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# PSEUDO ONLINE FRAMEWORK

I. Carrara<sup>1,2\*</sup>, T. Papadopoulo<sup>1, 2</sup>

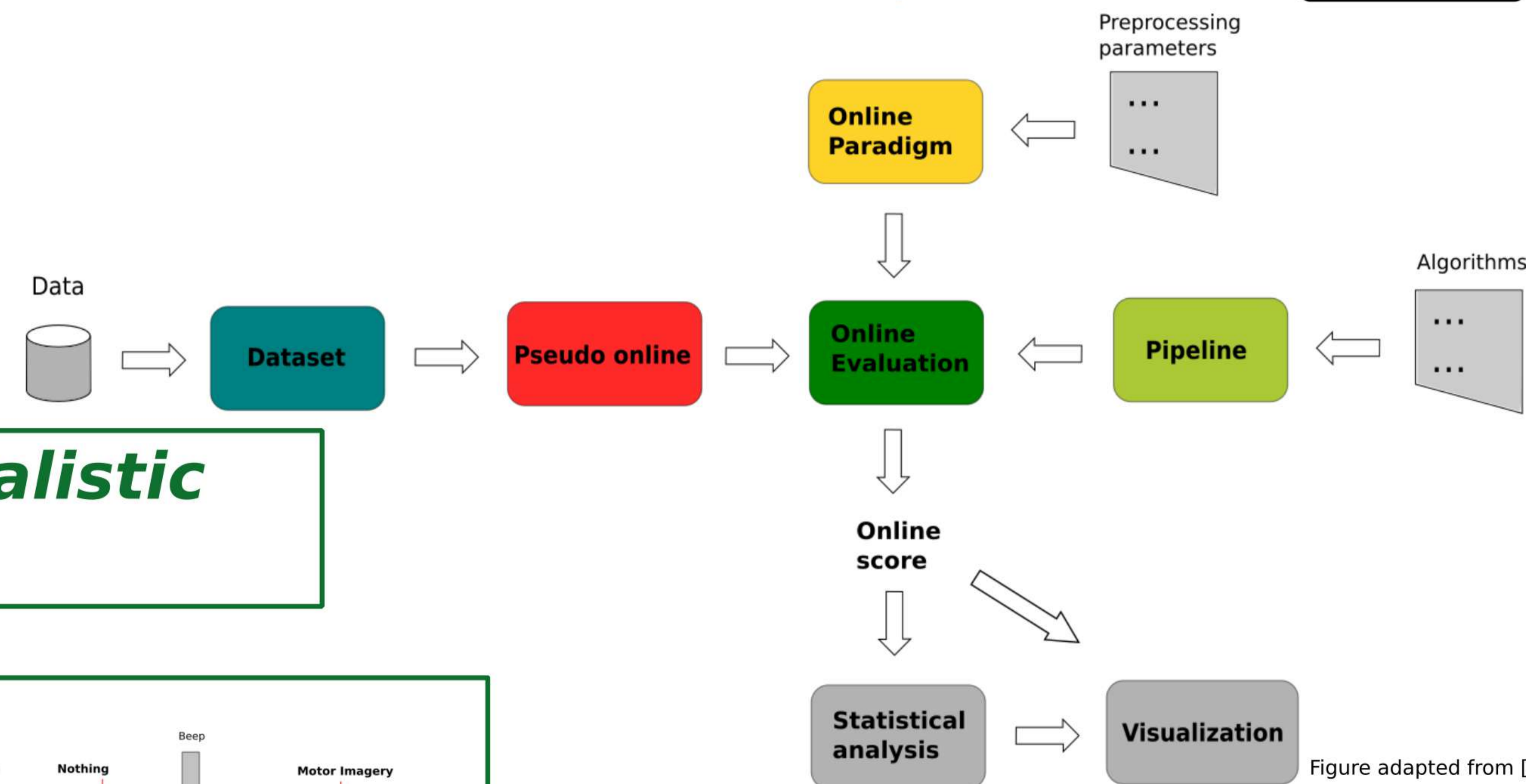
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BCI can be defined as a technology that measures brain activity and translates that signal into instructions for a digital system. We focus on **non-invasive (EEG)-based BCI (BCI-EEG)**.

A BCI technology can operate in 3 different modalities: **online mode** which requires to constantly analyze the new EEG real-time input data, **offline** which post-processes the signal acquired in a first stage and, lastly **pseudo-online** which uses the same two-stage approach as in the offline mode but post-processes the data incrementally as if they were received by the online mode.

Most studies concerning BCI are tested in **offline mode**, thus generating unrealistic performance compared to real-life scenario [1].



## Can a Pseudo-Online framework allow a more realistic algorithm performance comparison?

### METHODS

Idea: extend the current MOABB [2] framework developed for offline analysis with a pseudo-online mode.

Working on 4 level:

#### Dataset conversion:

BCI datasets used in MOABB were recorded to perform an offline analysis. The first step is to transform them to introduce a **nothing even** [3].

#### Evaluation:

Change **Within-Session** evaluation of MOABB to remove the use of **Cross Validation** in order to keep causal relation on the data. Use the common split of the dataset into a training dataset (80%) and a test dataset (20%).

Unchange Cross-Session and Cross-Subject evaluation.

#### Asynchronous Mode:

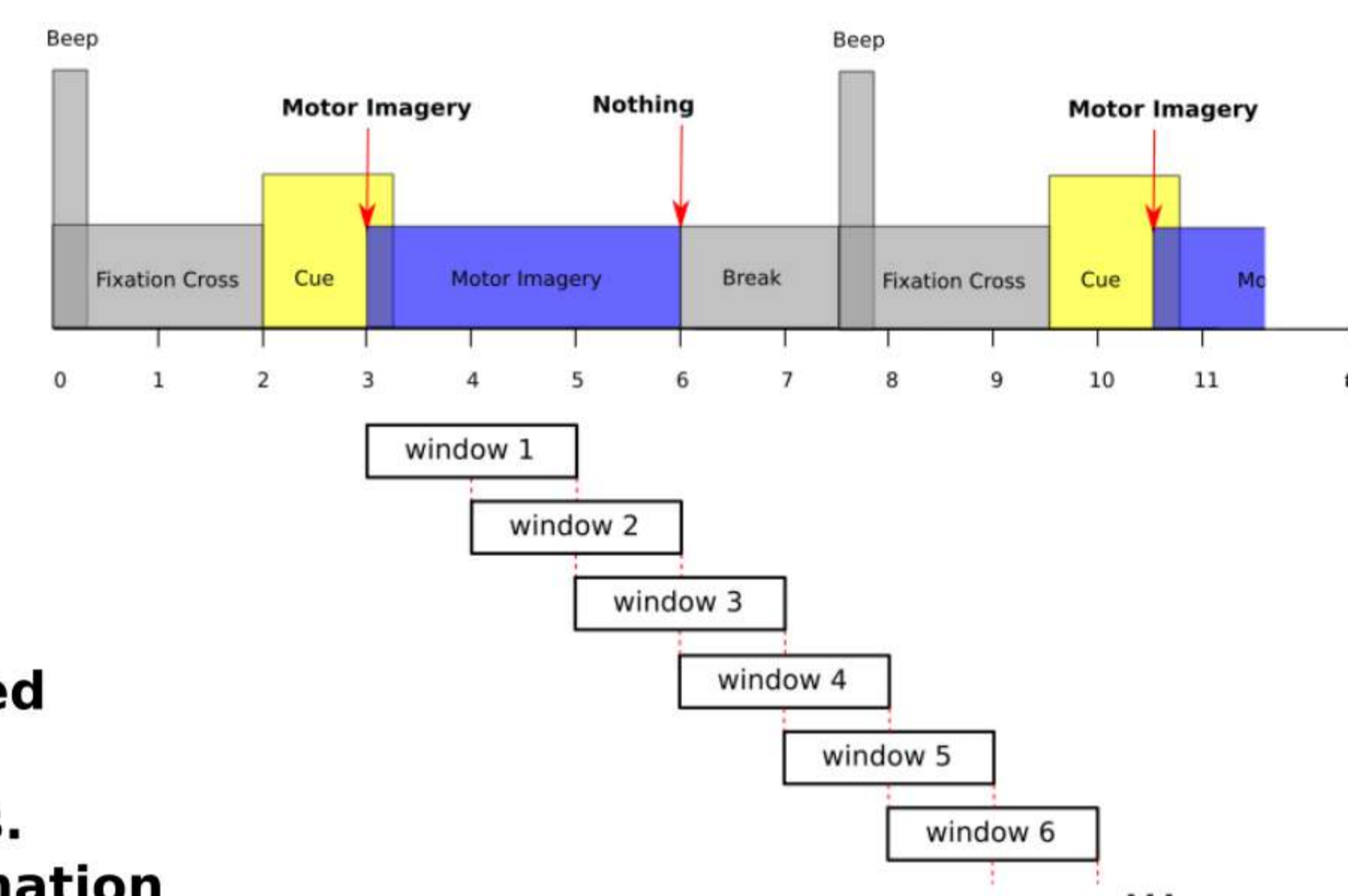
use an **overlapping sliding windows** approach (dealing with mixed events) to have a performance evaluation much closer to a real BCI application.

#### Metrics:

Such constructed datasets are **strongly unbalanced with respect to the nothing event**. Accuracy is not very meaningful in such cases. Use **Matthew Correlation Coefficient** and **Information Transfer Rate** instead [4, 5].

$$nMCC = \frac{1}{2} \left( \frac{TP \times TN - FP \times FN}{\sqrt{(TP + FP)(TP + FN)(TN + FP)(TN + FN)}} + 1 \right)$$

$$ITR = MI(X, Y) \frac{60}{T}$$



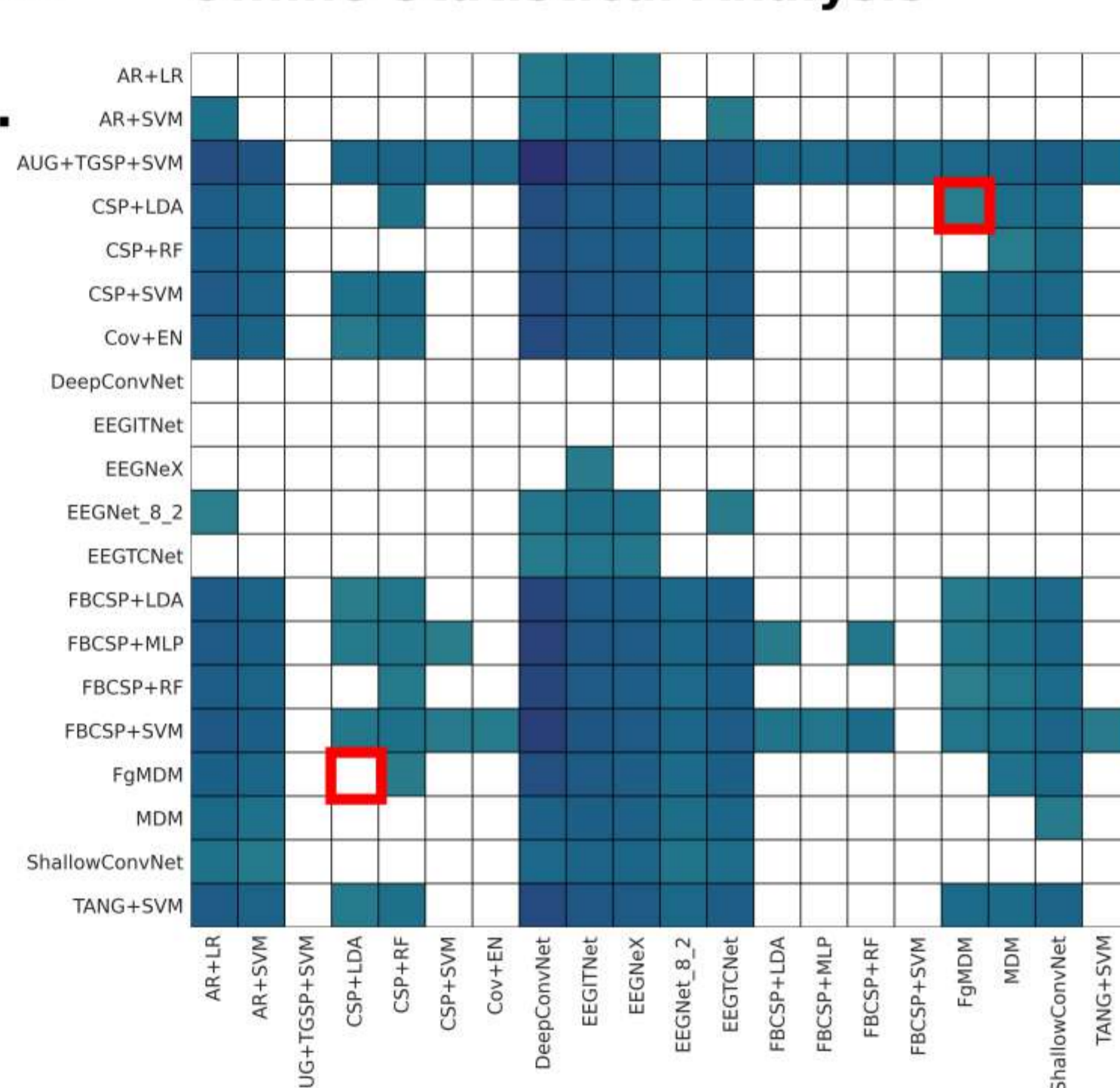
### RESULTS

We considered four **Motor Imagery BCI datasets** consisting of several subjects for each dataset and several sessions. We tested different methods on **different tasks** and **different evaluation procedures**.

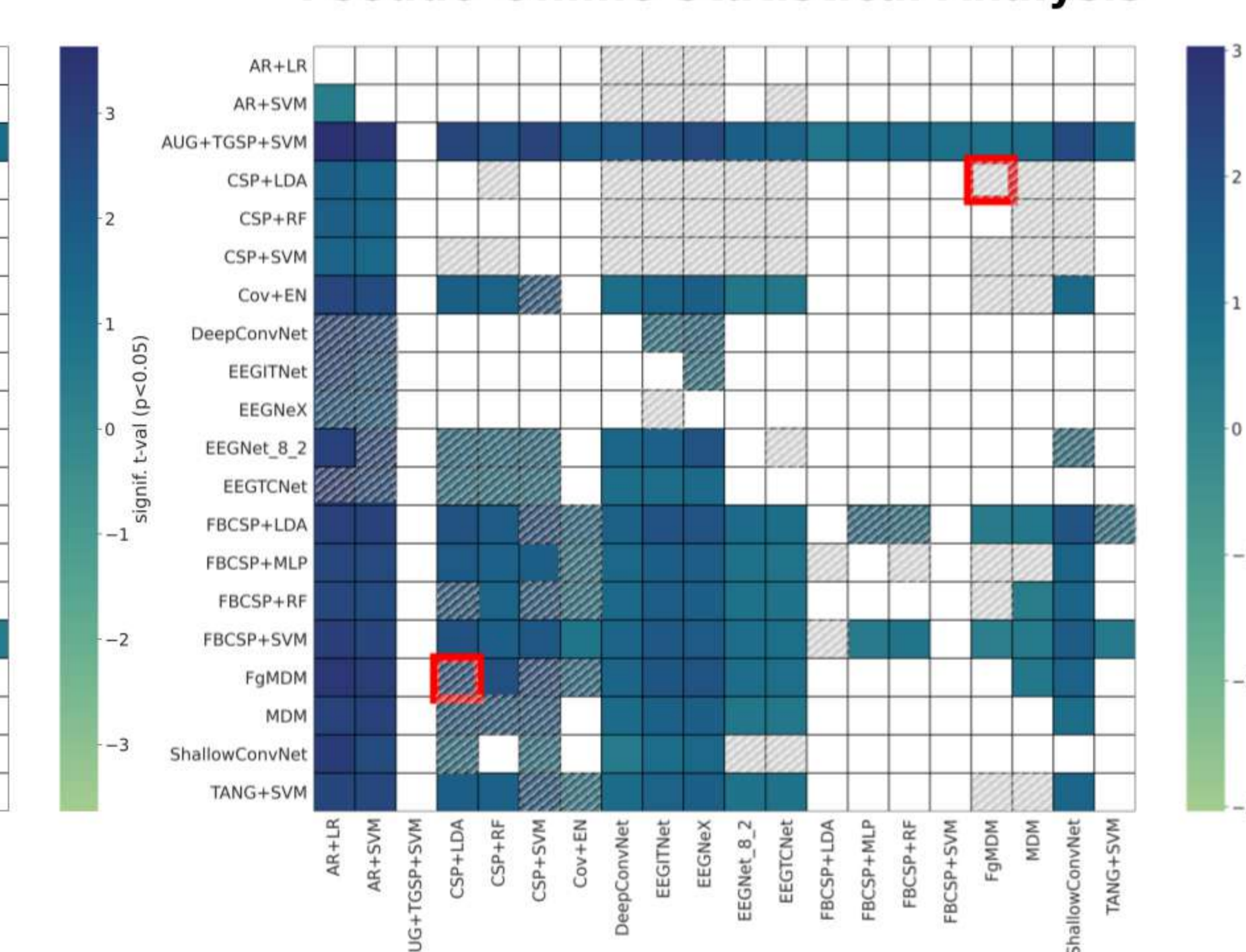
Dataset	Subjects	Channels	Sampling Rate	Sessions	Tasks
BNCI2014001	9	22	250 Hz	2	4
BNCI2015001	12	13	512 Hz	1	2
BNCI2014002	14	15	512 Hz	5	2
BNCI2014004	9	3	250 Hz	1	2

Example of a 3 tasks problem (RH/LH/nothing or RH/F/nothing) for the datasets in the bold red box.

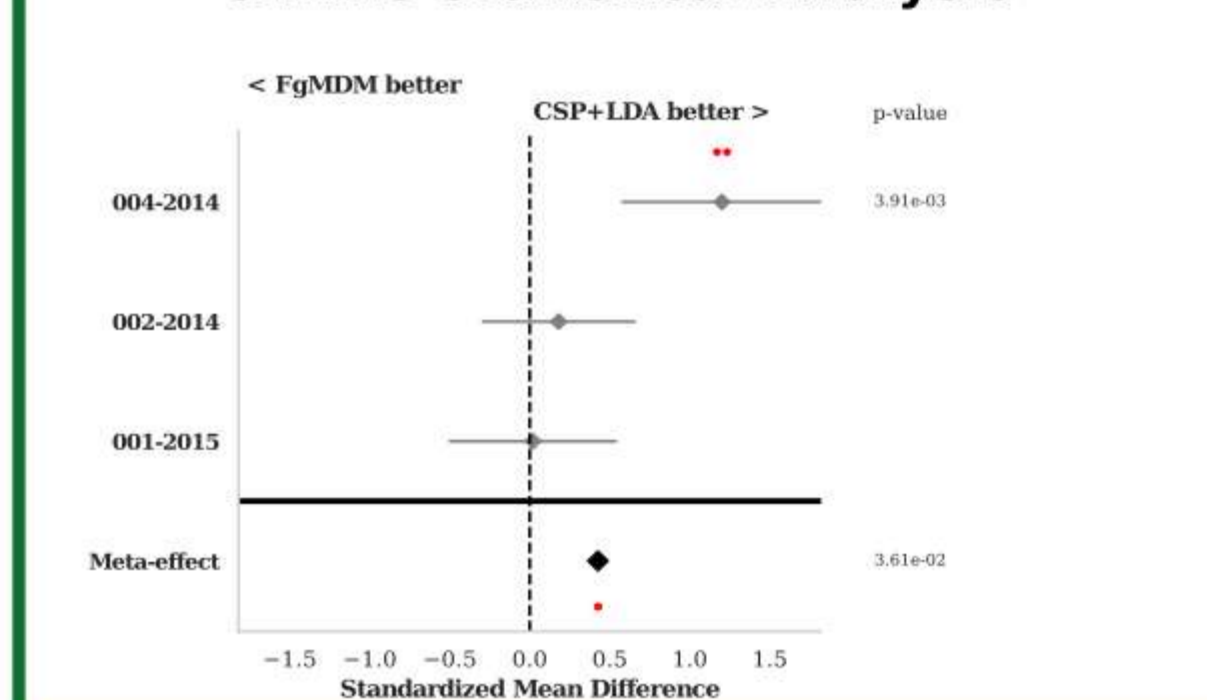
#### Offline Statistical Analysis



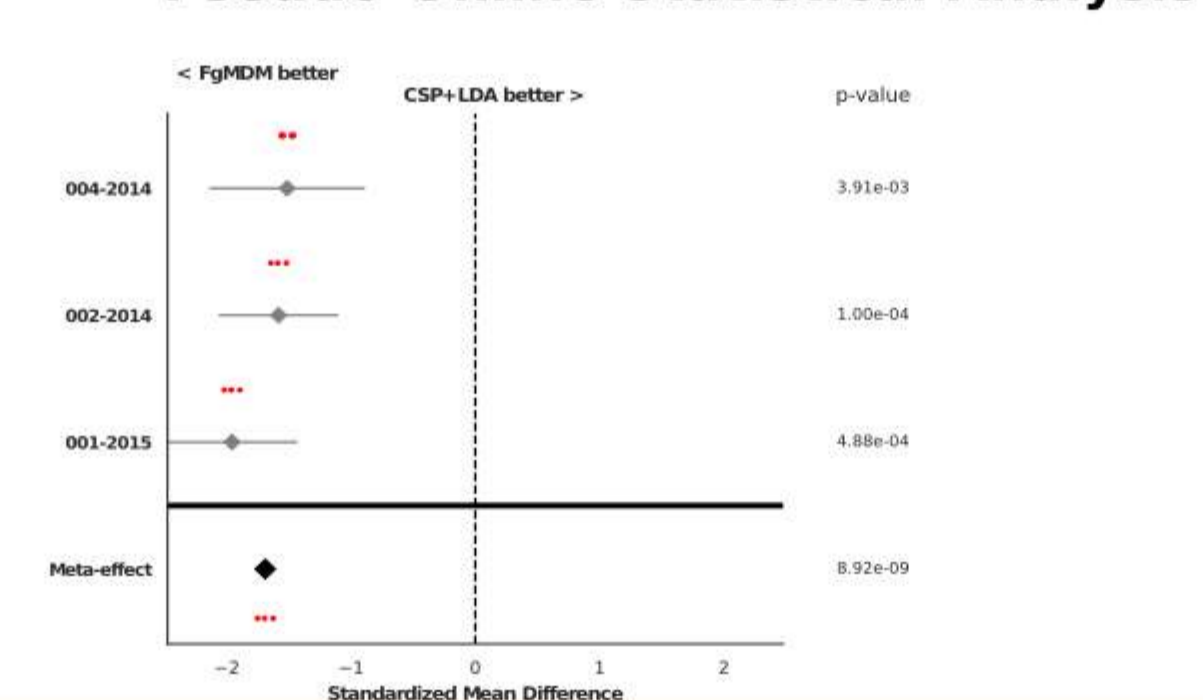
#### Pseudo-Online Statistical Analysis



#### Offline Statistical Analysis



#### Pseudo-Online Statistical Analysis



### TAKE HOME MESSAGE

The possibility of analyzing the performance of different algorithms **first offline**, followed by **subsequent validation of performance in pseudo-online mode**, will be able to **speedup advancement of performance of classification algorithms of the BCI community in real time application**. The code will be soon **integrated in MOABB**.

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#### References:

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- [2] Jayaram, Vinay, and Alexandre Barachant. "MOABB: trustworthy algorithm benchmarking for BCIs." Journal of neural engineering 15.6 (2018): 066011.
- [3] EB Sadeghian et al. "Continuous detection of motor imagery in a four-class asynchronous BCI." 2007 29th Annual International Conference of the IEEE Engineering in Medicine and Biology Society. IEEE, 2007.
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- [5] Delgado, Rosario, and Xavier-Andoni Tibau. "Why Cohen's Kappa should be avoided as performance measure in classification." PloS one