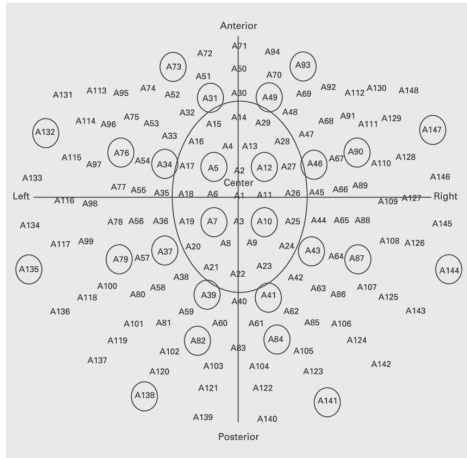


☒ Visual ☐ ...

☐ Motor ☐ ...

☐ Sensory ☐ ...

MEG



☒ Visual ☐ ...

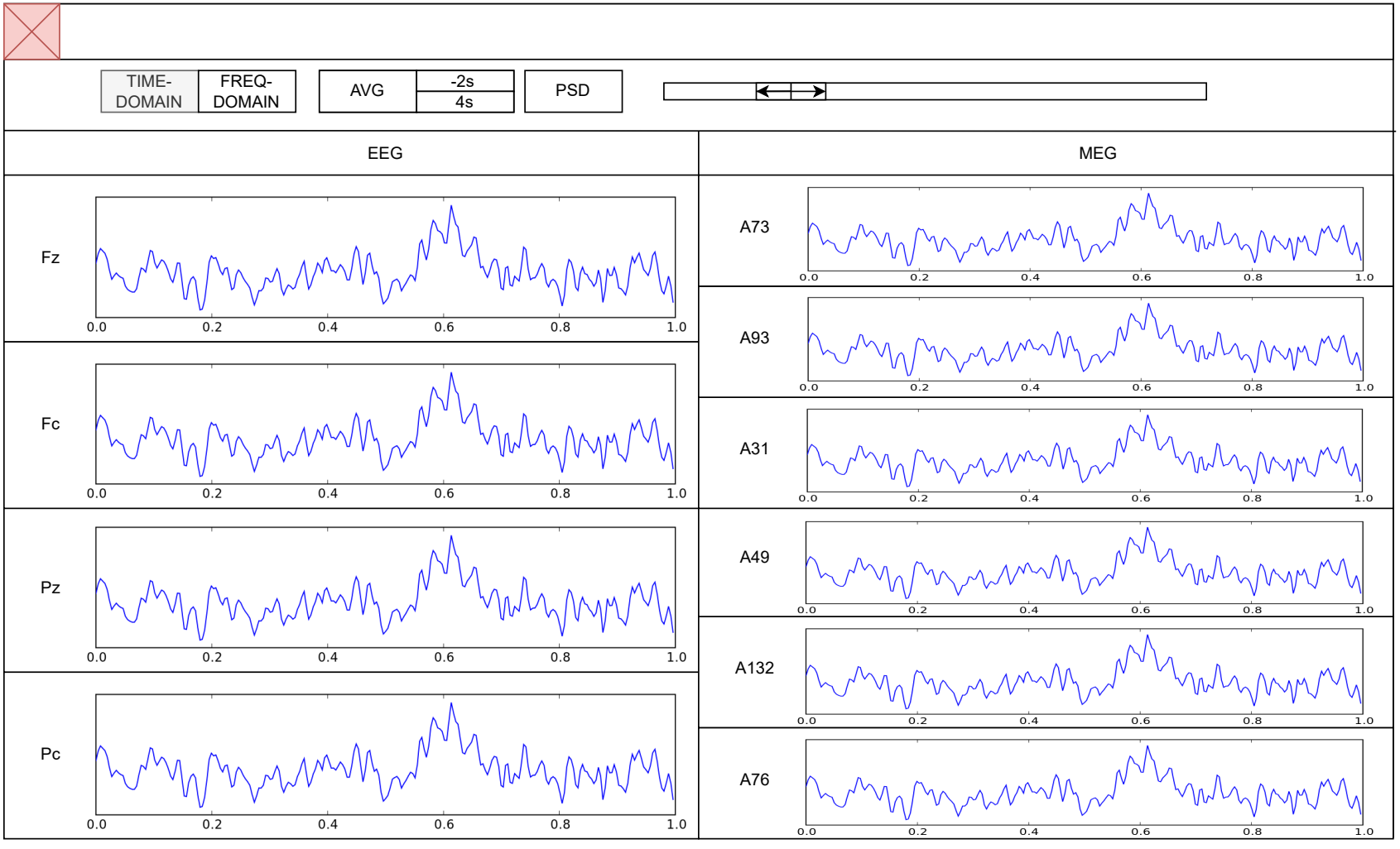
☐ Motor ☐ ...

☐ Sensory ☐ ...

GO

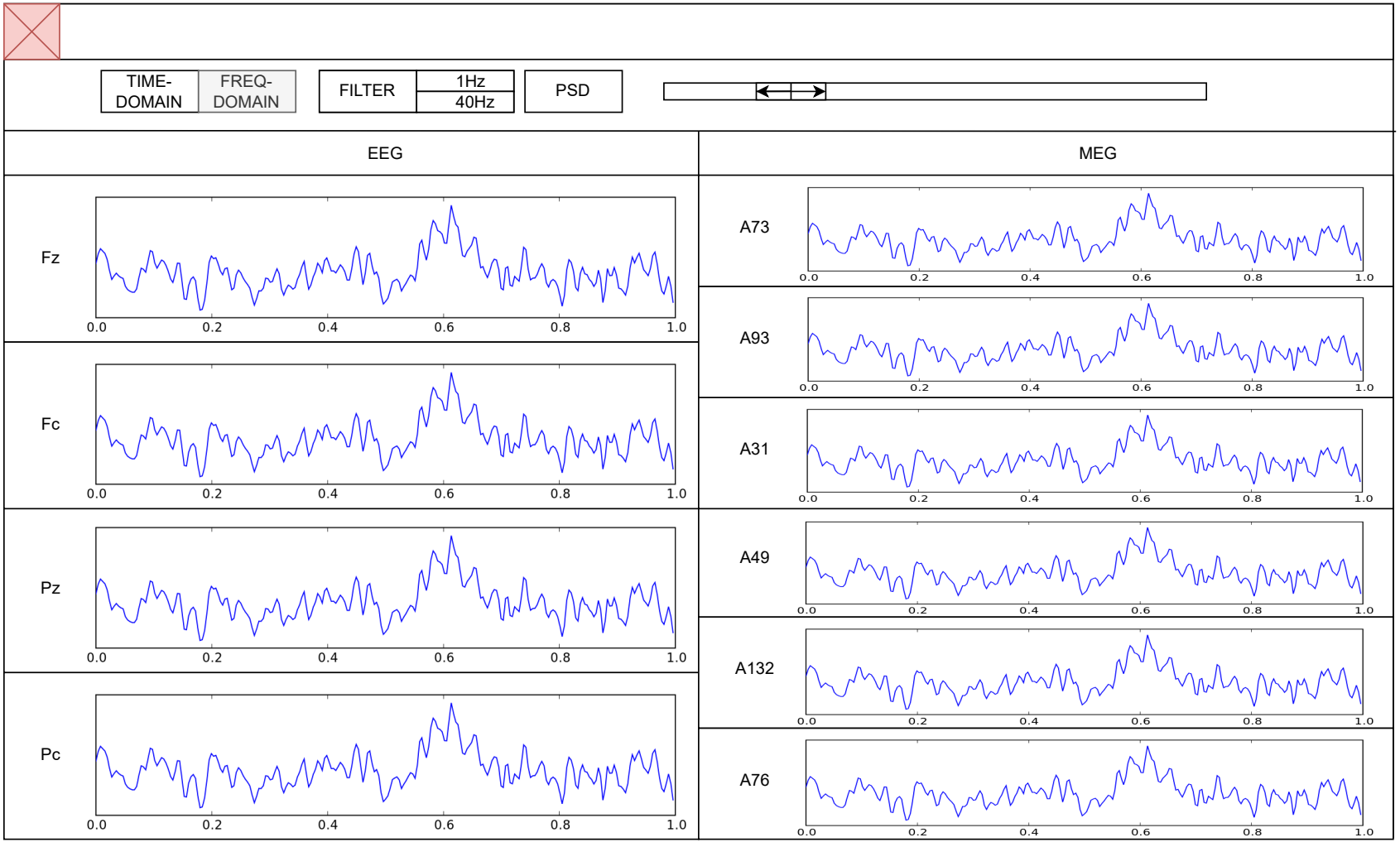
APPROACH

MOCK-UP: TIME DOMAIN PAGE



APPROACH

MOCK-UP: FREQUENCY DOMAIN PAGE



APPROACH

DEMO

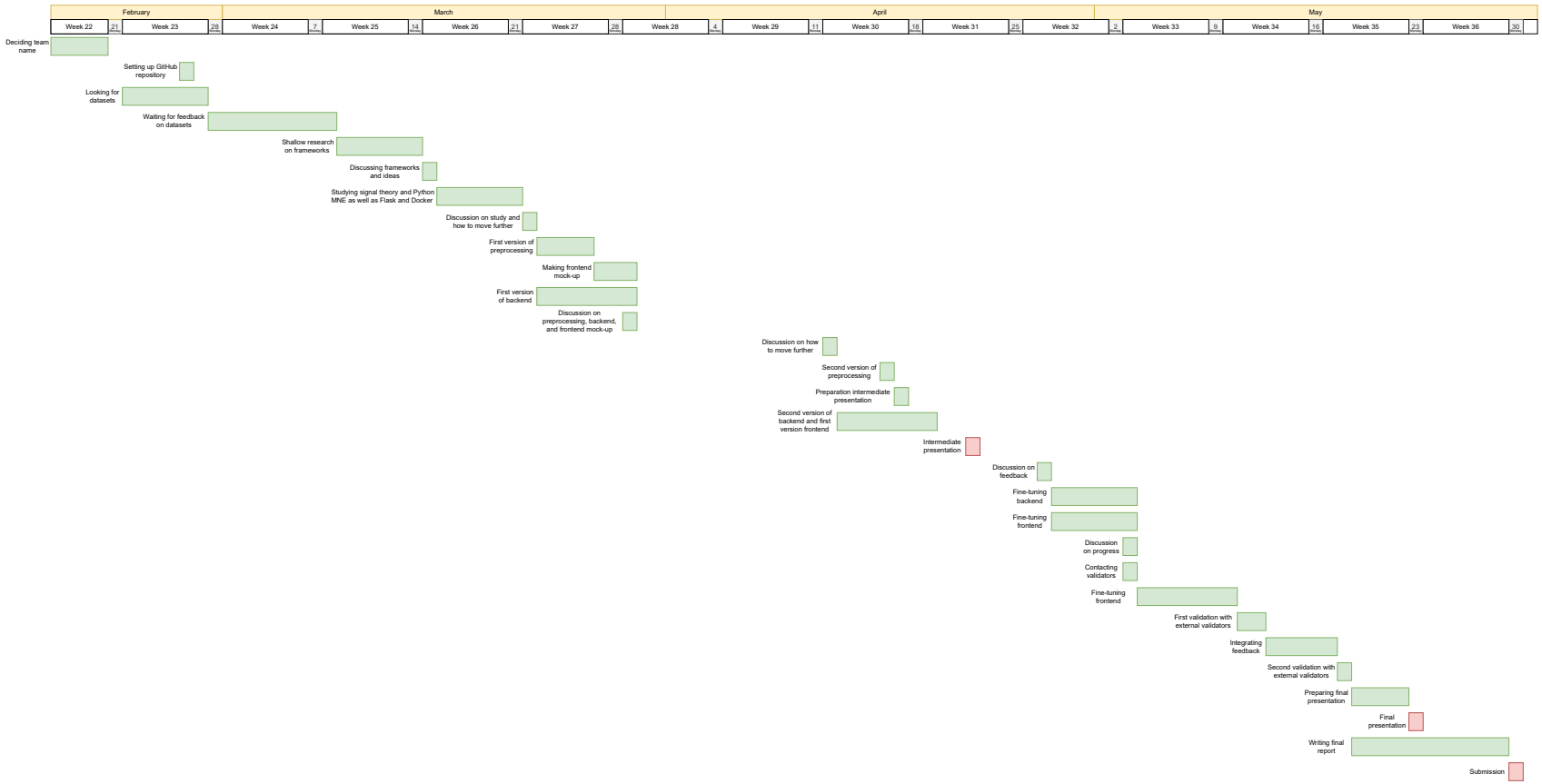
APPROACH

VALIDATION

- For the moment: friends and family who study medicine
  - Positive in general
  - There might be no need for visualising 20+ channels at the same time, most of the time 10 is more than sufficient
  - Frequency domain might be more for A.I. purposes

- Later: intend to contact Prof. dr. ir. Guy Nagels, head of the neurology department at UZ
  - Ask him about what he thinks and whether he can connect us to neurologists who could evaluate our visualisation

GANTT


February
March
April
May
Week 22
21
Week 23
28
Week 24
7
Week 25
14
Week 26
21
Week 27
28
Week 28
4
Week 29
11
Week 30
18
Week 31
25
Week 32
2
Week 33
9
Week 34
16
Week 35
23
Week 36
30
Deciding team name
Setting up GitHub repository
Looking for datasets
Waiting for feedback on datasets
Shallow research on frameworks
Discussing frameworks and ideas
Studying signal theory and Python MNE as well as Flask and Docker
Discussion on study and how to move further
First version of preprocessing
Making frontend mock-up
First version of backend
Discussion on preprocessing, backend, and frontend mock-up
Discussion on how to move further
Second version of preprocessing
Preparation intermediate presentation
Second version of backend and first version frontend
Intermediate presentation
Discussion on feedback
Fine-tuning backend
Fine-tuning frontend
Discussion on progress
Contacting validators
Fine-tuning frontend
First validation with external validators
Integrating feedback
Second validation with external validators
Preparing final presentation
Final presentation
Writing final report
Submission

QUESTIONS FOR YOU

- Is current loading time acceptable?
- Is it okay that we have two pages?
- Are the visualisations adequate?

QUESTIONS FROM YOU

?

REFERENCES

Kawala-Sterniuk, A., Browarska, N., Al-Bakri, A., Pelc, M., Zygarlicki, J., Sidikova, M., ... Gorzelanczyk, E. J. (2021, January). Summary of over Fifty Years with Brain-Computer Interfaces—A Review. Brain Sciences, 11(1), 43. doi: 10/gjjzqr

Shannon, C. (1949, January). Communication in the Presence of Noise. Proceedings of the IRE, 37(1), 10–21. doi: 10/ftzz7r

Sun, L., Liu, Y., & Beadle, P. (2005, May). Independent component analysis of EEG signals. In Proceedings of 2005 IEEE International Workshop on VLSI Design and Video Technology, 2005. (pp. 219–222). doi: 10/c8q6qt

Wakeman, D. G., & Henson, R. N. (2015, January). A multi-subject, multi-modal human neuroimaging dataset. Scientific Data, 2(1), 150001. doi: 10.1038/sdata.2015.1