

Multiscale Deep Learning Reveals Regional Brain Aging Topography And Its Clinical Relevance In Alzheimer'S Disease

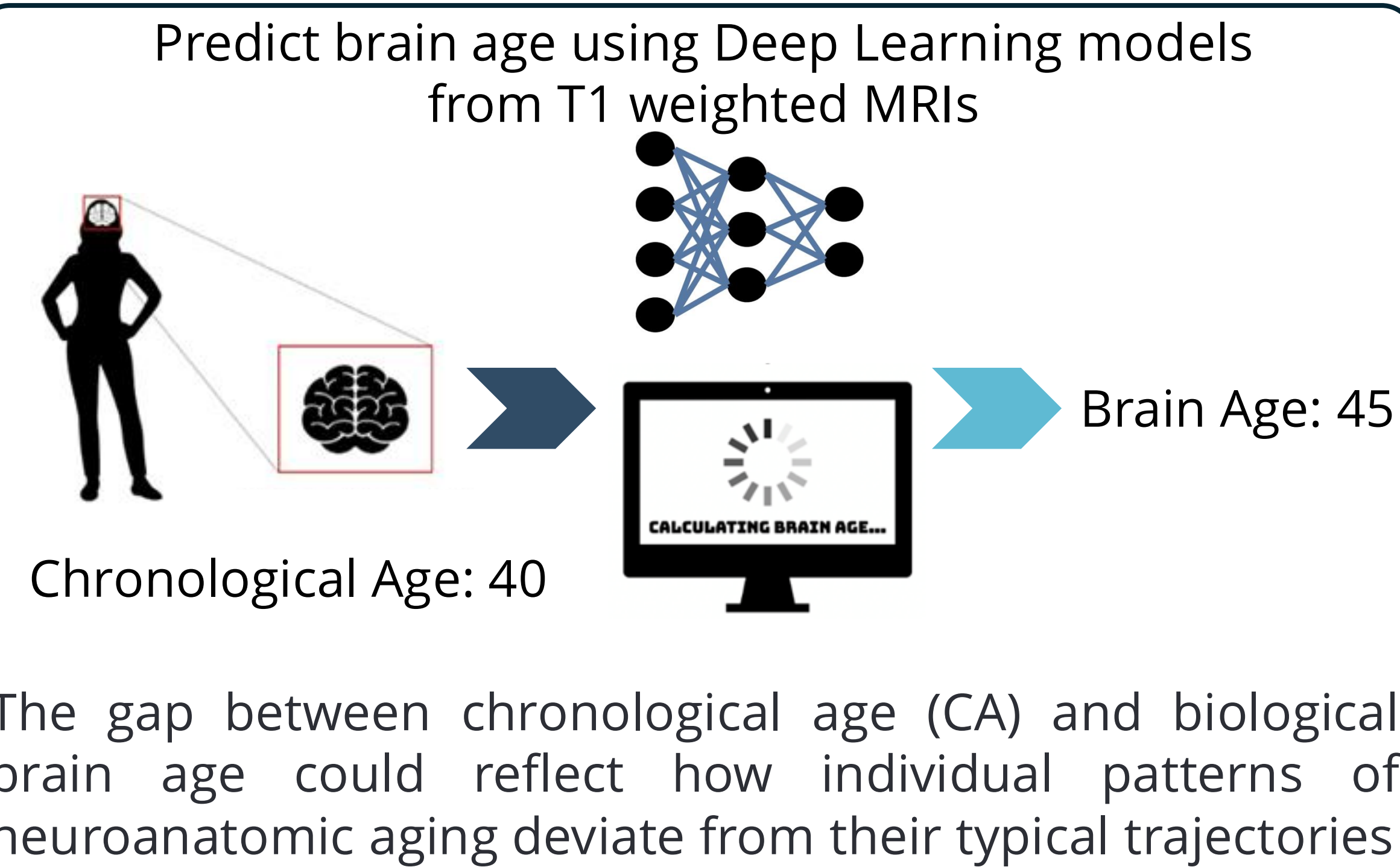
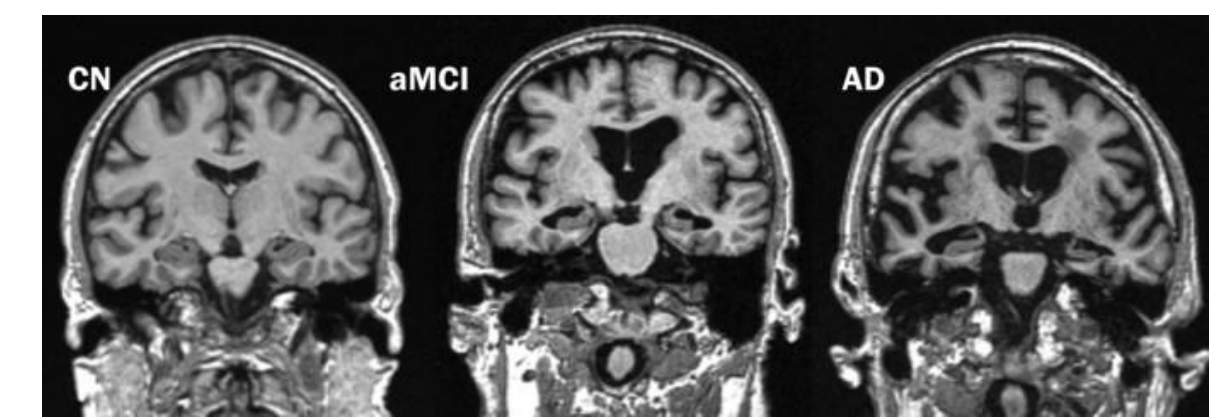
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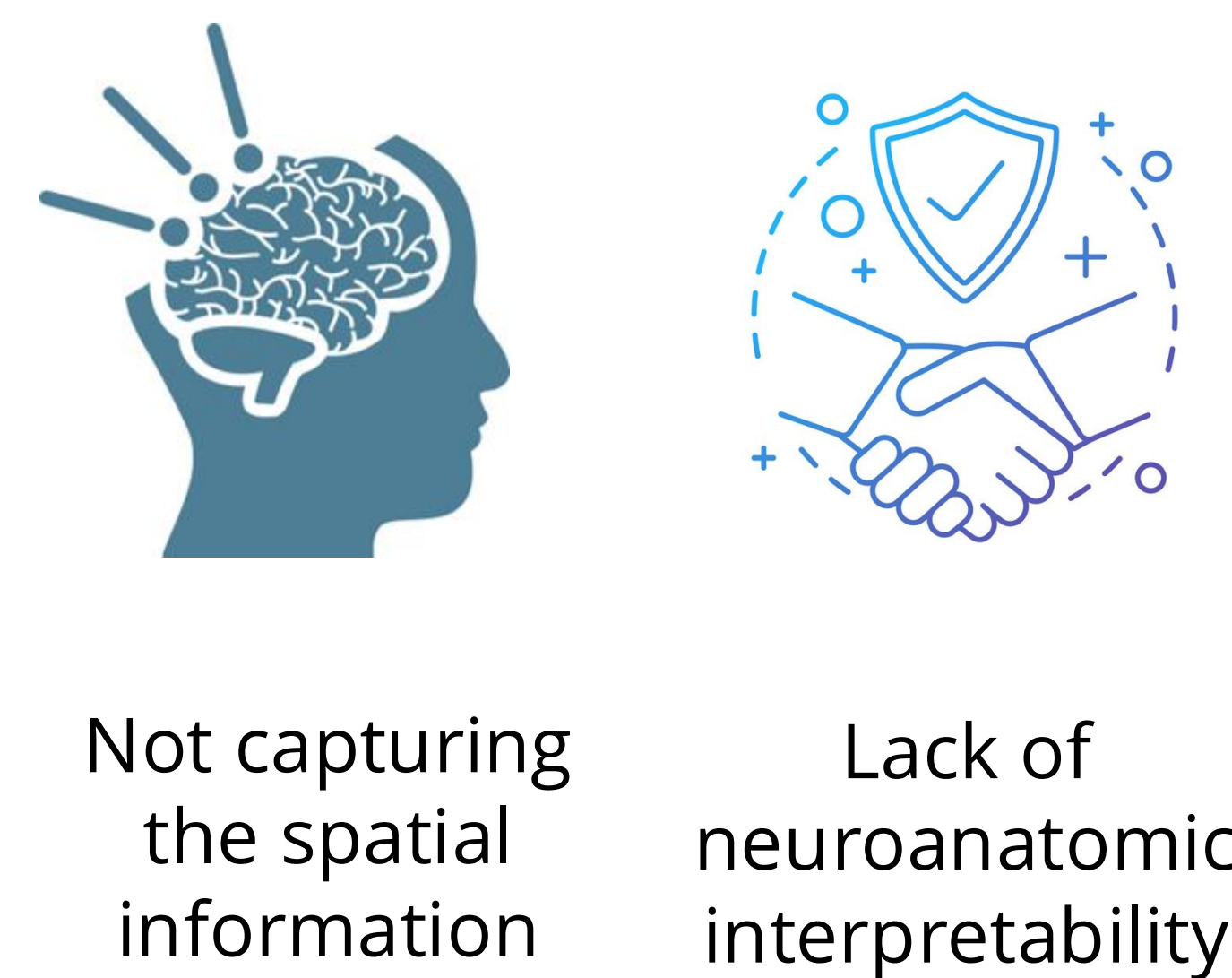
BACKGROUND

Prior studies: MRI-detected atrophy was found to have the closest relationship with cognitive decline.

Hypothesis: Accelerated neurodegeneration can be detected in AD through brain age gap estimation.

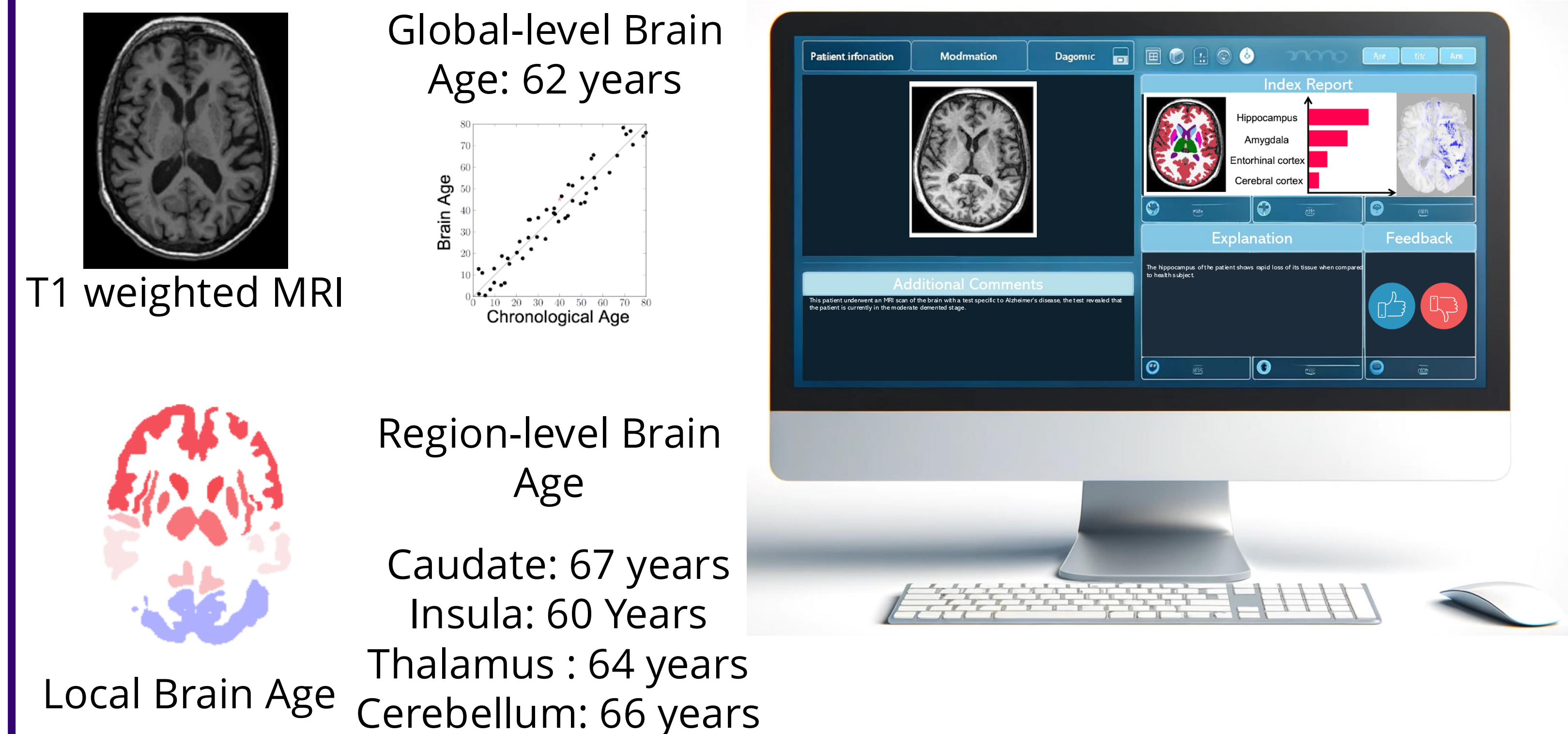


Current Clinical Challenges in Brain Age



RESULTS

Our model achieves an MAE of 4.25 in global age prediction on the ADNI held-out test set. The multi-loss model demonstrates stronger clinical associations compared to the simple classification model.



METHODS

DATASETS

- Total of **7,784 T1 Structured MRIs** (subjects ≥ 40 years) from multiple datasets OpenBHB, ADNI, OpenMind.
- Held-out test set: **381 ADNI T1 Structured MRIs** with clinical diagnoses (AD, MCI, CN) and cognitive assessments.
- We train deep regression models on T1-weighted MRI scans to predict brain age using 3D ResNet-18 and VQ-VAE.

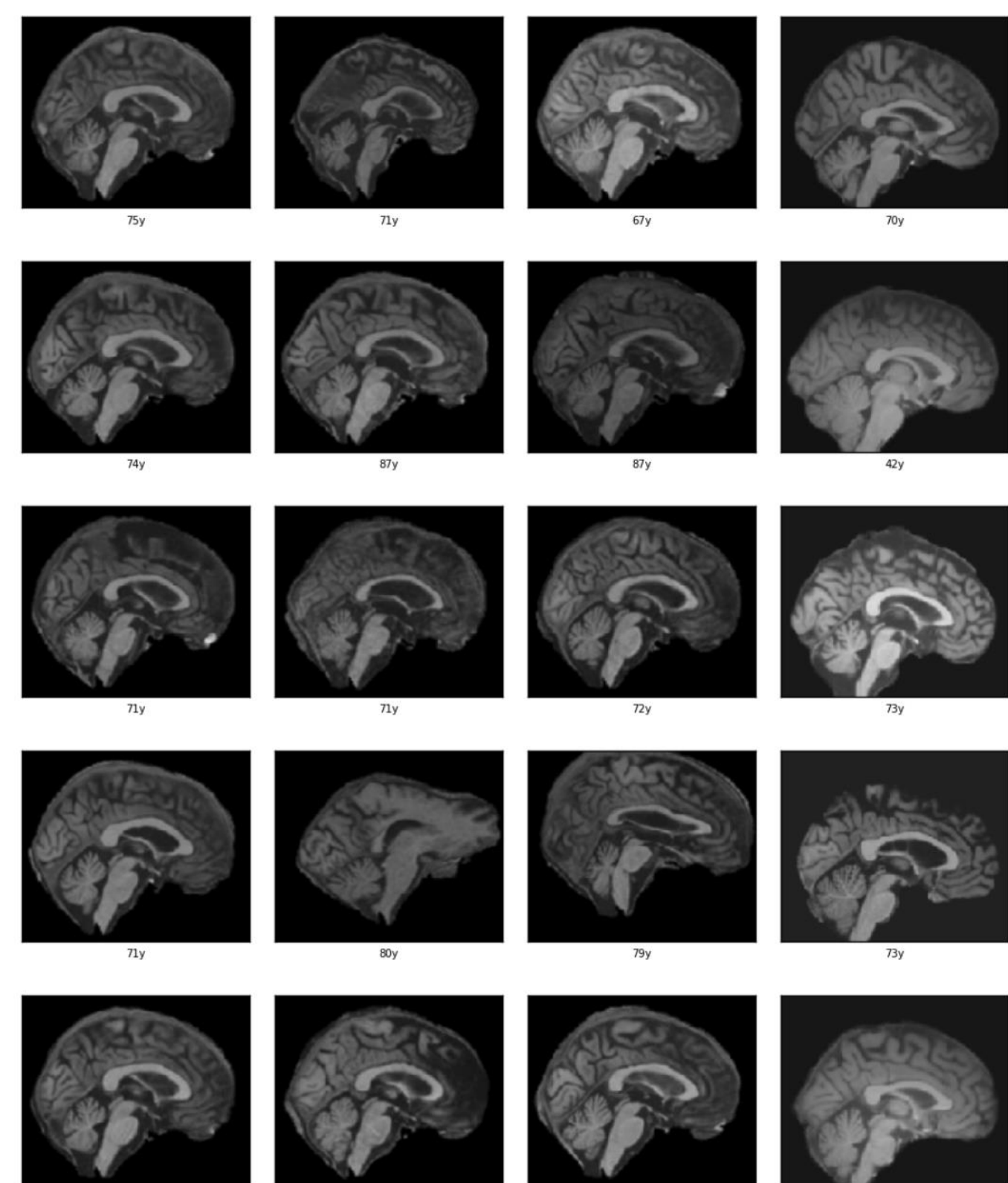


Figure 2: Examples of preprocessed T1 structured MRIs.

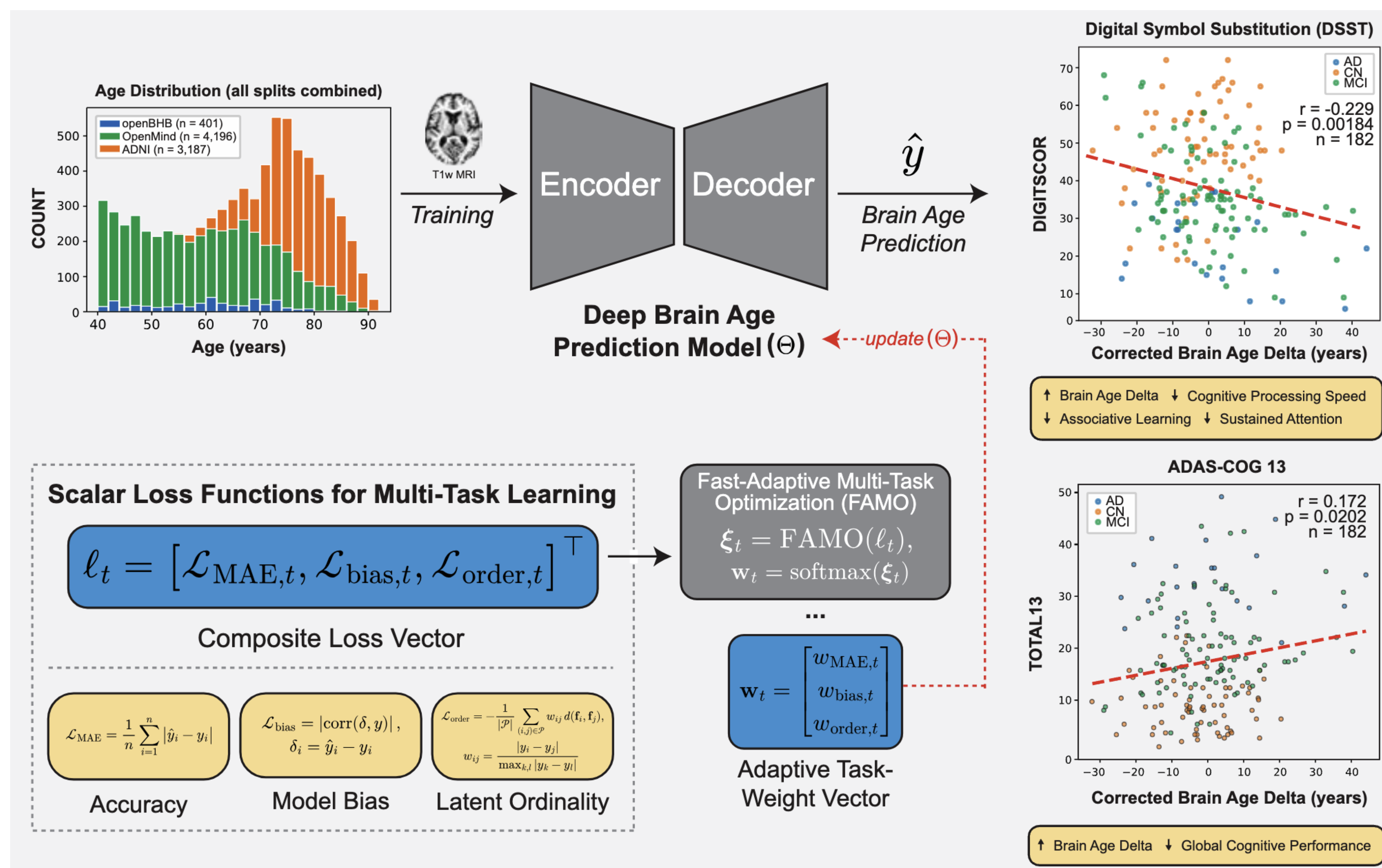


Figure 3: Proposed framework overview, the composite loss is balanced automatically by FAMO for multi-criteria brain age optimization.

TRAINING

- Framework: PyTorch, Adam optimizer, cosine LR schedule
- Bias Loss: penalizes $|\text{corr}(\text{delta}, \text{age})|$ end-to-end
- FAMO: auto-balances MAE, bias, and ordinal losses without manual tuning
- Nvidia A40 GPU; preprocessing: skull stripping, intensity normalization, MNI registration

¹Ren et al. *ISBI*, 2026

²Ren et al. *MICCAI*, 2026

DISCUSSIONS

Pretraining combined with improved representation learning effectively reduces regression to the mean bias while maintaining strong predictive accuracy. A multi criteria evaluation framework shows higher clinical relevance.

Future work:

- Include larger dataset in the training including UK biobank.
- Validate framework in diverse cohorts including women and racial/ethnic minorities.
- Include multiple modality data.

INFO

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