Evaluation of ASR for Automatic EEG Artifact Removal

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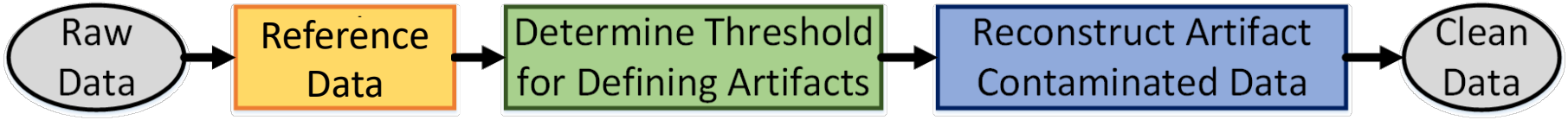
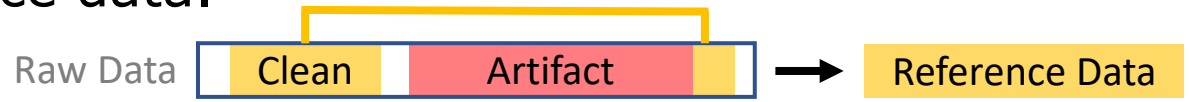
Chang et al., *IEEE Transactions on Biomedical Engineering*,67(4): 1114 - 21, 2019.

Artifact Subspace Reconstruction (ASR)

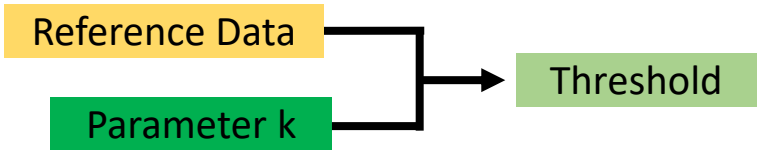
Christian A Kothe



1. ASR selects and concatenate "clean" sections of data from raw data and use them as the reference data.

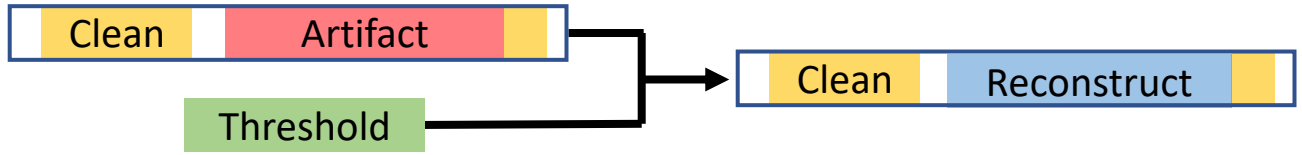


2. ASR uses the reference data and a user-defined cutoff parameter k to determine threshold for artifact recognition.



$$Threshold_i = \mu_i + k \times \sigma_i$$

3. Apply ASR and the threshold back on raw data and reconstruct artifact contaminated portion.



C. Chang, et al., 2019
C. Chang, et al., 2018
C.A. Kothe, et al., 2016 (U.S. patent)
T Mullen, et al., 2015

Real-time EEG Source-mapping Toolbox (REST)

Luca Pion-Tonachini

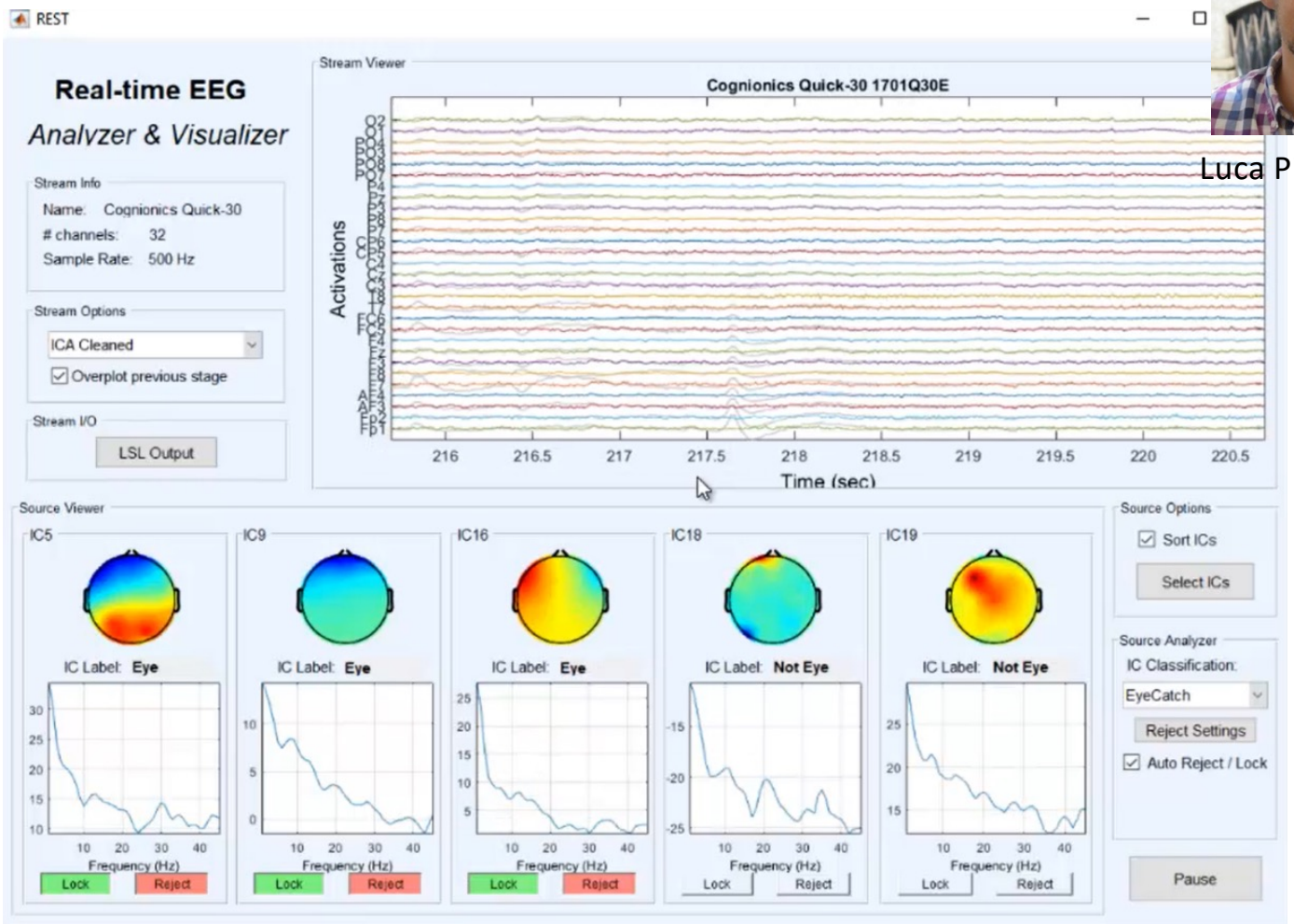
Live streaming multi-channel data (LSL)

Preprocessing:
- Re-reference
- Band-pass filtering (IIR)
- Data cleaning (ASR)

Source separation:
- Online Recursive ICA

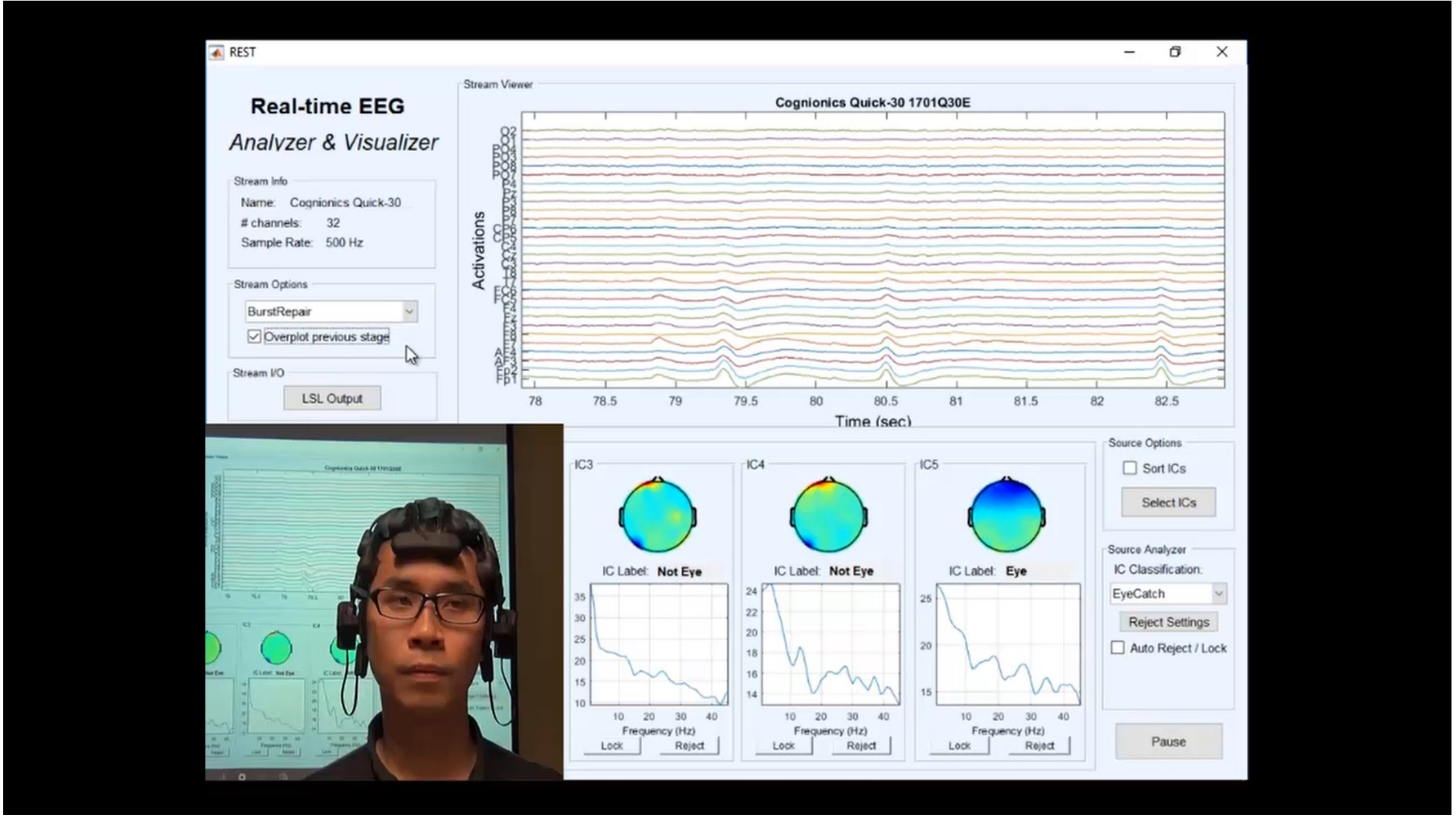
Source-level analysis:
- Source localization
- Source classification

Real-time applications:
- Automatic artifact removal
- Brain-state monitoring



Download: https://github.com/goodshawn12/REST

Pion-Tonachini & Hsu, *IEEE EMBC*, 2015
Hsu et al., *IEEE EMBC*, 2015
Hsu et al., *IEEE TBME*, 2016
Pion-Tonachini & Hsu et al., IEEE EMBC, 2018

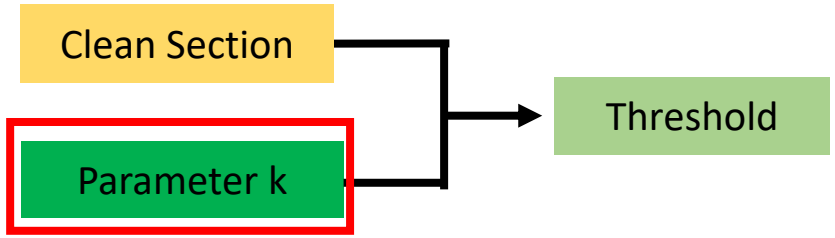


- Real-time EEG Source-mapping Toolbox (REST): https://github.com/goodshawn12/REST

L Pion-Tonachini, et al., 2018
L Pion-Tonachini, et al., 2015

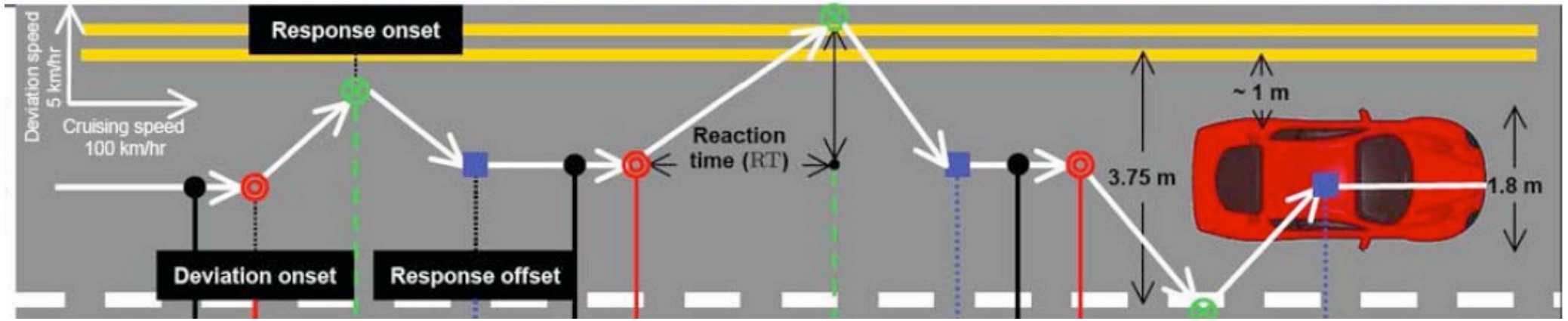
Challenges: lack of validation

1. How to select ASR threshold for removing artifact components?

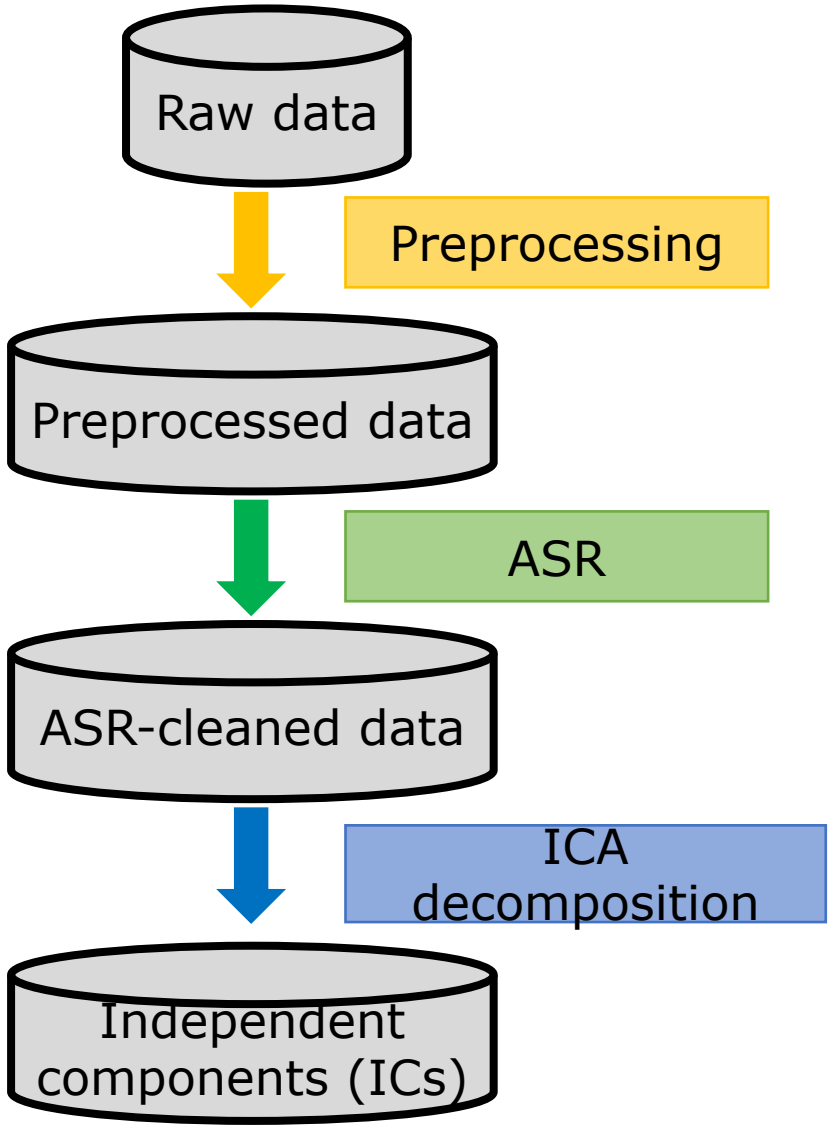


2. How effective is the ASR on removing artifacts? Are brain signals affected by ASR?

Dataset: EEG during Simulating Driving in a Real Car

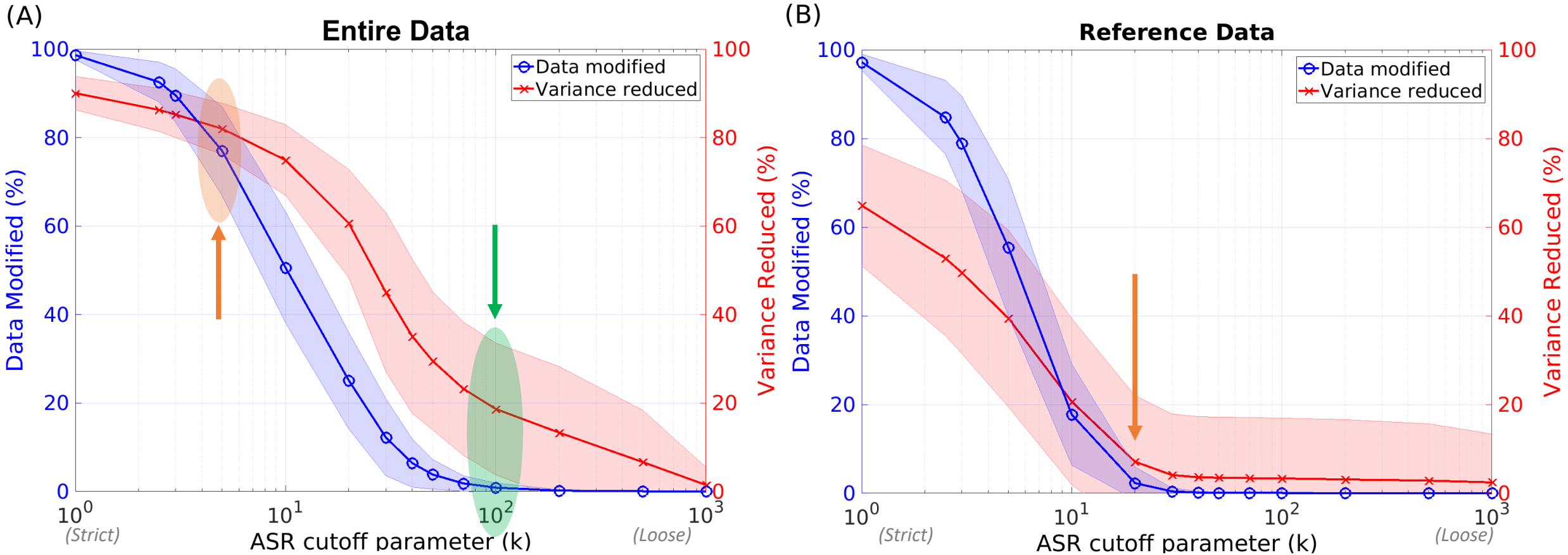


Data preprocessing and analysis



- Remove bad channel(s) in preprocessing
  - ASR will include bad channels when concatenating clean sections.
- Apply ASR with different values for the cutoff parameter k
- Apply ICA to the ASR-corrected data

Results: EEG Signals Modified by ASR



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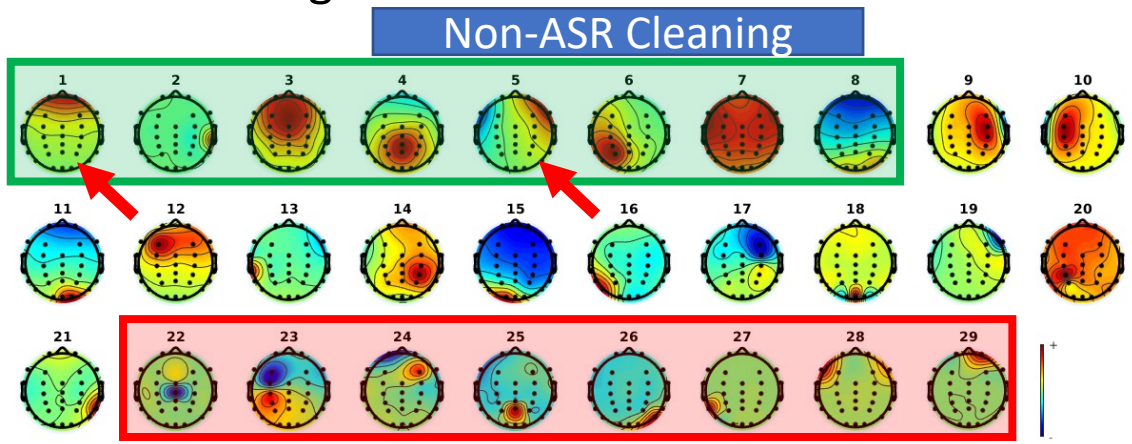
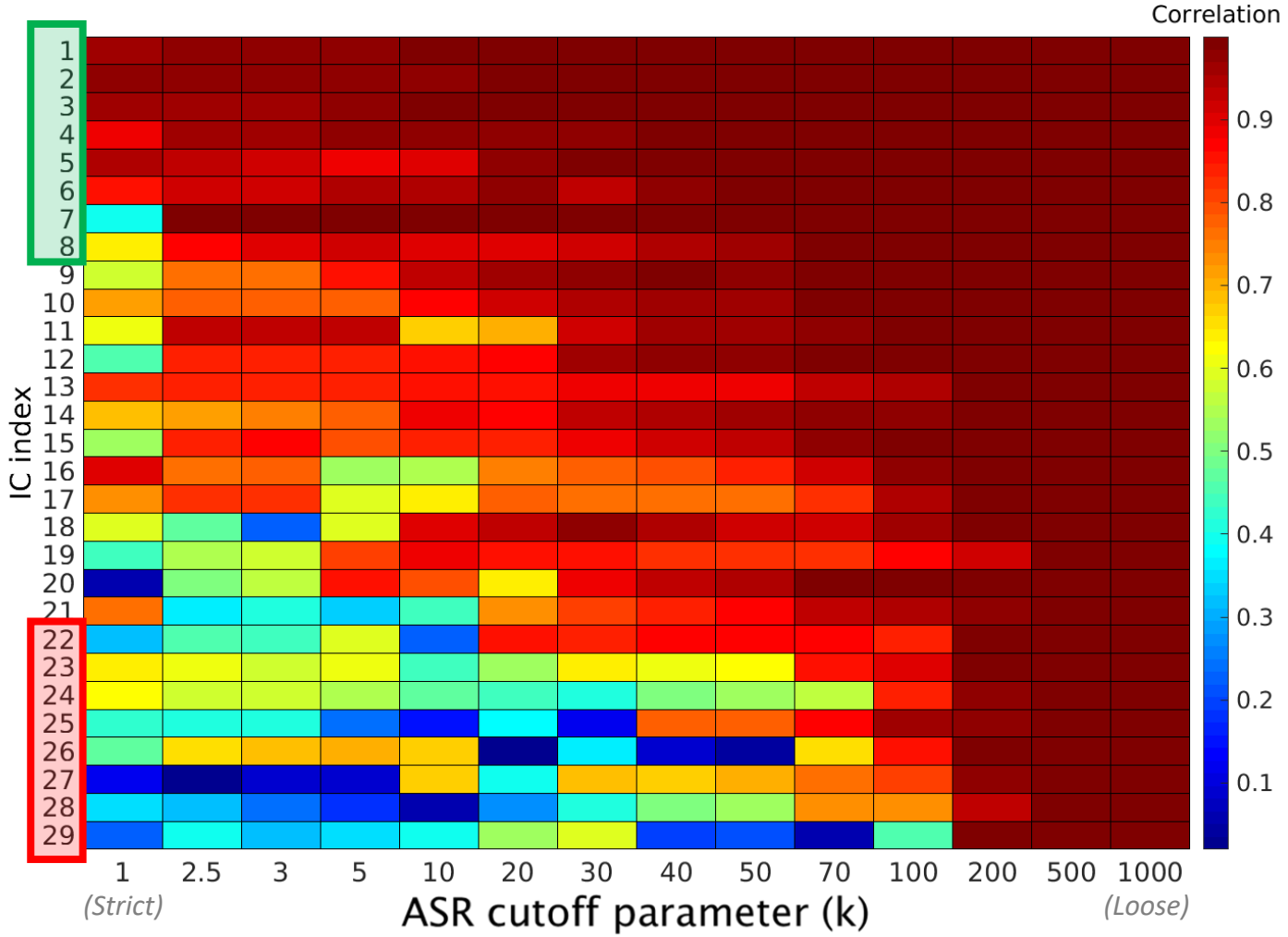
Changes in IC Scalp Maps

1. Apply ICA to EEG data with and without ASR cleaning.
2. Obtain ICs' scalp maps
   - Projection of IC activities on the scalp.
3. Calculate the correlation coefficient between scalp maps with and without ASR cleaning.





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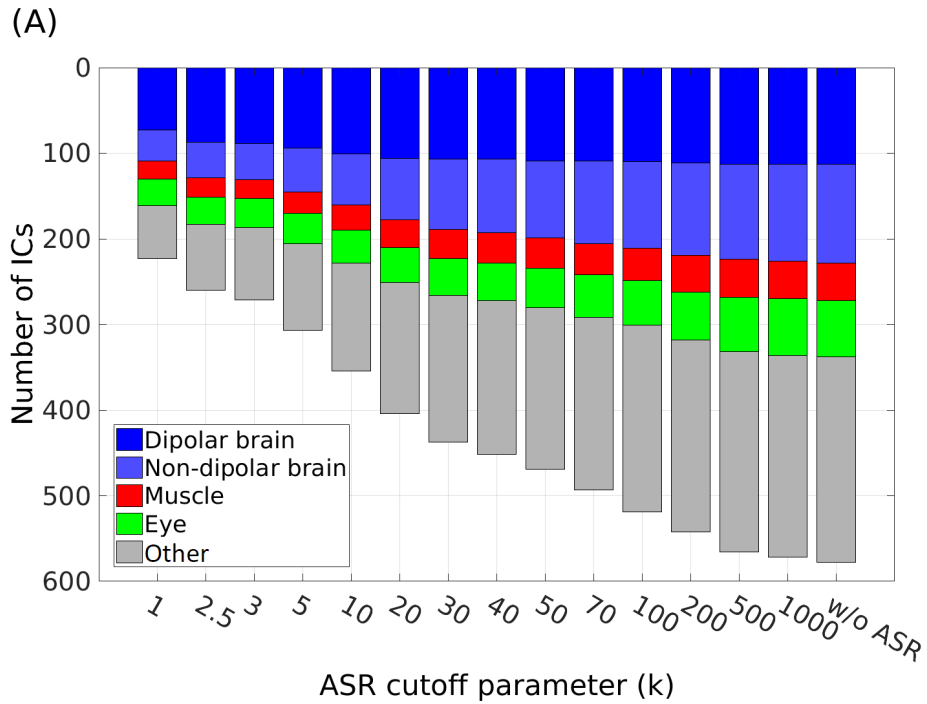
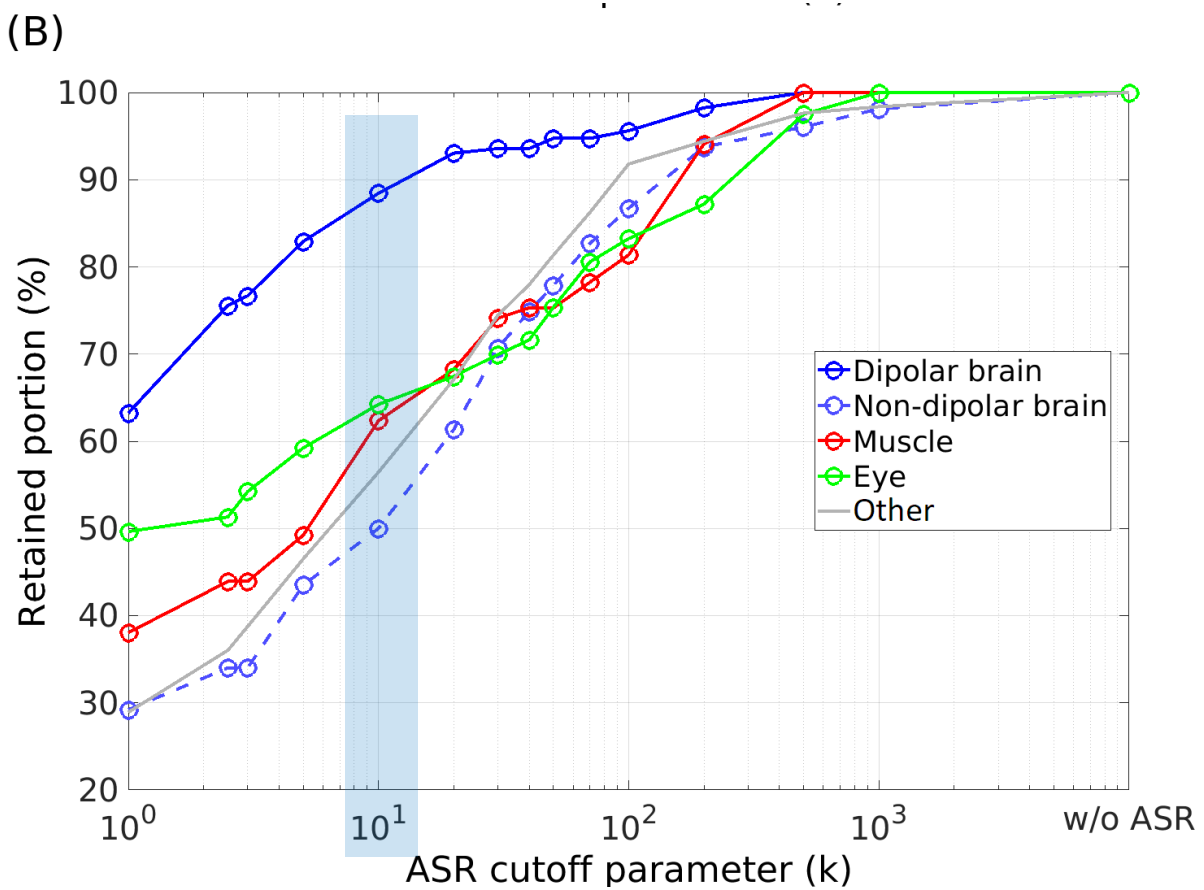
Changes in IC Scalp Maps Cross-subject Result

1. Use *ICLabel* to classify ICs into **Brain, Muscle, Eye,** and **Other.**
2. Calculate the dipolarity of each IC.
3. Count the number of retained ICs (*r > 0.8*) in each class after ASR cleaning.

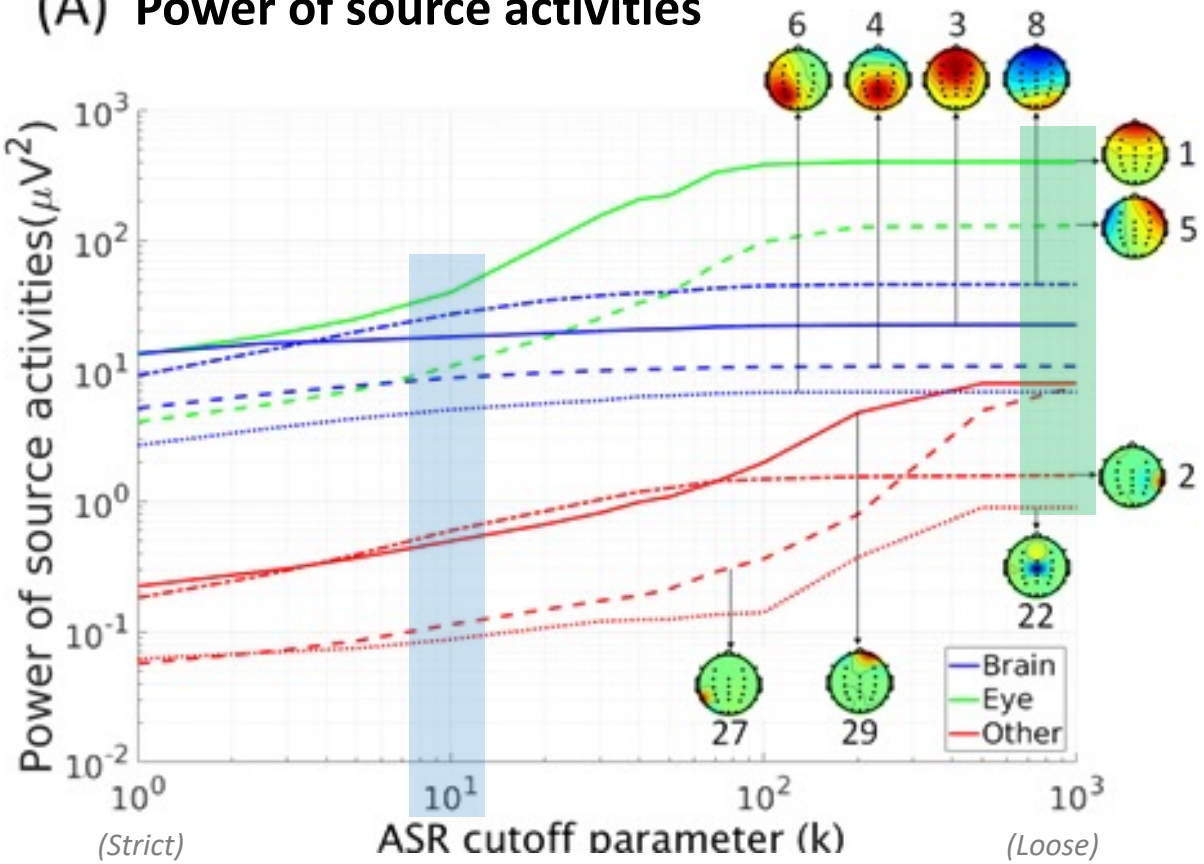




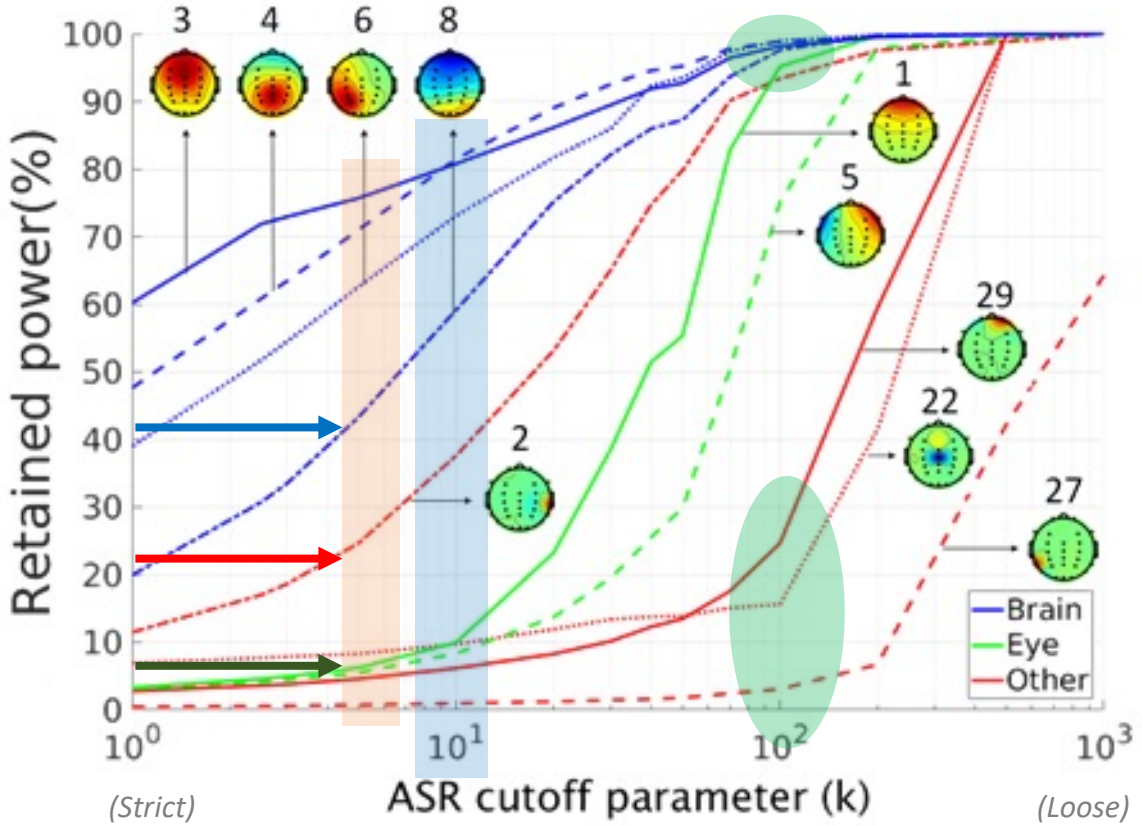
- Classifier: *ICLabel* (Luca Pion-Tonachini, 2019) https://labeling.ucsd.edu/tutorial/overview

Changes in IC Activities in a Sample Subject

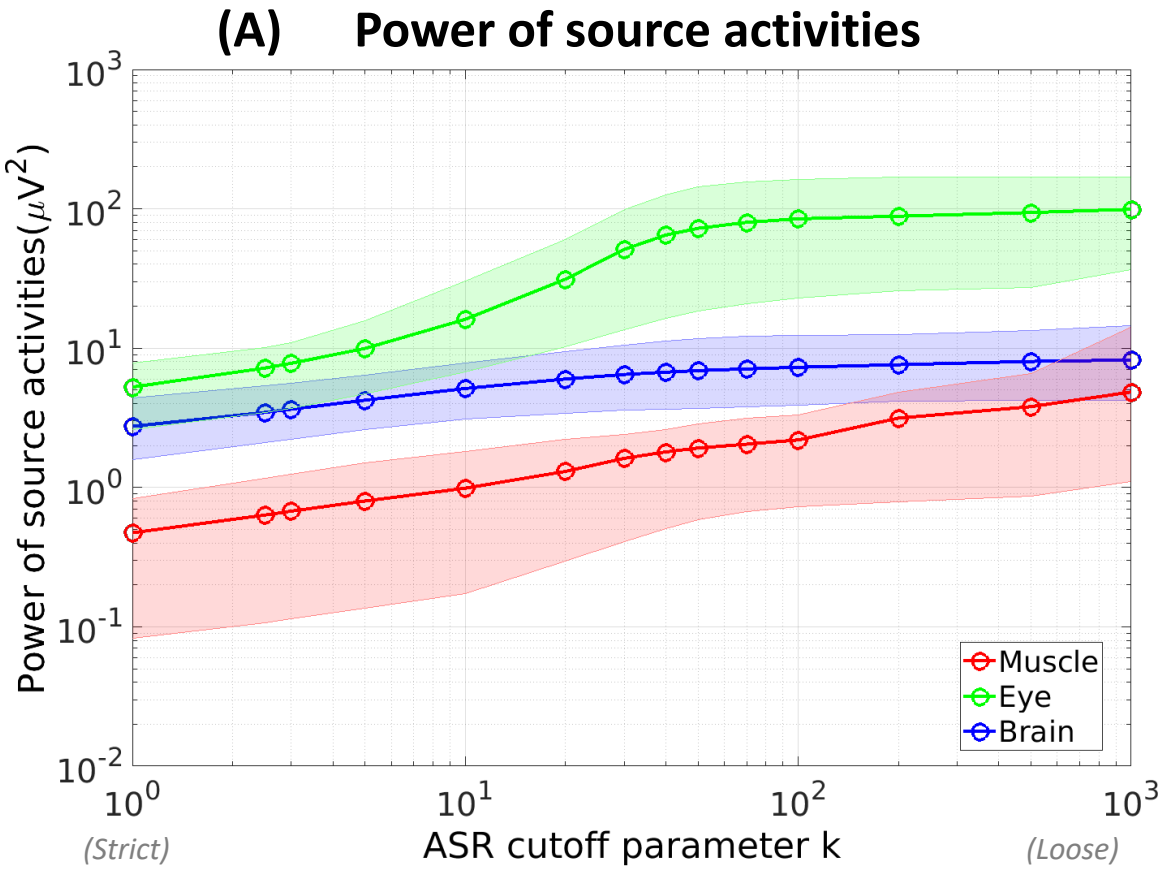
(A) Power of source activities

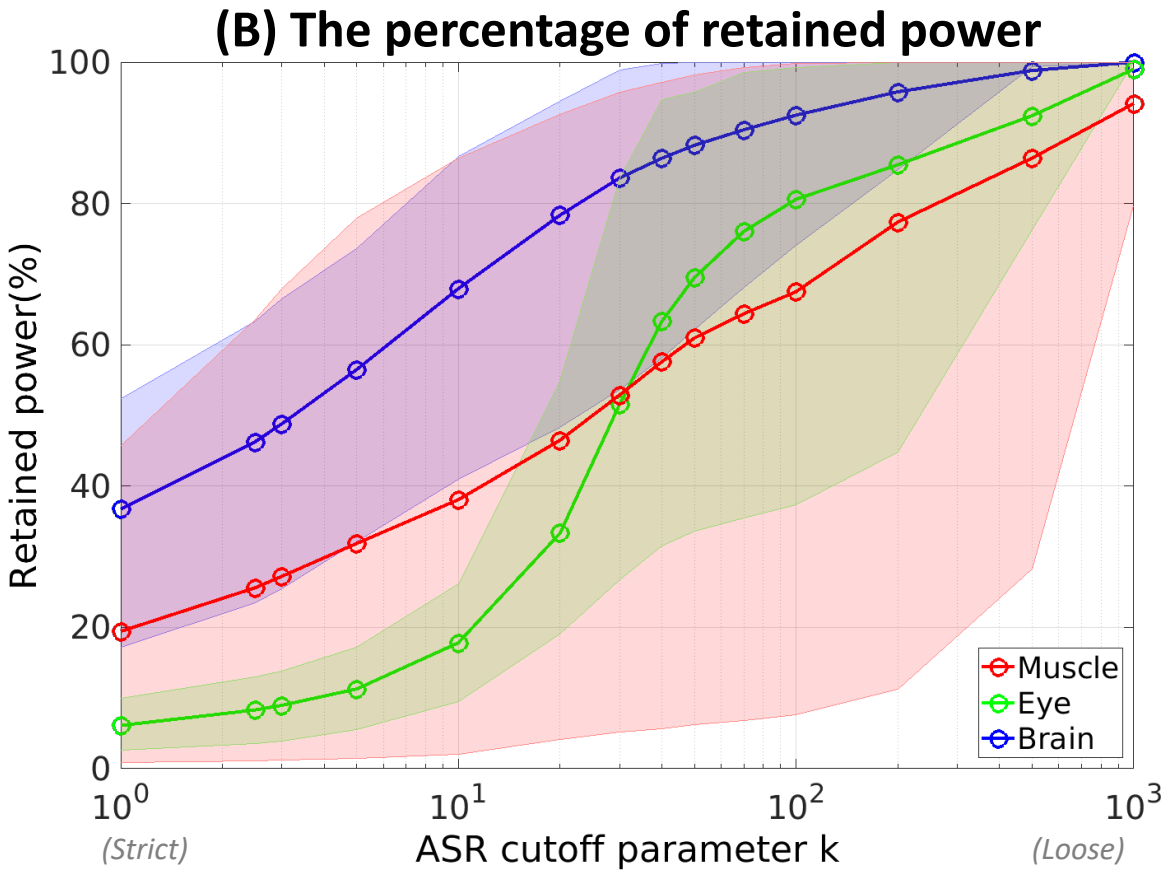


(B) The percentage of retained power



Changes in IC activities (a Group Study)





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An Experiment Paradigm for an Online Evaluation

- Cued-artifact experiment: Motion-related artifacts

Artifact-free Oddball Experiment

Eye Closed Resting → Audio Oddball Experiment

180 sec | 180 sec

Target artifacts:
Turning head
Nodding
Walking

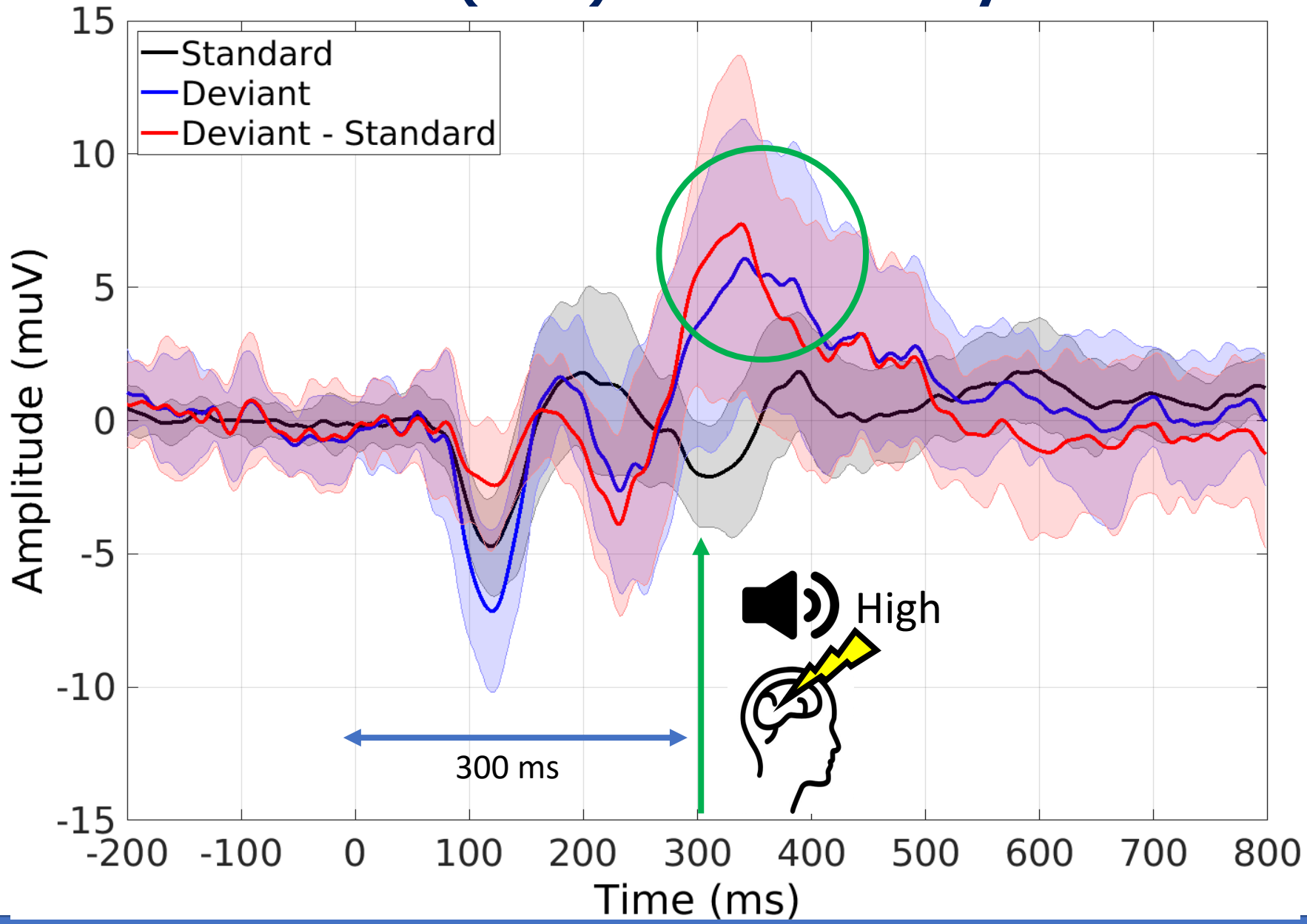
Block 1 & 2

Eye Open Resting → Head Turning @1 Hz → Eye Open Resting → Nodding @1 Hz → Eye Open Resting → Eye Open Standing → Walking @1.5 Hz

80 sec

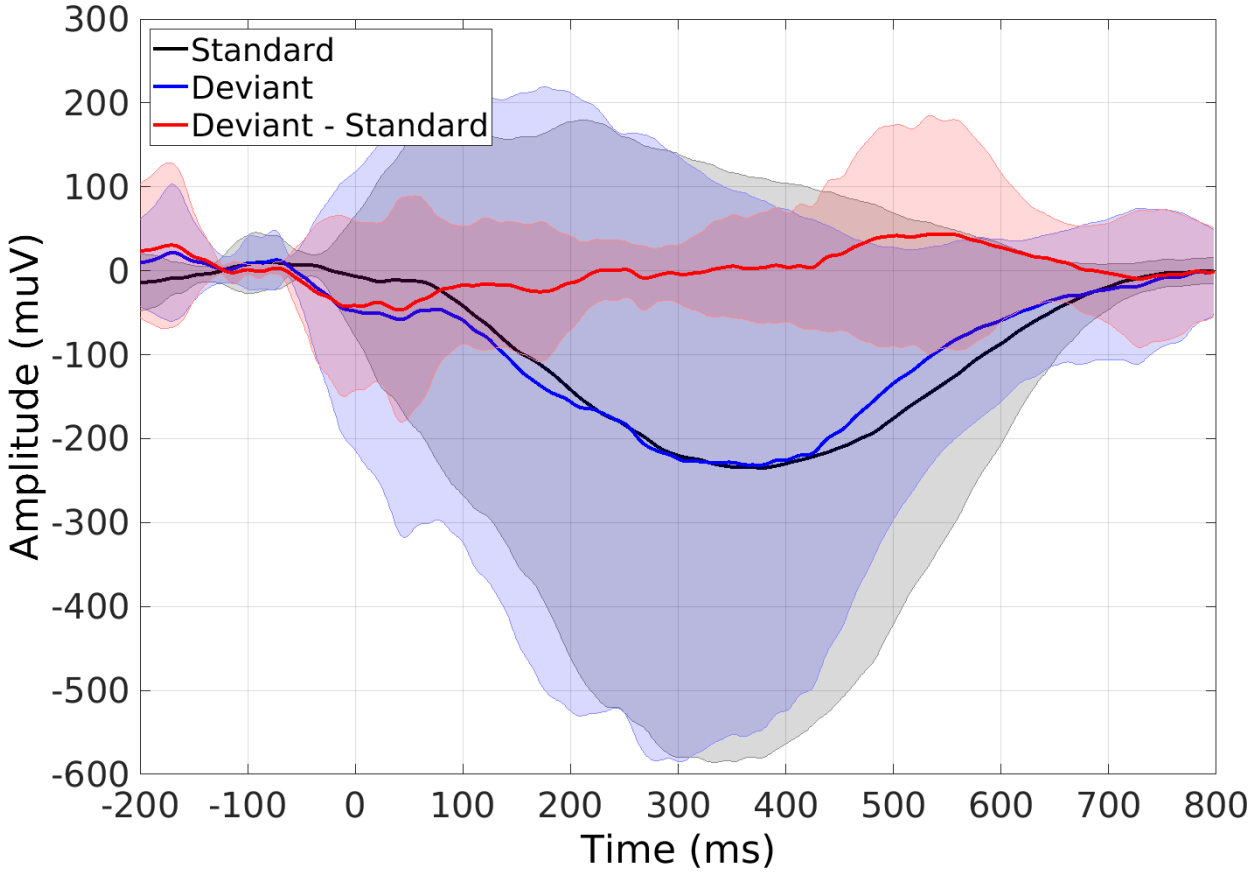
Audio oddball experiment is implemented in each session.

Event-Related Potential (ERP) in an Auditory Oddball Experiment

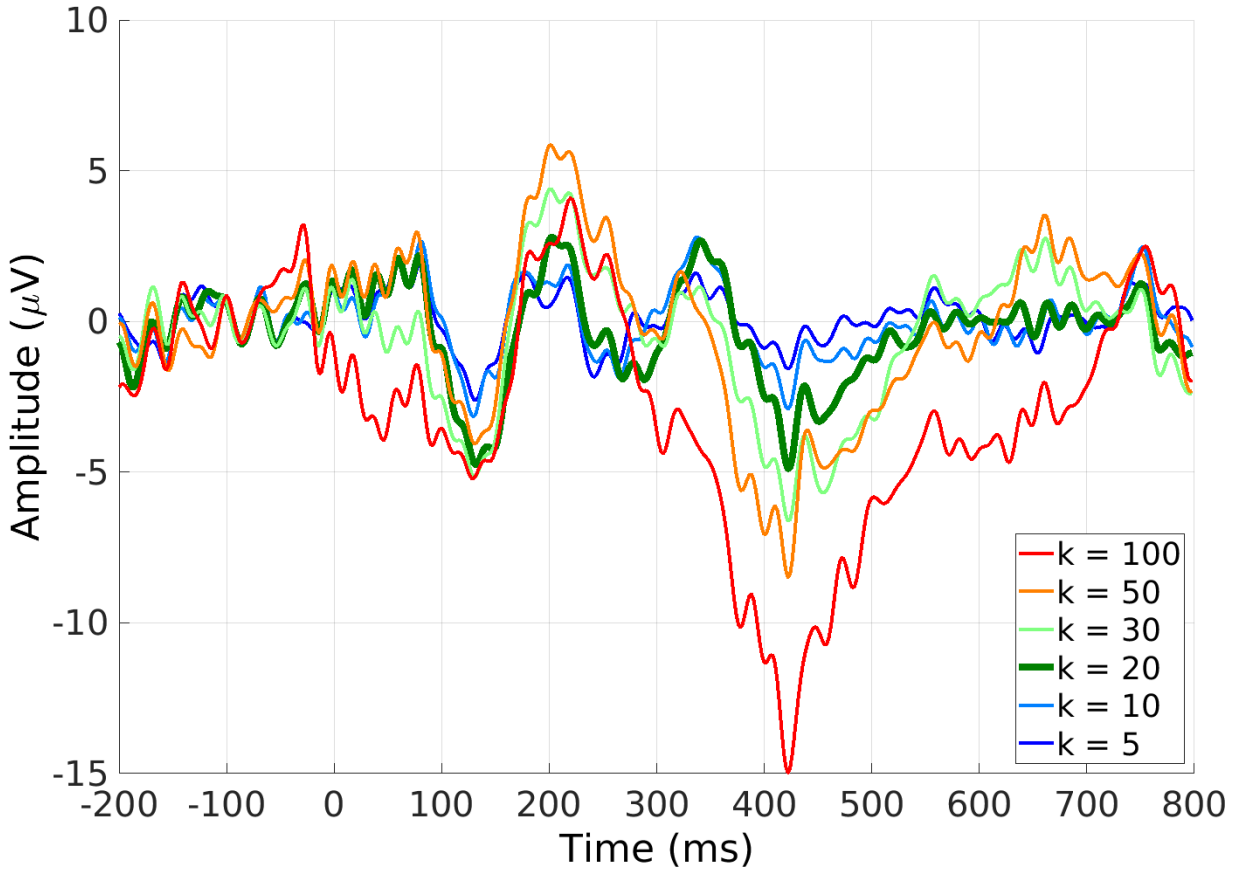


Recover P300 at Cz with ASR during Head Nodding

After FIR band pass filter [1 50]

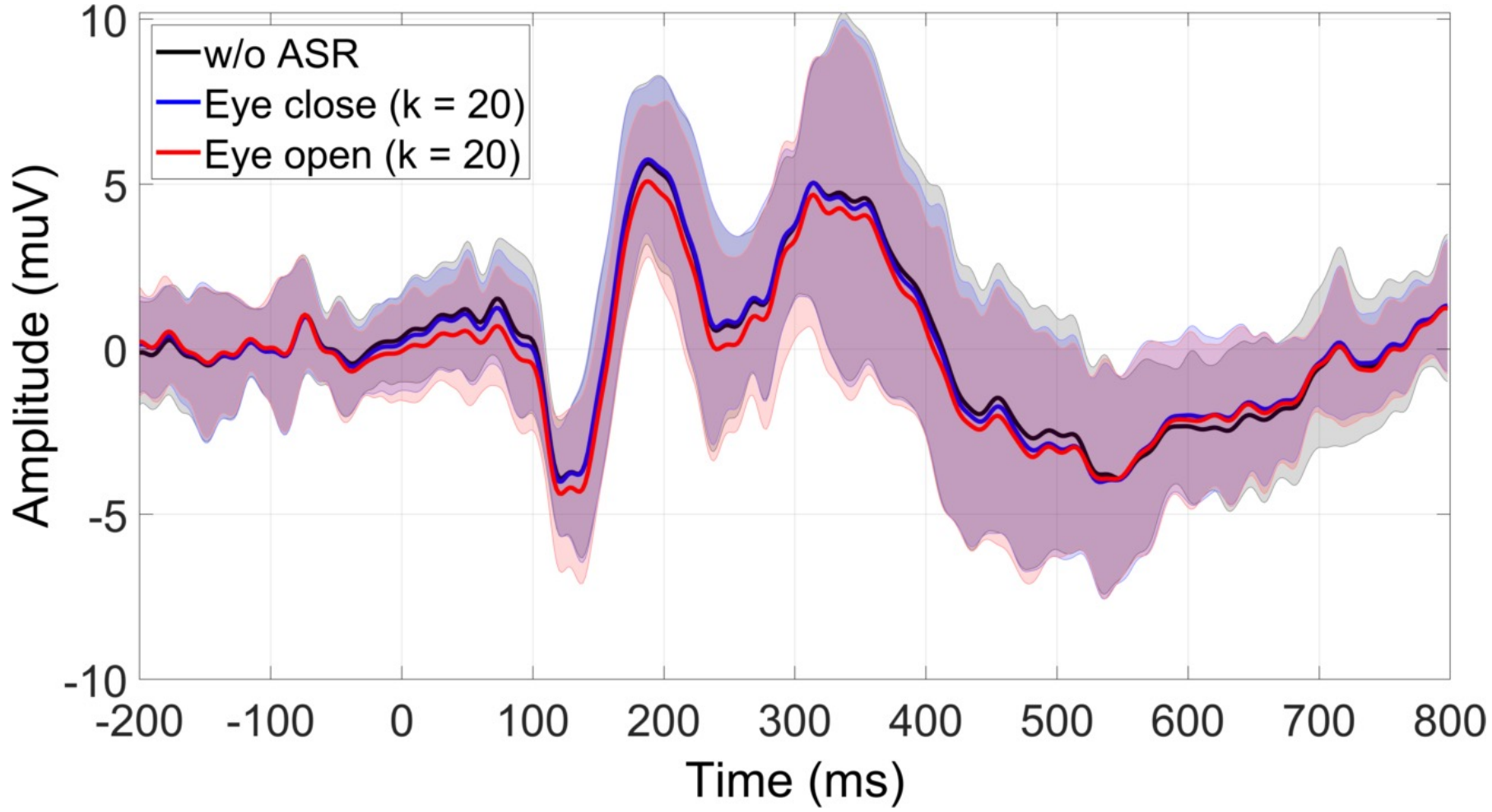


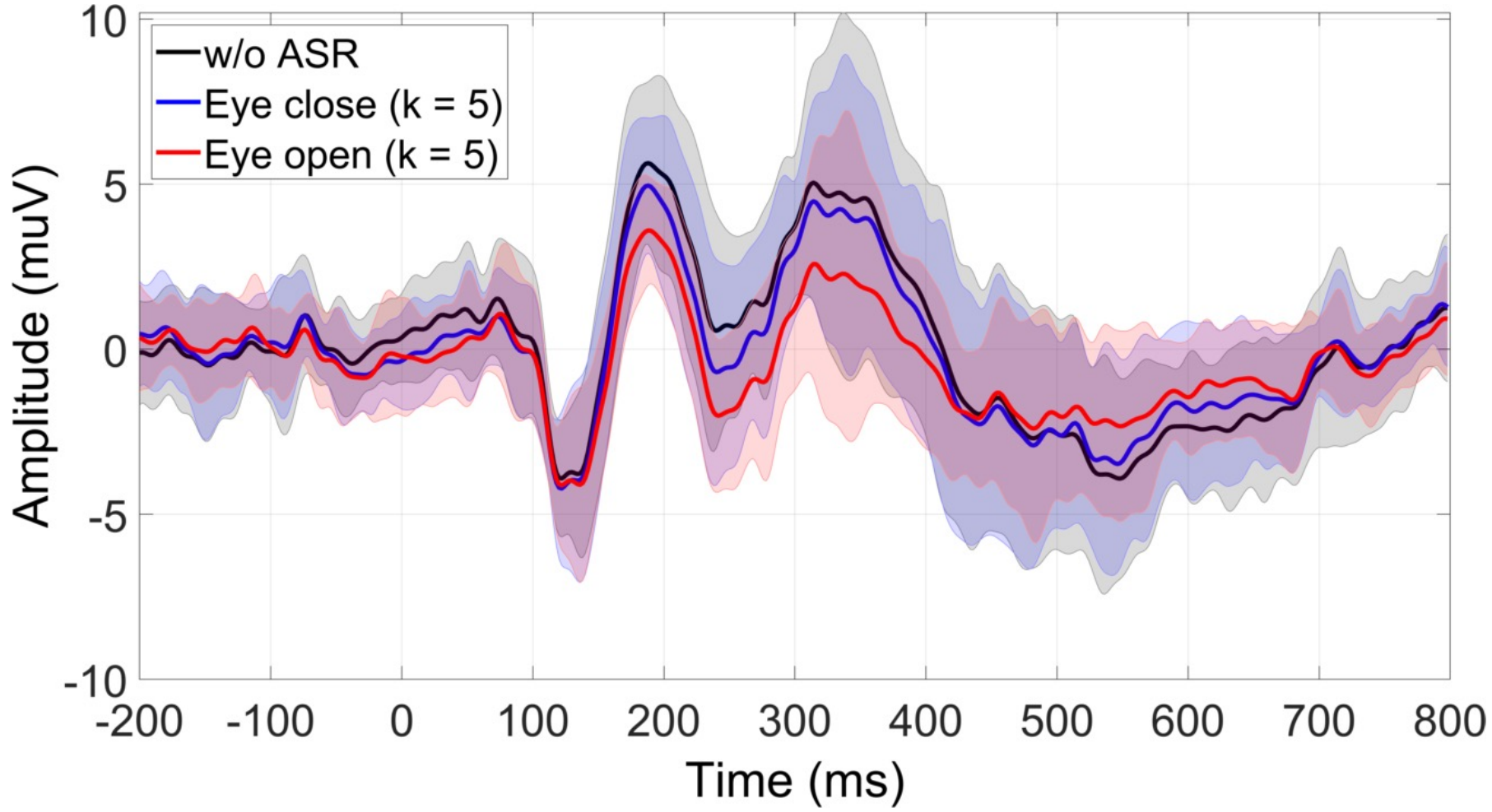
After ASR with different cutoff parameter



Summary

- ASR is an **automatic**, **online-capable**, **artifact-removal** method.
- ASR with a mild threshold (k = 100) could effectively remove large-amplitude artifacts.
- Previously suggested threshold (k = 5-7) could remove up to 50% of brain signal's power.
- This study suggested that a sensible ASR cutoff parameter k might be between **20 to 30.**


w/o ASR
Eye close (k = 20)
Eye open (k = 20)
Amplitude (muV)
10
5
0
-5
-10
-200
-100
0
100
200
300
400
500
600
700
800
Time (ms)


w/o ASR
Eye close (k = 5)
Eye open (k = 5)
Amplitude (muV)
10
5
0
-5
-10
-200
-100
0
100
200
300
400
500
600
700
800
Time (ms)