Machine Intelligence to Predict Human Intelligence

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Background

- Intelligence quotient (IQ), the proxy of a person's neurocognitive ability,[1] is an important factor in a person's health and socioeconomic status.[2]
- Accurate prediction of a person's future course of IQ may boost individual potential as well as help in clinical support on intervening early and changing the course for those vulnerable.[3]
- State-of-the-art convolutional neural networks showed great promise in medical imaging (e.g., magnetic resonance imaging (MRI))-based predictive tasks.
- However, predicting a person's IQ level from brain MRI is not a trivial task.
- In this study, we have conducted a feasibility study using state-of-the-art convolutional neural networks (CNNs) in predicting IQ scores from brain MRIs.

Data Statistics

- Used 850 T1-weighted brain MRIs from autism brain imaging data exchange (ABIDE I)
- **Age range:** 6-64 years; **Mean** ($\pm$ Standard Deviation)**:** 16.79$\pm$7.28 years
- **Male:** 85.29%; **Autistic:** 49% (Control: 51%)
- **IQ Scores:** Full Scale IQ (FIQ), Performance IQ (PIQ), Verbal IQ (VIQ)

Data Preprocessing

Used the following steps for preprocessing and harmonizing raw MRI data:
1. N4 bias correction,[4]
2. Field of view normalization,[5]
3. Multi-Atlas skull stripping,[6] and
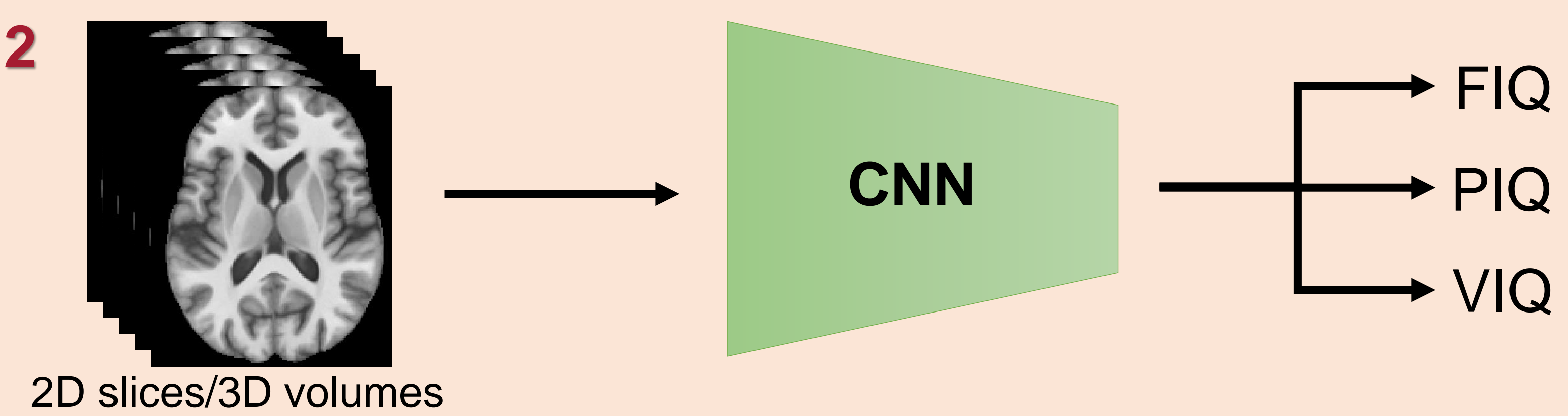4. Non-rigidly registered to the SRI24 atlas[7] by the DRAMMS algorithm.[8]

Methodology

Setting 1 — 2D slices/3D volumes → CNN → FIQ/PIQ/VIQ

Setting 2 — 2D slices/3D volumes → CNN → FIQ, PIQ, VIQ
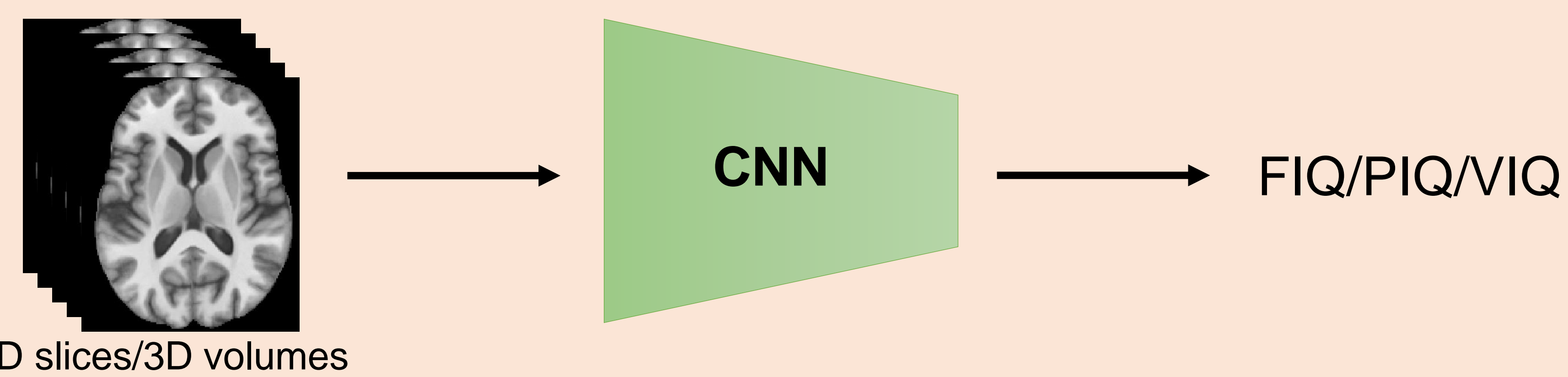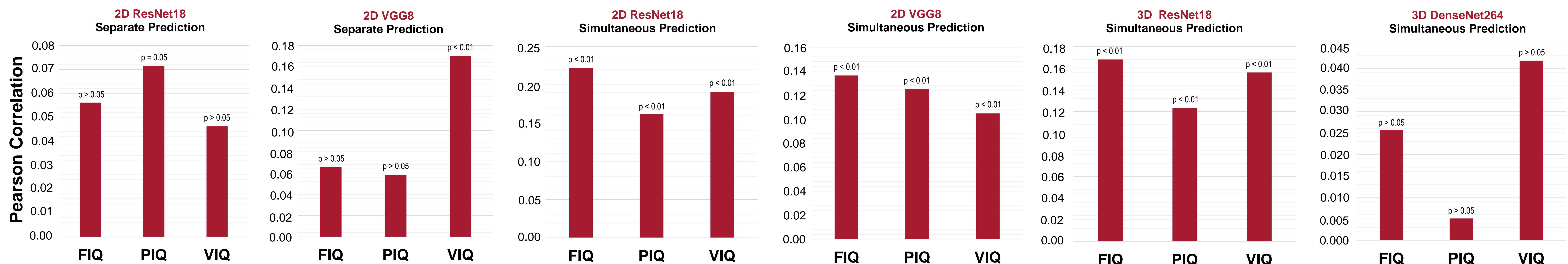
- **CNN used:** 2D ResNet18, 2D VGG8, 3D ResNet18, 3D DenseNet264
- **Training/Validation Strategy:** 5-fold cross-validation

- In setting 1, FIQ, VIQ, and PIQ are predicted separately
- In setting 2, FIQ, VIQ, and PIQ are predicted simultaneously

Results

Pearson Correlation plots:
- 2D ResNet18 Separate Prediction: FIQ ($p > 0.05$), PIQ ($p = 0.05$), VIQ ($p > 0.05$)
- 2D VGG8 Separate Prediction: FIQ ($p > 0.05$), PIQ ($p > 0.05$), VIQ ($p < 0.01$)
- 2D ResNet18 Simultaneous Prediction: FIQ ($p < 0.01$), PIQ ($p < 0.01$), VIQ ($p < 0.01$)
- 2D VGG8 Simultaneous Prediction: FIQ ($p < 0.01$), PIQ ($p < 0.01$), VIQ ($p < 0.01$)
- 3D ResNet18 Simultaneous Prediction: FIQ ($p < 0.01$), PIQ ($p < 0.01$), VIQ ($p < 0.01$)
- 3D DenseNet264 Simultaneous Prediction: FIQ ($p > 0.05$), PIQ ($p > 0.05$), VIQ ($p > 0.05$)

Discussion

- Our results depicted that the high-performing 2D and 3D CNNs perform poorly in predicting FIQ, PIQ, and VIQ scores from T1-weighted MRI.
- Our results are similar to CNN-based fluid score prediction in the ABCD dataset.
- This performance raises several questions, e.g., are 850 training samples sufficient? Are state-of-the-art CNNs able to capture the IQ-specific discriminatory features in the brain T1-weighted MRI?

References

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