Surrogate modelling to study E/I imbalances in children with Developmental Dyslexia

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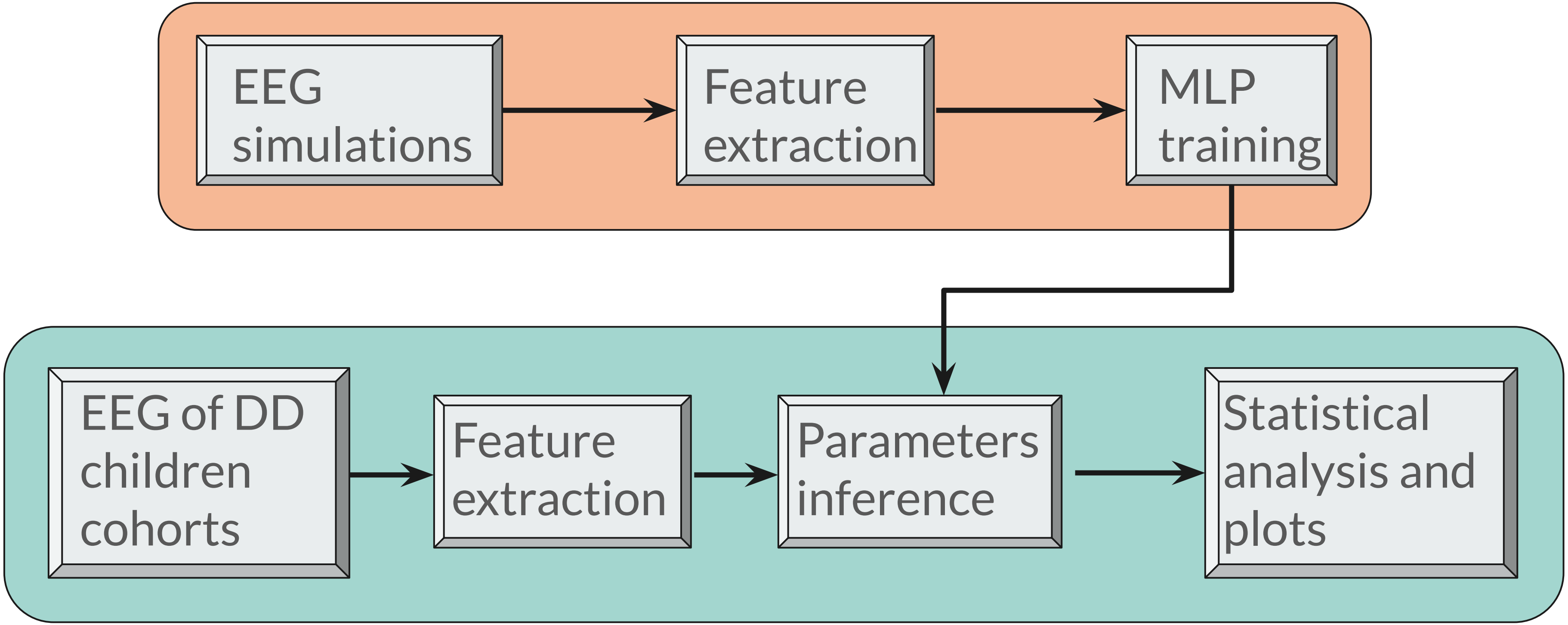
We apply a framework that combines **brain activity simulation** with **machine learning** to detect imbalances in the ratio of **excitation and inhibition** (E/I) through **electroencephalography** (EEG) signals in children with **Developmental Dyslexia** (DD).

This approach enables us to understand the mechanisms associated with this disorder and act in the early stages of children's development, avoiding problems that may occur in their academic or social lives.

Methodology



1.- Training

Generic recurrent network model of **excitatory** (E) and **inhibitory** (I) **integrate-and-fire** neuronal populations, driven by external fixed-rate Poisson processes.

2×10^6 simulations were performed varying the following parameters :

- J_{EE}, J_{EI}, J_{IE}, J_{II}, $\tau_{syn\ E}$, $\tau_{syn\ I}$, J_{ext}

Defined **$E/I = (J_{EE}/J_{EI})/(J_{IE}/J_{II})$** to capture the global E/I ratio.

Convolved spike rates with spatiotemporal filter kernels (*LFPykernels*) to estimate **current dipole moment** from a **ball-and-sticks multicompartment** neuron network.

Extracted features from EEG simulations and trained a Multi Layer Perceptron to infer model's parameters. The training of the MLP was performed using 20 repeats of 10-fold cross validation.

Hagen, E., Magnusson, S.H., Ness, T.V., Halnes, G., Babu, P.N., Linssen, C., Morrison, A., Einevoll, G.T.: Brain signal predictions from multiscale networks using a linearized framework. PLOS Computational Biology 18(8), 1–51 (08 2022).

2.- Database

50 children having 7 years:

- 31 Control subjects
- 19 Subjects with Developmental Dyslexia

EEG cap with 31 electrodes following 10-20 system.

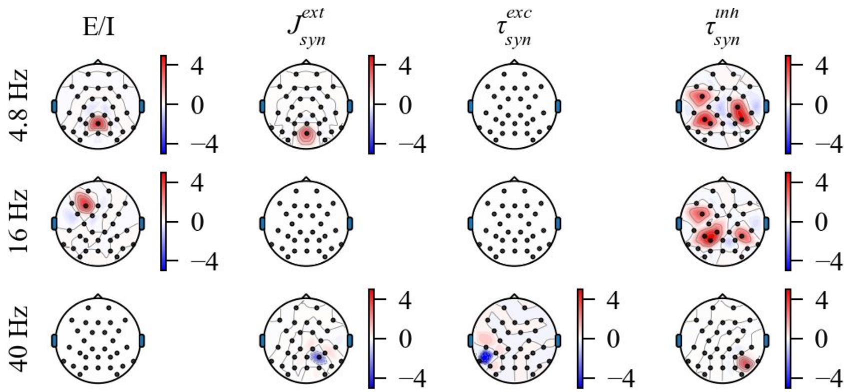
Resting state while receiving ASSR-like auditory stimuli of **three different frequencies**:

- 4.8 Hz
- 16 Hz
- 40 Hz

Progressive increase 4.8 Hz -> 40 Hz and then returned to 4.8 Hz

The data used in this research were provided by the LEEDUCA research group at the University of Malaga (Spain) [www.leeduca.uma.es].

3.- Results

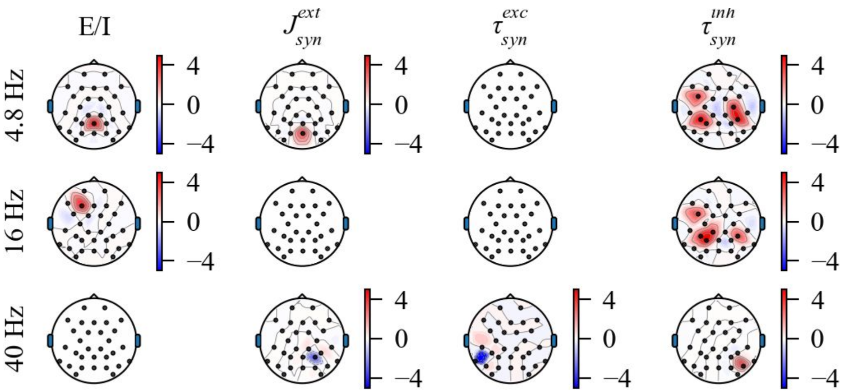


catch22 features were extracted for each frequency to every subject and then inference the simulation model parameters.

Linear Mixed Effects models with group membership and sensor location as fixed effects and individuals ID as random effect.

Then applied marginal means for each group and electrode followed by a pairwise comparison between DD and Control groups for each electrode and computed p-value using **Holm-Bonferroni** correction.

3.- Results



↑ **E/I** in parietal (4.8 Hz) & frontal (16 Hz)

↑ **Jext** (4.8 Hz) in occipital regions.

↓ **Jext** (40 Hz) in parietal zones.

No significant differences (4.8 Hz & 16 Hz).

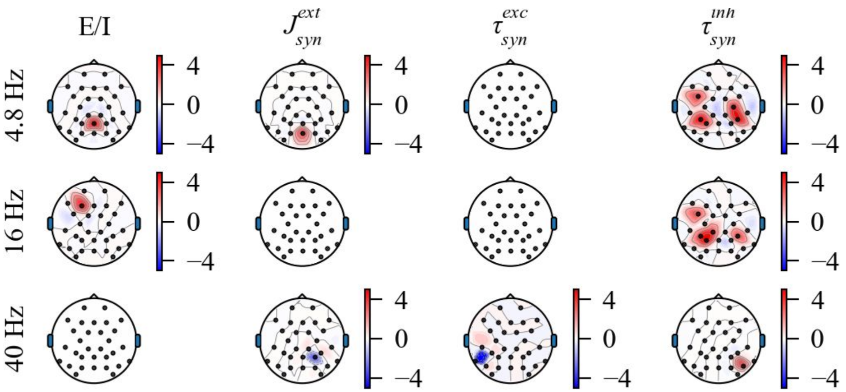
↑ **τexc** (40 Hz) in temporo-parietal.

Most significant differences across electrodes.

↑ **τinh** (4.8 Hz) in frontal & parietal-central.

Higher frequencies → effects localized to fewer electrodes.

3.- Results

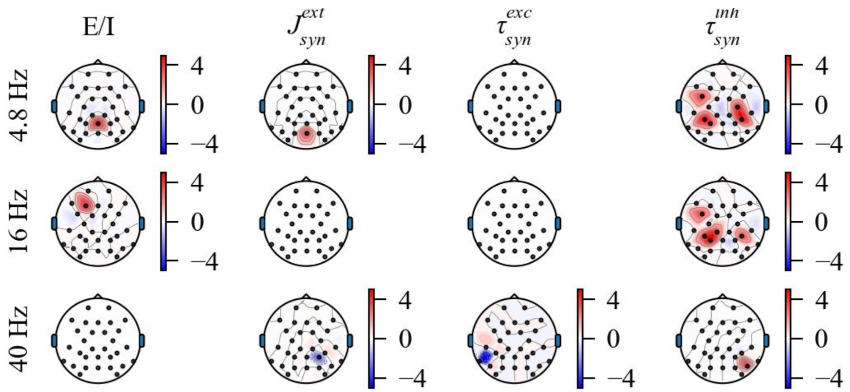


Increase in E/I in parietal and frontal regions -> Neural Noise Hypothesis in Dyslexia

Increment of $\tau_{syn\ I}$ in frontal and parietal-central for 4.8 Hz. Significant differences decreases as stimuli increases.

Delayed responses of inhibitory currents due to increment of $\tau_{syn\ I}$ also aligns with Neural Noise Hypothesis in Dyslexia.

3.- Results



Temporal Sampling Framework hypothesis -> deficit in syllables processing which is associated with the Theta band (4-7 Hz)

Decrease of significant differences -> phoneme segmentation

4.- Conclusions

Combined simulation with machine learning to study E/I imbalances through EEG recording and applied to a cohort of children.

Obtained results that align with the neural noise hypothesis in Dyslexia and the temporal sampling framework.

It is interesting for the future to use brain models that captures large-scale brain activity and try different features libraries to identify other EEG proxy markers.

Thanks!