

Neuroimaging and Machine
Learning for Biomedicine

EEG Hyperscanning During Cooperative and Competitive Interaction

Team GEE:

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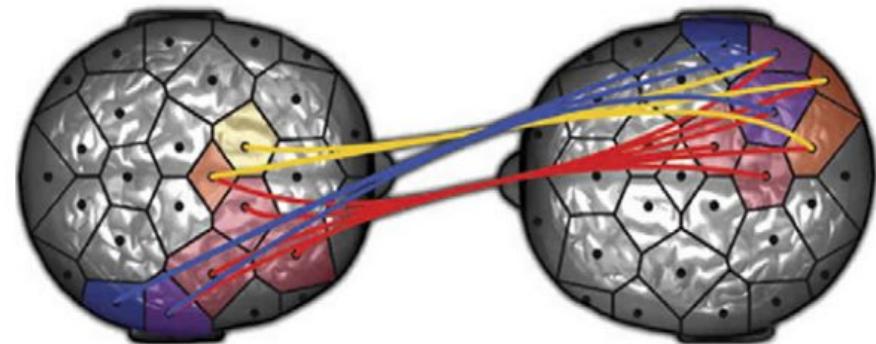
Oct, 2020

Overview

- Problem statement
- Methodology and equipment
- Data preprocessing
- Analysis pipeline
- Results
- Conclusions

Problem statement

- Hyperscanning - simultaneous recording of multiple subjects' brain activity
- Aim: study the nature of human interaction, evaluate cooperation skills of subjects



Synchronization of the brain activity of two interacting subjects*

* Babiloni F., Astolfi L., "Social neuroscience and hyperscanning techniques: Past, present and future", 2012

Methodology and equipment

- 8 channel EEG data acquisition system
- 24bit and 250Hz signal
- Wet electrodes

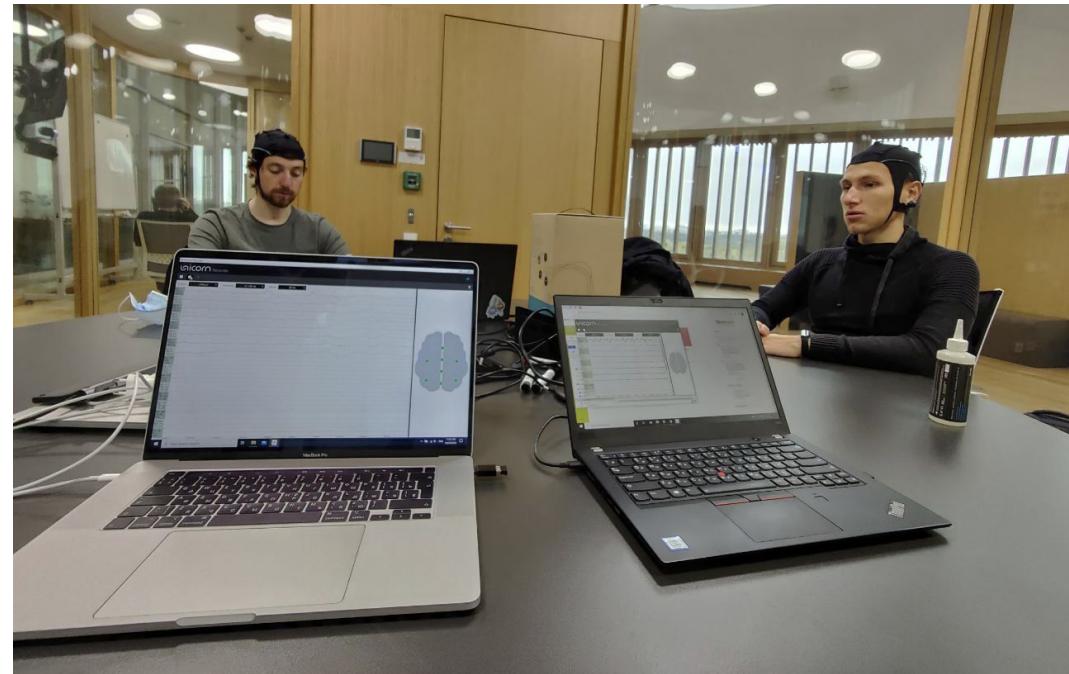


Unicorn Hybrid Black

Methodology and equipment

Experiment #1:

- Condition1: Subjects count numbers;
When one stops, the other has to continue and name larger numbers;
- Condition2 (reference):
Each subject counts numbers alone with some pauses;



Experiment #1, EEG data acquisition

Methodology and equipment

Experiment #2:

- Condition1: Subjects play 2D ping-pong game against each other;
- Condition2 (reference): Each subject plays the game alone against PC;



Experiment #2, EEG data acquisition

Methodology and equipment

Experiment #3:

- Condition1: Subjects play Counter-Strike (CS) game against each other;
- Condition2 (reference): Each subject plays the game alone against PC;



Experiment #3, EEG data acquisition

Methodology and equipment

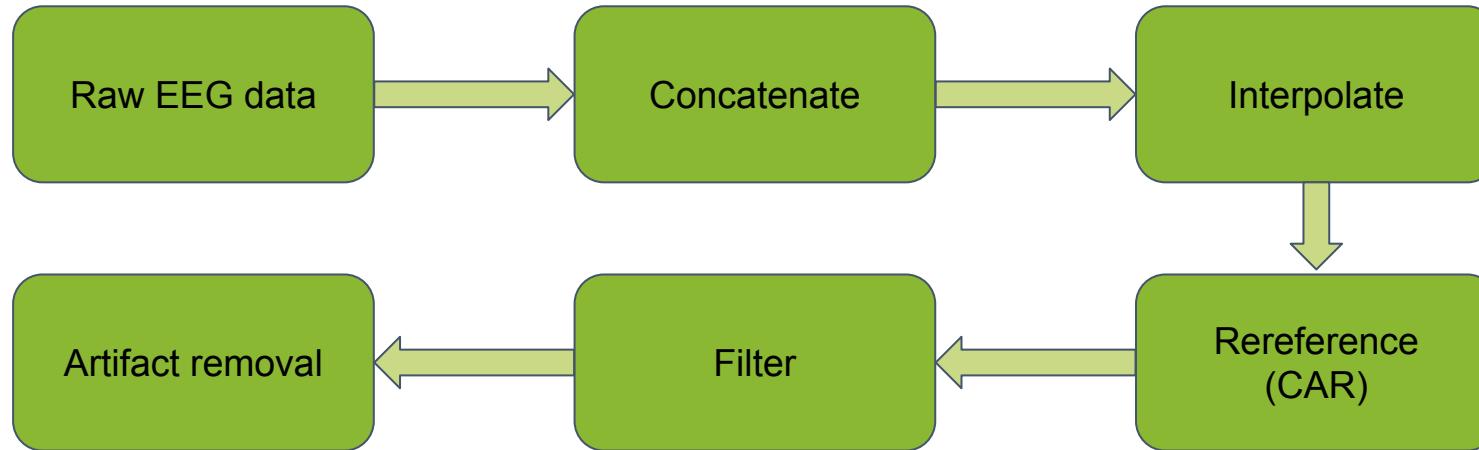
Experiment #4:

- Condition1: Subjects play Counter-Strike (CS) game together against PC;
- Condition2 (reference): Each subject plays the game alone against PC;



Experiment #4, EEG data acquisition

Data preprocessing



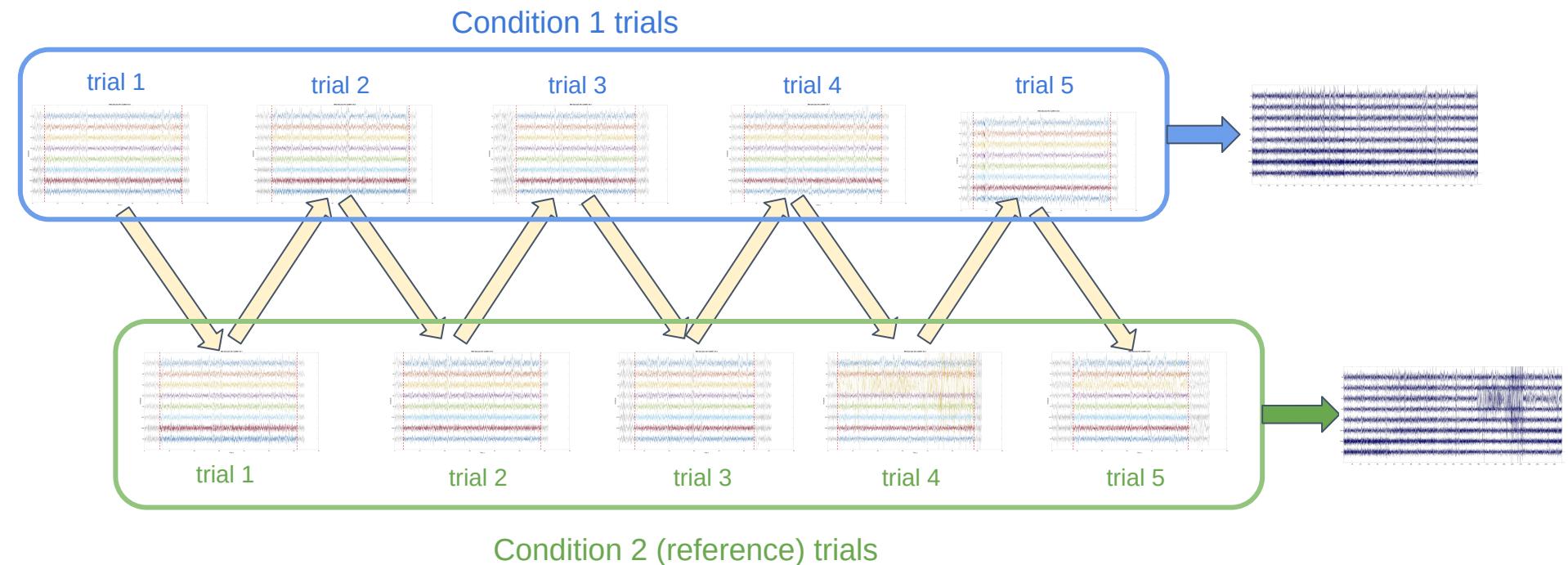
Pipeline available at:

https://github.com/AndreiZn/eSports_ERP_project/tree/gUnicorn

Inspired by Makoto's preprocessing pipeline:

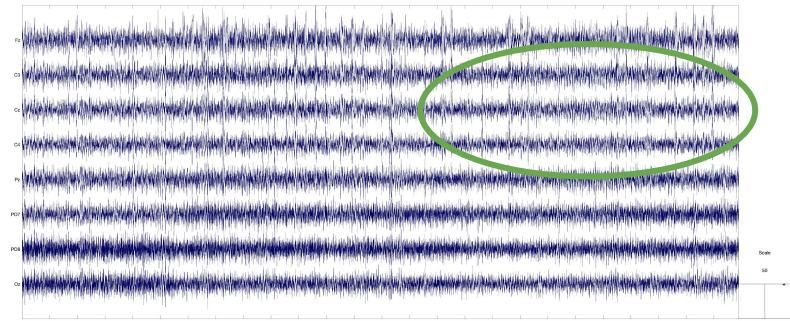
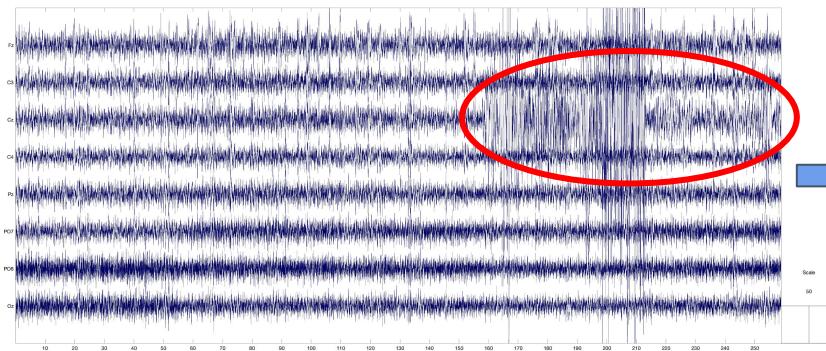
https://scn.ucsd.edu/wiki/Makoto's_preprocessing_pipeline

Data preprocessing. Concatenation



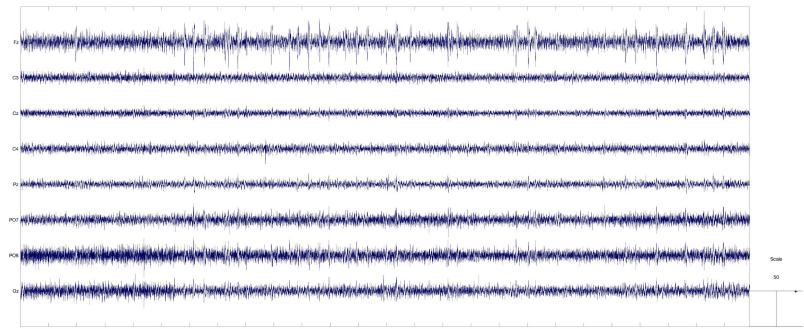
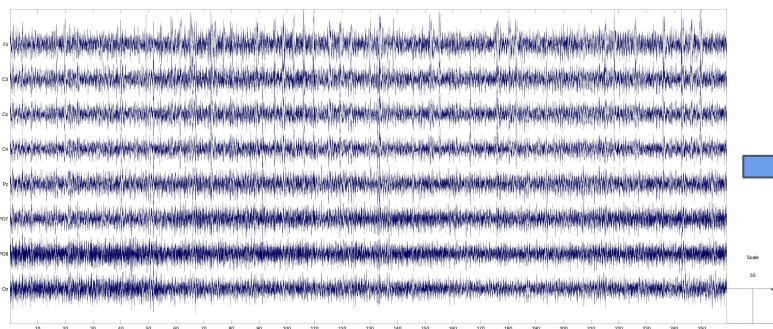
Raw data concatenation. Arrows illustrate the order in which data was recorded. Rectangles show how data was concatenated

Data preprocessing. Channel interpolation



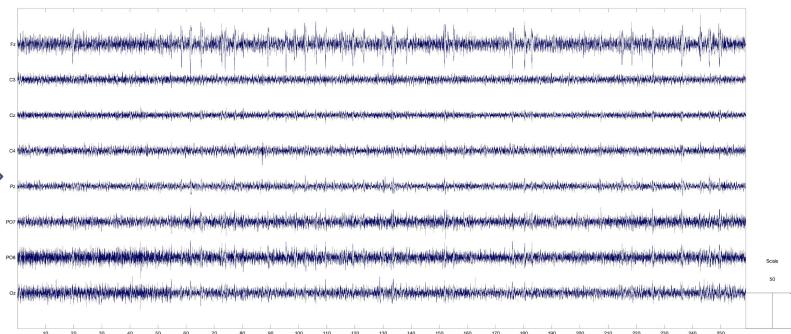
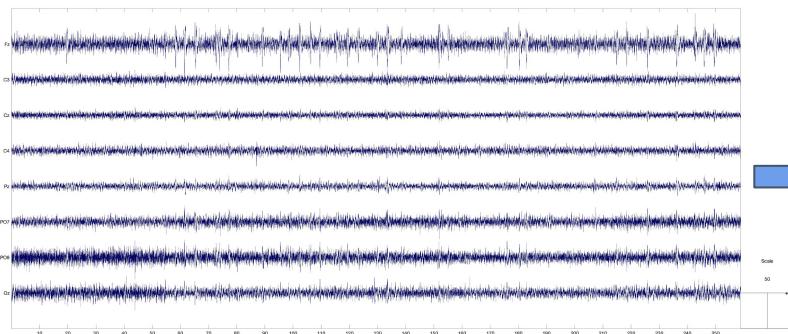
Channels marked “bad” were interpolated

Data preprocessing. Common average referencing



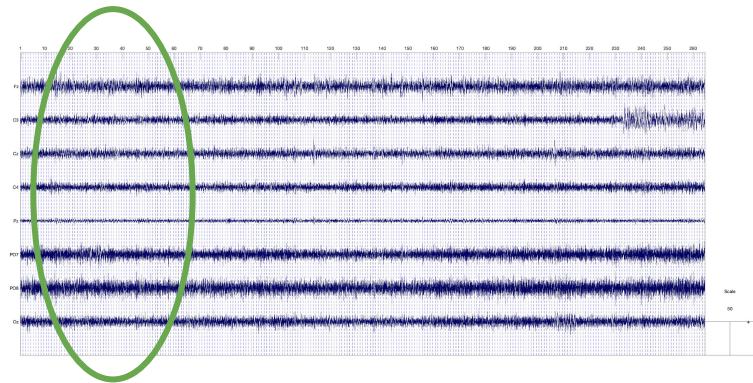
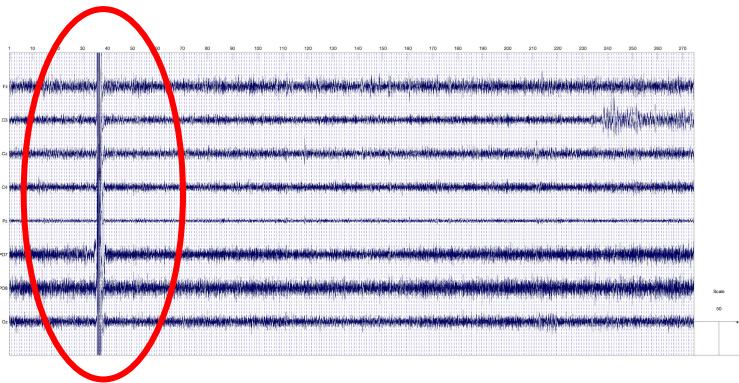
Data was re-referenced using common average referencing (CAR)

Data preprocessing. Filtering



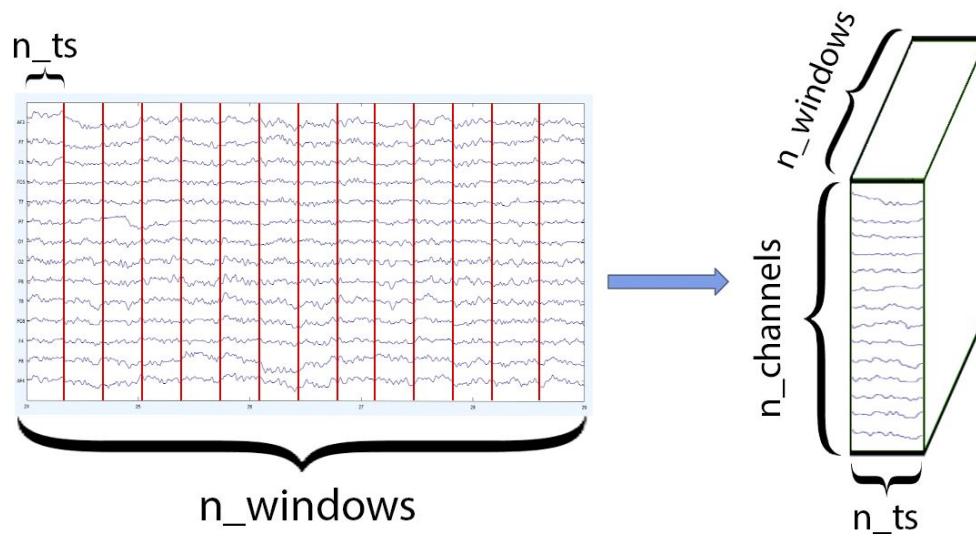
Data was filtered with the IIR filter from 1 to 30Hz and with the notch filter at 50Hz

Data preprocessing. Artifact removal



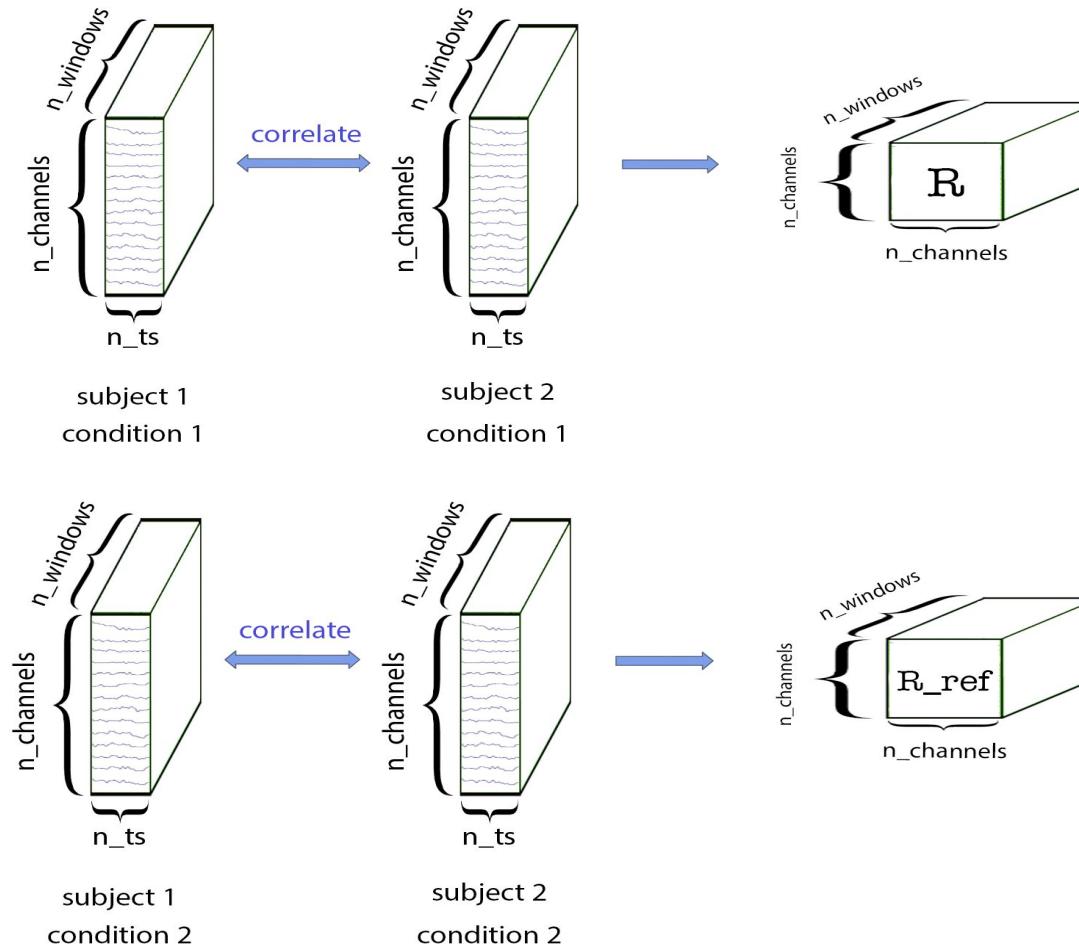
Pieces of data contaminated with artifacts were removed

Analysis, Approach #1: Correlation



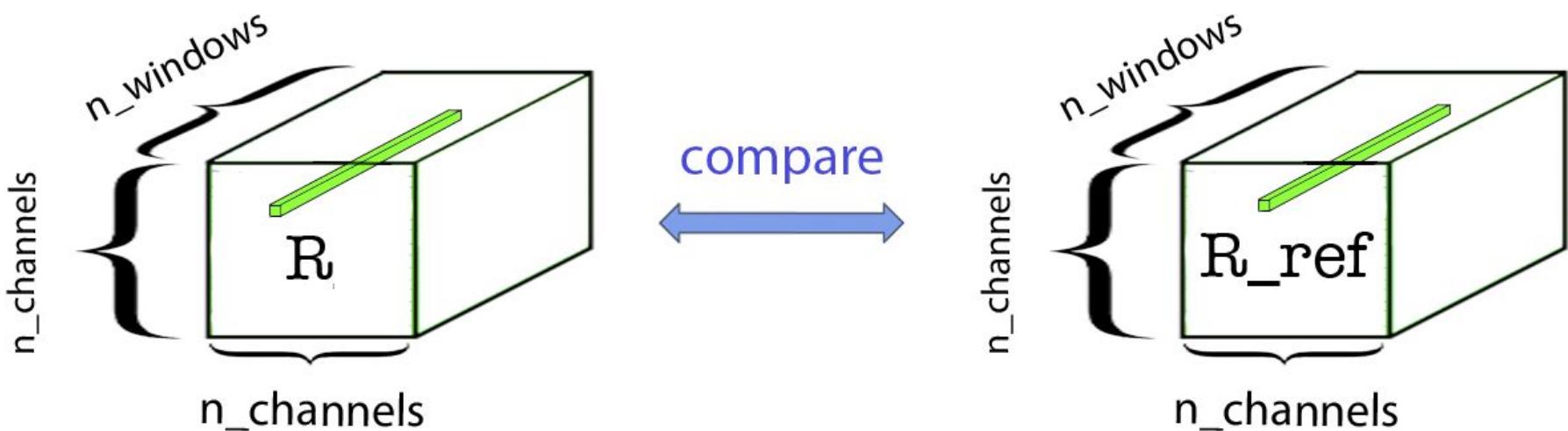
Step1. Data was split into non-overlapping windows (width 5 sec, stride 5 sec) and reshaped

Analysis, Approach #1: Correlation



Step2. Each time-series for subject 1 was correlated with the corresponding time-series for subject 2

Analysis, Approach #1: Correlation

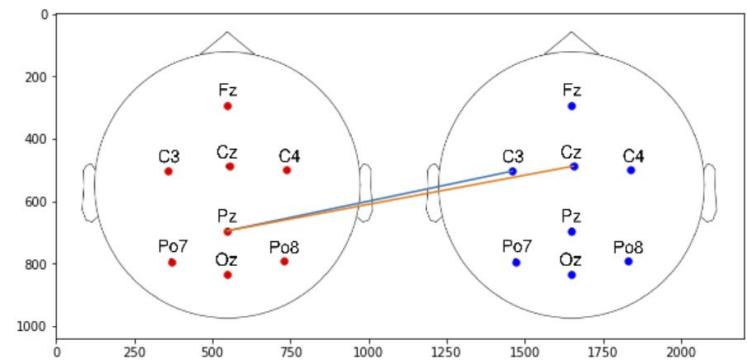
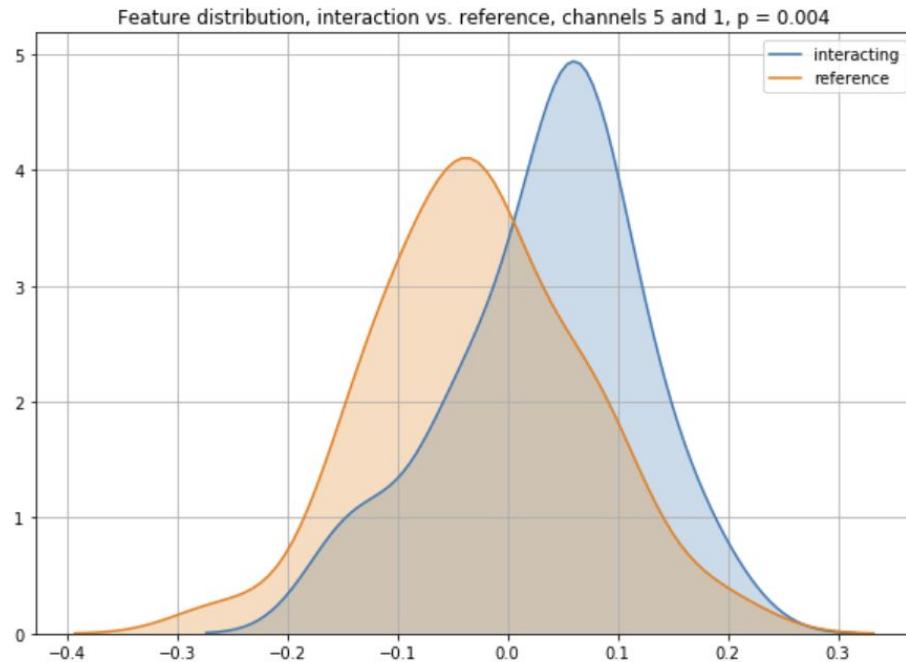


Step3. Each vector along the $n_windows$ dimension was compared
between correlation matrices R and R_{ref} using ANOVA

Results

Method [3] (correlation)

Comparison of two experiments: Speaking together vs Speaking alone

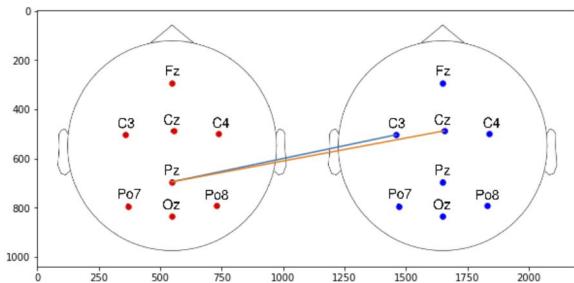


Correlation feature distribution and channel links visualization, Speaking experiment

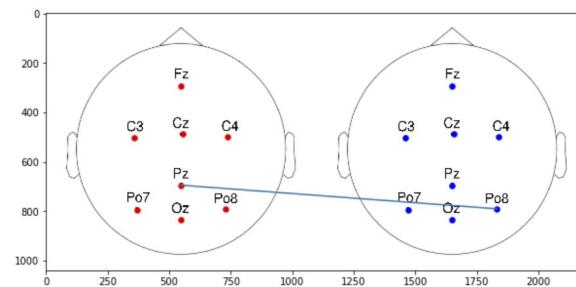
Results

Method [3] (correlation)

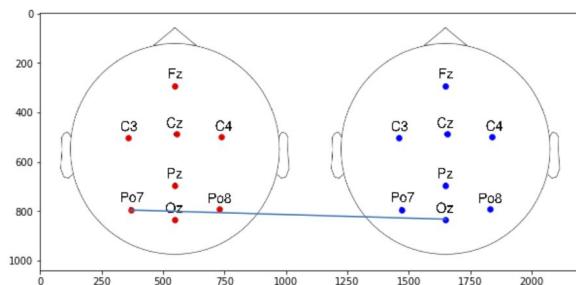
Speaking, $p < 5e-3$



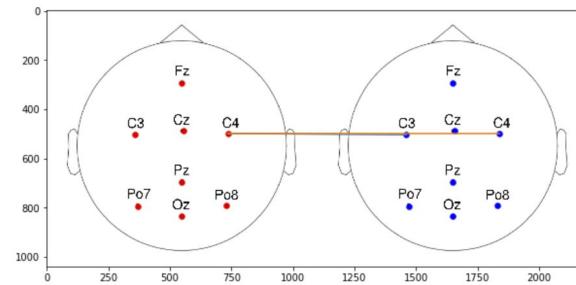
CS GO (competition), $p < 5e-3$



Ping-pong, $p < 5e-3$

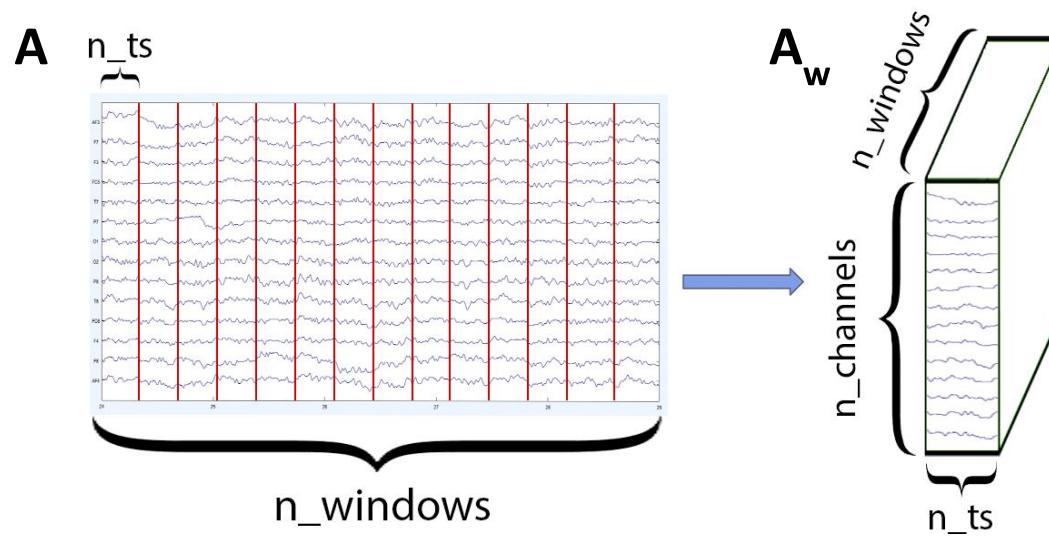


CS GO (cooperation), $p < 5e-2$



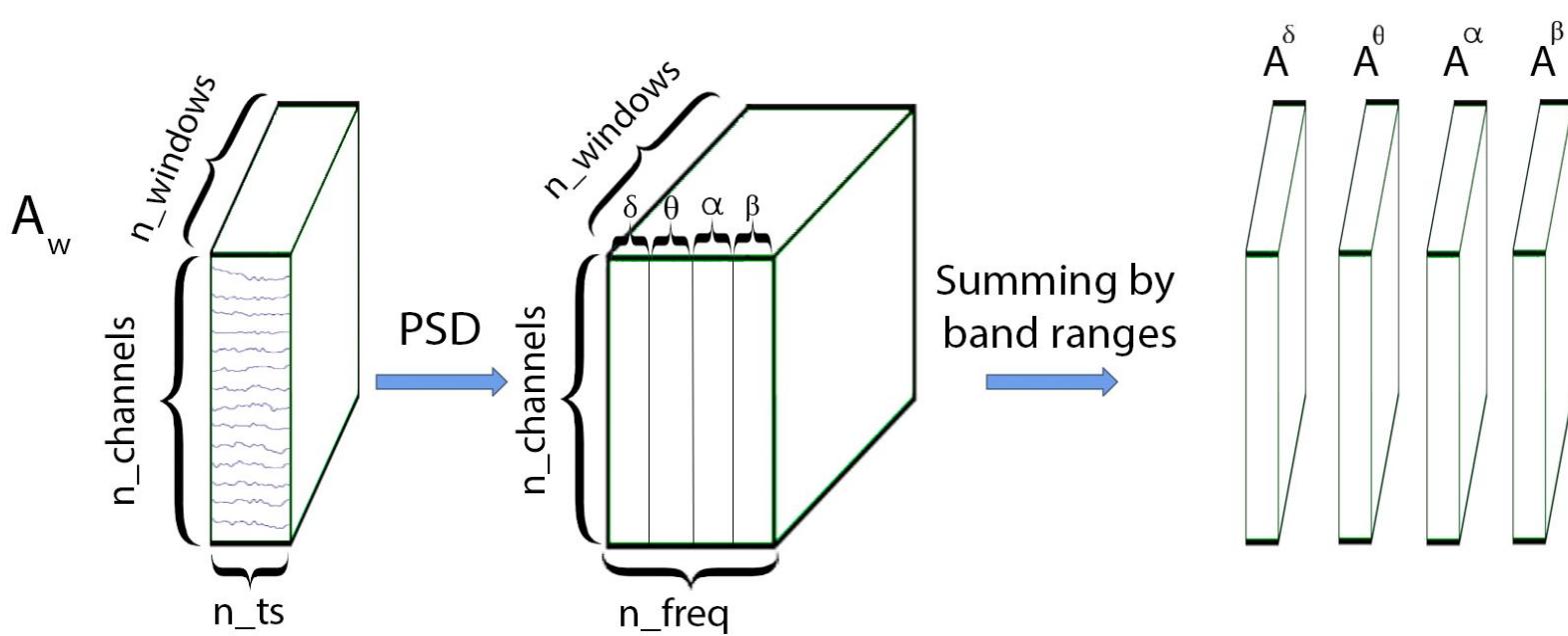
Channel links with significant difference between interactive and reference experiments.

Analysis, Approach #2: Bandpass



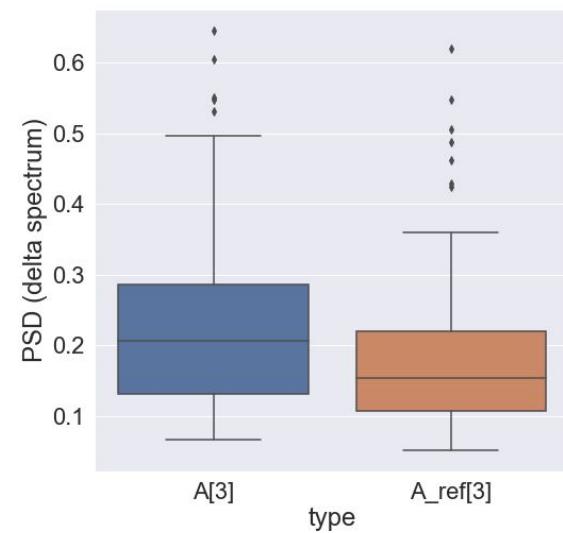
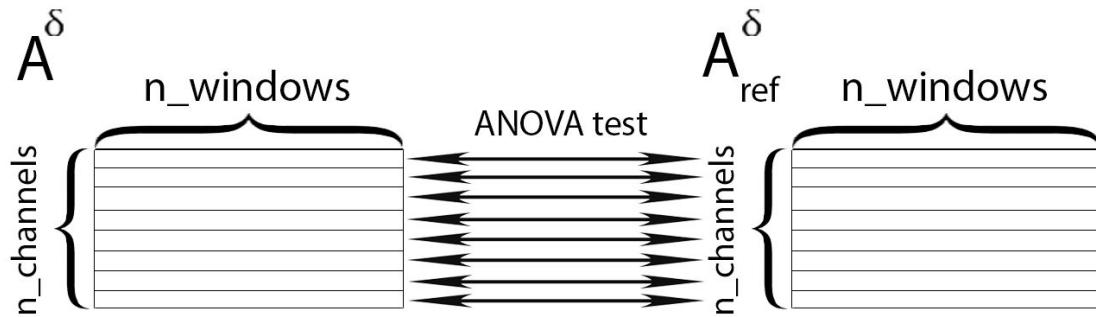
Step 1. Data was split into non-overlapping windows (width 2 sec, stride 2 sec) and reshaped

Analysis, Approach #2: Bandpass



Step 2. Calculating power spectral density (PSD) followed by summing by band ranges

Analysis, Approach #2: Bandpass

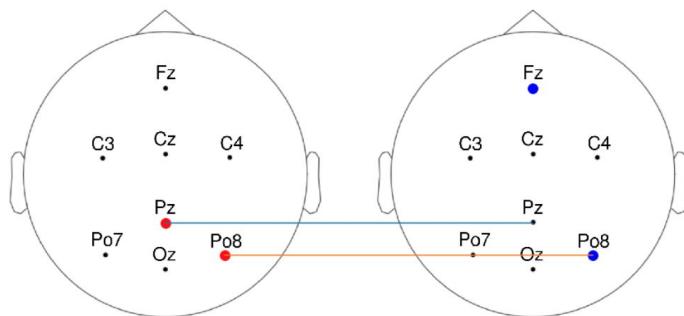


Step 3. Run ANOVA test to compare obtained matrices corresponding to interactive and reference experiments

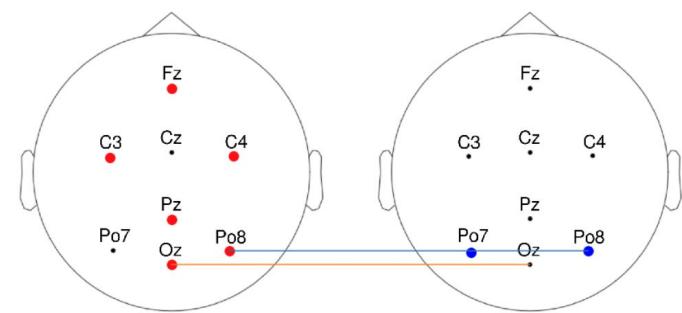
Results

Method [8] (bandpass)

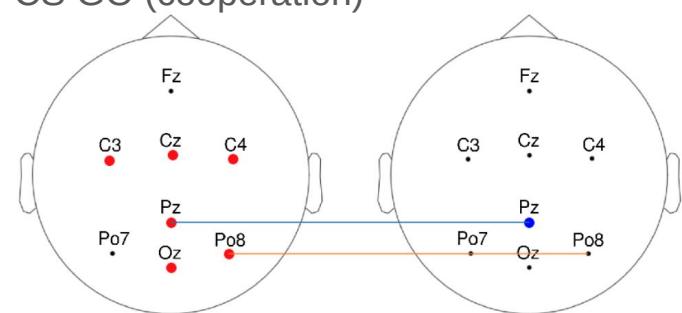
Speaking



CS GO (competition)



CS GO (cooperation)



Channels with significant difference for each of the subjects. ANOVA @ $p=0.0001$ for independent tests (bold points), $p=0.01$ for joint tests (lines). Considered activations in δ and θ range only.

Conclusion

Results can be improved:

- More data recorded (at least 10-20 pairs of subjects)
- Better EEG acquisition system (at least 32 channels)
- Enhanced artifact removal (ICA and other algorithms)

Interpretation of the findings:

- Obtained channel links might give insights for studies of human interaction
- Found biomarkers can be used to evaluate subjects' cooperation abilities

References

- [1] Czeszumski A., et al., "Hyperscanning: A Valid Method to Study Neural Inter-brain Underpinnings of Social Interaction", 2020;
- [2] Balconi M., Vanutelli M., "Cooperation and Competition with Hyperscanning Methods: Review and Future Application to Emotion Domain", 2017;
- [3] Sinha N., et al., "EEG hyperscanning study of inter-brain synchrony during cooperative and competitive interaction", 2016;
- [4] Astolfi L., et al., "Imaging the Social Brain by Simultaneous Hyperscanning During Subject Interaction", 2011;
- [5] Astolfi L., et al., "Study of the Functional Hyperconnectivity between Couples of Pilots during Flight Simulation: an EEG Hyperscanning Study", 2011;
- [6] Babiloni F., et al., "High Resolution EEG Hyperscanning During a Card Game", 2007;
- [7] Stone D., et al., "Hyperscanning of Interactive Juggling: Expertise Influence on Source Level Functional Connectivity", 2019;
- [8] Sangtae A., et al., "Interbrain phase synchronization during turn-taking verbal interaction—a hyperscanning study using simultaneous EEG/MEG", 2017.

Thank you for your attention!