

LEGNet: A Lesion-aware Edge-based GNN for Predicting Language Ability in Patients with Post-stroke Aphasia

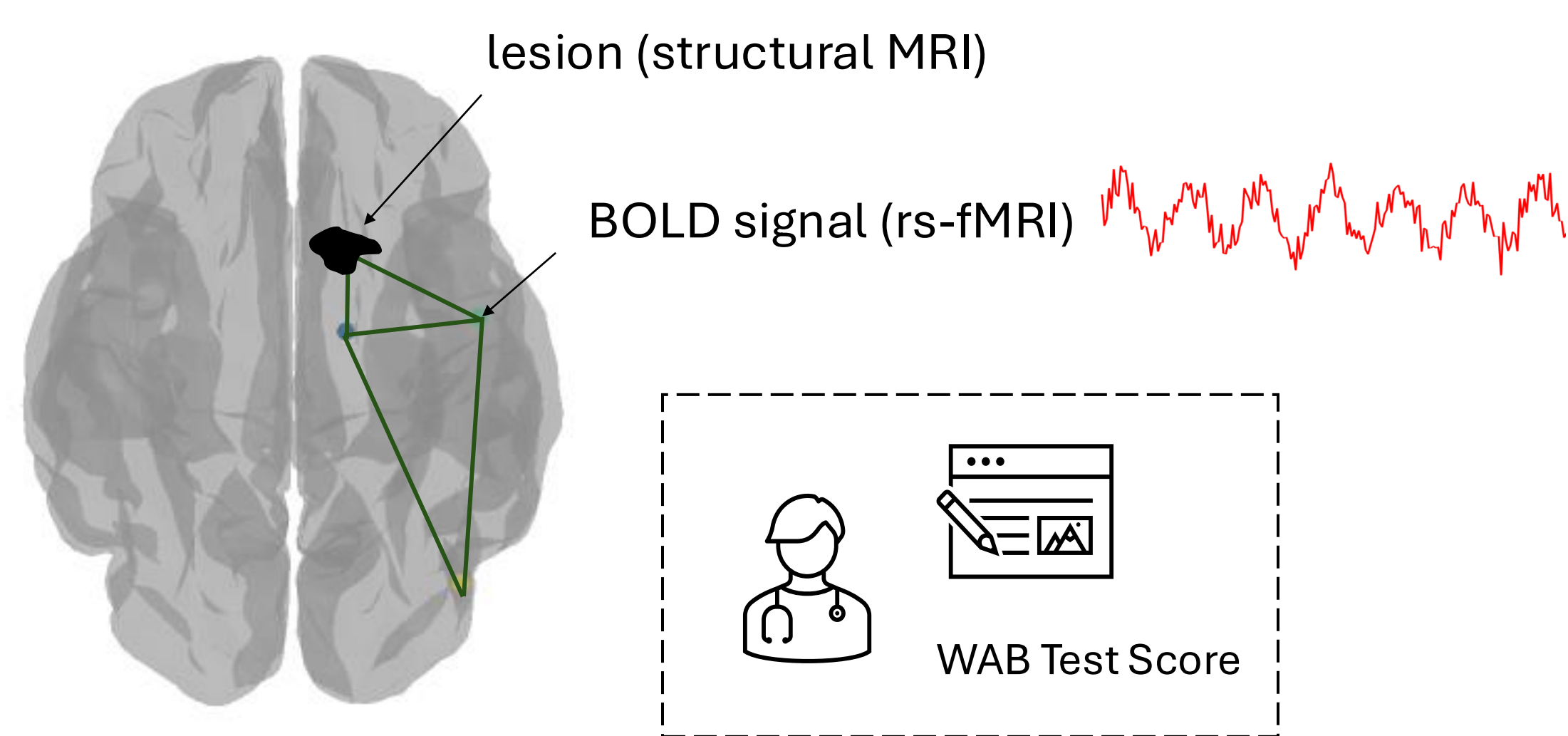
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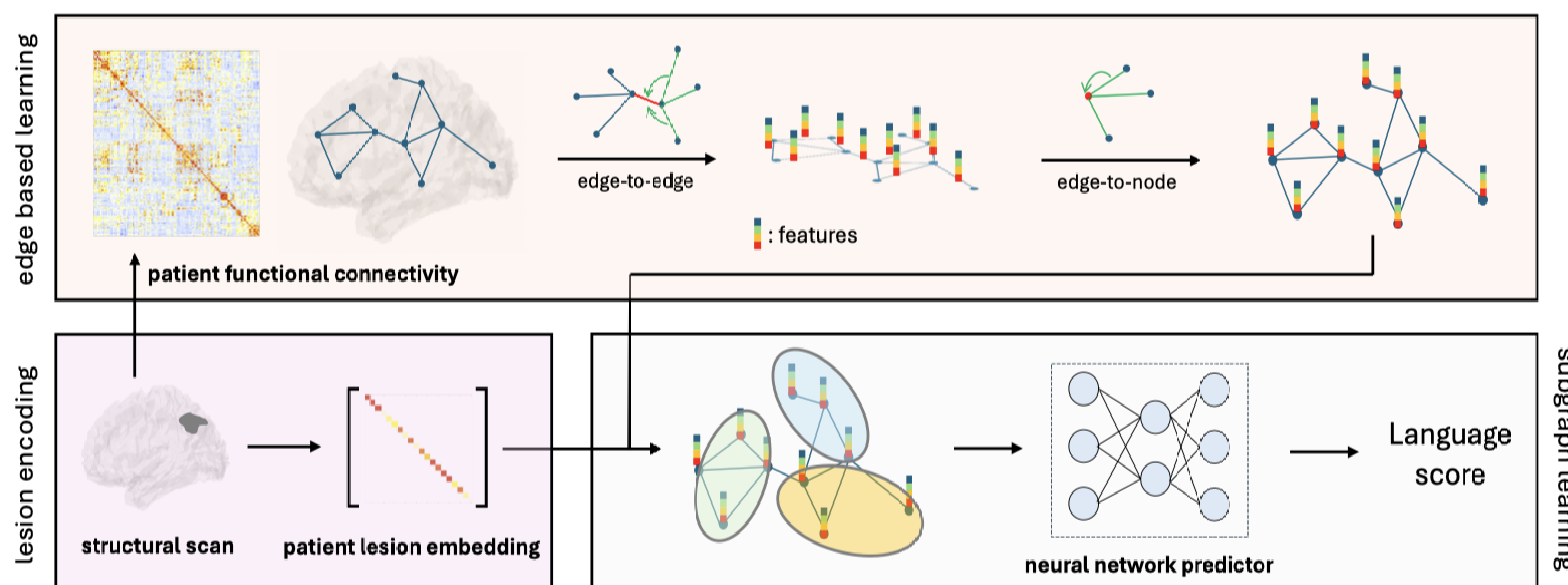


Background



- **Main objective:** prediction of language ability in post-stroke aphasia patients with mainly rs-fMRI scans, guided by structural information.
- **Available modalities:** structural MRI (stroke lesion), rs-fMRI, Western Aphasia Battery (WAB) test scores (0~100, the higher the better).
- **rs-fMRI:** measuring co-activation of brain regional activities.
- **WAB test component:** speech, verbal comprehension, repetition, naming, etc.

Methods

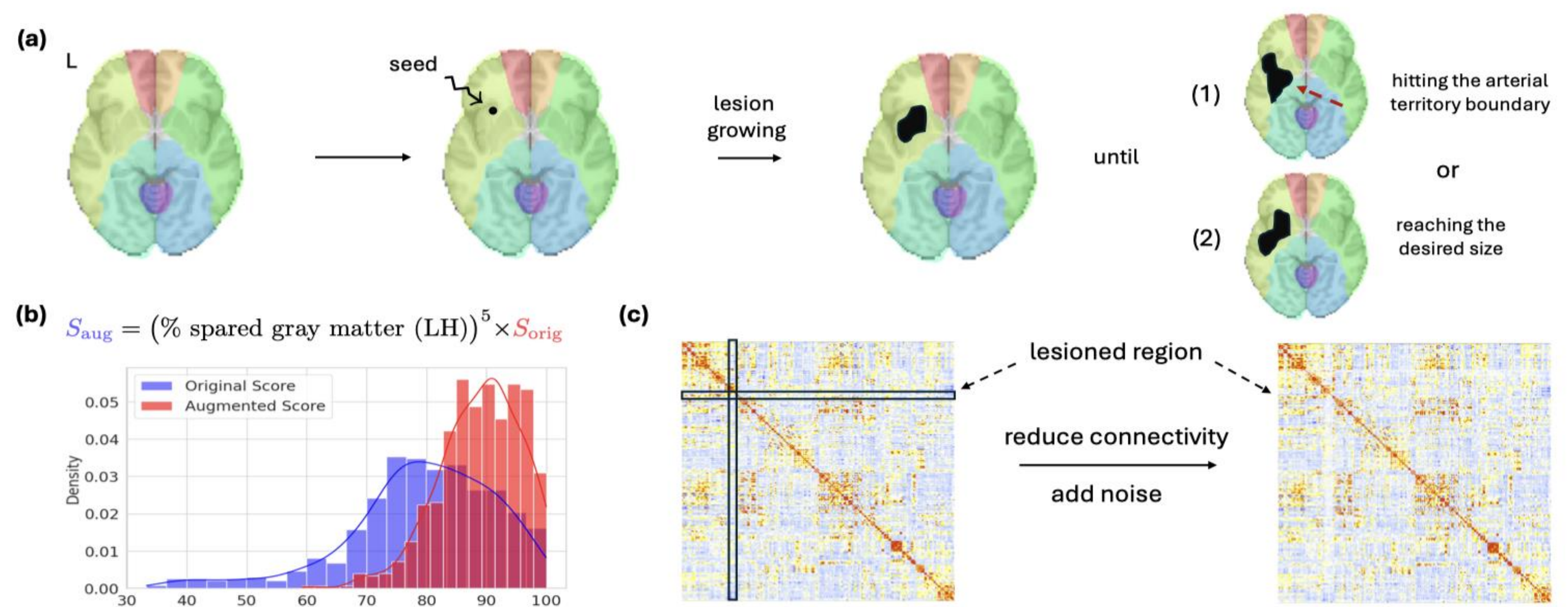


Three-module Graph Neural Network

- **Edge-based learning:** update edge features from neighboring edges and transfer back to nodes (brain regions).
- **Lesion encoding:** percentage spare gray matter of each region embedding.
- **Subgraph learning:** Regions with similar lesion encoding and contributions to the prediction will have similar parameters.

Data Simulation for Pre-training

- **Material:** 700 healthy subjects from HCP
- **Lesion simulation:** 3D random walk from a random seed. Holes inside are filled ad-hoc.
- **Language score:** scaled down version of the in-scan language task accuracy (by HCP).
- **Connectivity:** voxels are masked out by lesions; connection strengths are reduced; noise added.



Results

Validation (10 repeated 10-fold CV) on DS-1

Method	RMSE	MAE	R ²	Corr Coef
LEGNet	17.38 ± 0.44	12.56 ± 3.02	0.35 ± 0.03	0.61 ± 0.03
BrainGNN	19.46 ± 0.30	14.02 ± 2.59	0.29 ± 0.04	0.59 ± 0.02
BNC-m	19.18 ± 1.82	11.61 ± 2.33	0.22 ± 0.05	0.55 ± 0.03
BNC-2c	22.78 ± 0.53	19.41 ± 0.89	0.21 ± 0.10	0.53 ± 0.05
SVR	20.45 ± 0.35	16.85 ± 0.26	0.13 ± 0.05	0.55 ± 0.03
LEGNet(w/o HCP)	18.39 ± 0.68	15.33 ± 0.57	0.29 ± 0.05	0.58 ± 0.04

Testing (best model from validation) on DS-2

Method	RMSE	MAE	R ²	Corr Coef
LEGNet	17.71	8.74	0.19	0.44
BrainGNN	18.52	12.64	0.11	0.34
BNC-m	19.24	12.68	0.04	0.31
BNC-2c	19.70	13.47	0.01	0.28
SVR	18.43	12.56	0.12	0.35
LEGNet(w/o HCP)	18.36	11.26	0.12	0.40

Datasets

DS-1

- Sample size: 52
- Site: BU, NEU, JHU
- Age: 35~80
- WAB: 68.42±23.32
- Time post-stroke: 55 months
- LH stroke, chronic aphasia

DS-2

- Sample size: 18
- Site: BU, MIT
- Age: 35~80
- WAB: 79.28±20.20
- Time post-stroke: 113 months
- LH stroke, chronic aphasia

Conclusions

- Three-module design combining structural and functional info.
- Simulated data pre-training enhances model performance.
- Outperforms state-of-the-art in accuracy and generalization.
- Easily adaptable to tumors, brain resections, etc.
- Explore prediction of post-treatment cognitive states.