Explainable 3D CNN-Based Classification of Parkinson's Disease Using ^{123}I-FP-CIT SPECT

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Abstract

Parkinson's disease (PD) involves degeneration of nigrostriatal dopaminergic neurons, and ^{123}I-FP-CIT SPECT reflects presynaptic dopamine transporter availability. Three-dimensional convolutional neural networks (3D CNNs) classify such scans accurately but do not reveal which regions drive their predictions. This study compared 3D CNN architectures for PD classification and evaluated their explanations with multiple XAI methods. Of 146 ^{123}I-FP-CIT SPECT examinations (136 PD, 10 healthy controls [HC]), 139 (129 PD, 10 HC) were analyzed after spatial normalization with SPM12. ResNet-10, ResNet-18 and DenseNet-121 were trained in nested cross-validation (stratified five-fold outer, four-fold inner) on identical folds. Integrated Gradients, layer-wise relevance propagation (LRP) and occlusion sensitivity were applied using held-out models, and the top 10% of cells by absolute attribution were compared between methods, between architectures, and with the striatum. Out-of-fold performance for ResNet-10 / ResNet-18 / DenseNet-121 was AUC 0.989/0.978/0.991, sensitivity 0.915/0.992/0.984, specificity 1.000/0.700/1.000 (95% CI 0.692-1.000, 0.348-0.933, 0.692-1.000), and F1 0.955/0.985/0.992 for PD and 0.645/0.778/0.909 for HC. The three methods agreed within every architecture (median Dice 0.42-0.71; chance 0.10) but agreed less across architectures (0.29-0.37), and attributions concentrated on the striatum (median Dice 0.18-0.28; chance 0.041). Comparing multiple 3D CNN architectures and XAI methods provided an interpretable framework for the spatial patterns underlying PD classification from 123I-FP-CIT SPECT; explanations were less reproducible across architectures than across methods, and external validation is required.

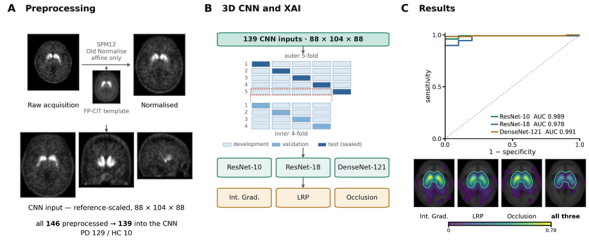

Figure1. From 123I-FP-CIT SPECT to attribution maps: affine-only preprocessing, one shared nested cross-validation across three 3D CNN architectures, and the regions on which they agreed.

Index Terms

Parkinson's disease; ^{123}I-FP-CIT SPECT; 3D Convolutional Neural Network; Explainable Artificial Intelligence; Dopamine Transporter