Increasing the sensitivity of brain age modelling with explainable artificial intelligence

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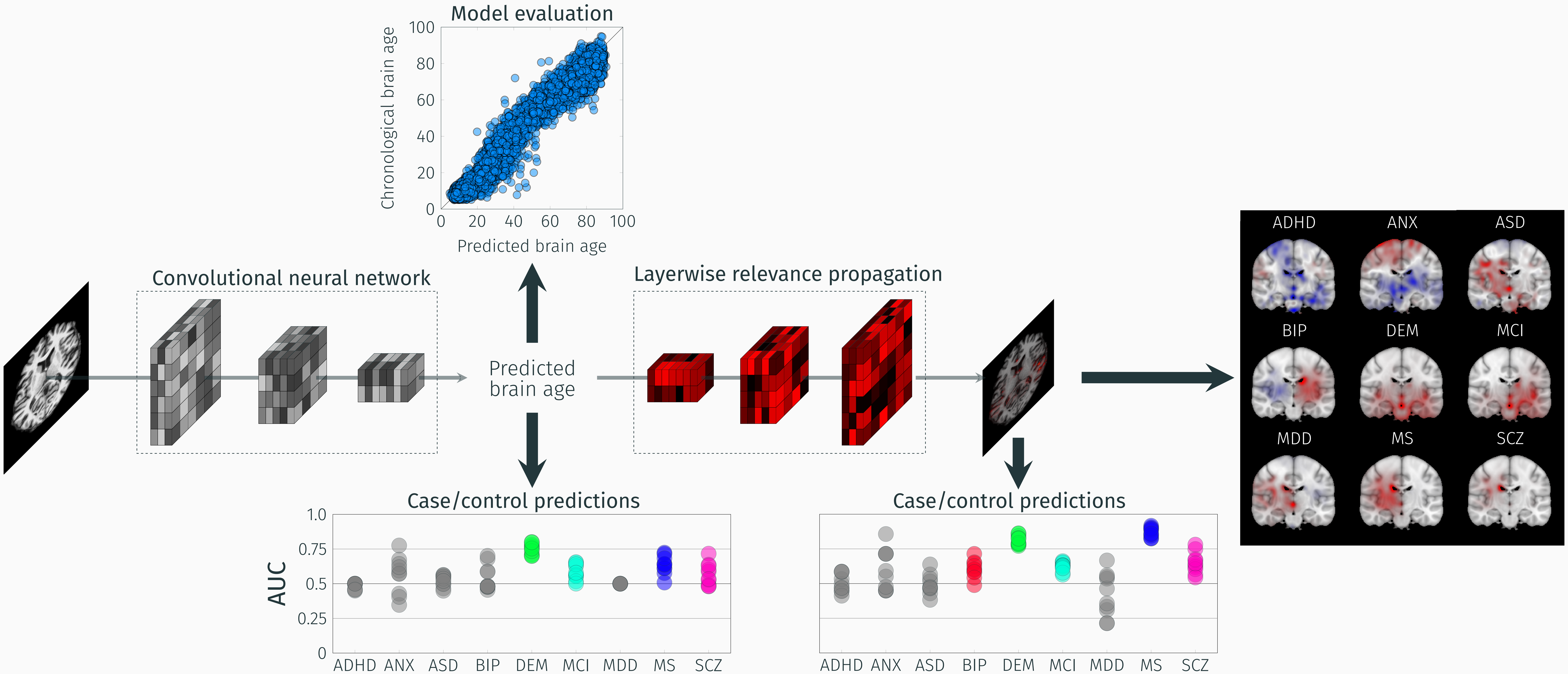

Introduction

The brain age gap (BAG), a neuroimaging-derived measure encoding the difference between the apparent and chronological age of the brain, has revealed older-appearing brains in patients with various conditions[franke_ten_2019]. Although this phenomena is evident at the group-level, the abstract nature of BAG limits its utility for individualized clinical decision-making. Explainable artificial intelligence (XAI) can unveil concrete and precise visual patterns in the individual patient causing deviations in BAG, that are plausibly more clinically useful than the singular measure

Methods

We trained a convolutional neural network to predict BAG using 80,007 structural magnetic resonance images from 67,881 participants. On top of the model we implemented layer-wise relevance propagation, a post-hoc XAI technique for explaining decision made by a model. This allowed us to procure heatmaps highlighting regions underlying a deviating BAG in individual participants. Finally, we investigated how these regions differed between participants, and whether their content could support clinical decision-making across nine conditions (Table 1).

Results

Our model achieved satisfactory predictive performance in a held-out dataset (MAE=4.51) from scanning sites unseen by the model during training. Singular BAGs from our model allowed us to meaningfully discriminate patients from controls (mean AUC>0.5, $p<0.05$) for four out of nine conditions (DEM, MCI, MS, SCZ). The heatmaps yielded significantly improved predictions (mean AUC_{map}>mean AUC_{age}, $p<0.05$) for five out of nine disorders (BIP, DEM, MCI, MS, SCZ). Beyond MCI and DEM, the highlighted regions varied distinctly between the patient cohorts.

Conclusion

XAI combined with brain age models produce high-dimensional information that outperforms singular BAGs for clinical predictive tasks.

References