

fNIRS-Based Machine Learning for Parkinson's Motor Subtype Classification

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Abstract: Parkinson's disease includes tremor-dominant and akinetic-rigid subtypes that differ in pathophysiology and treatment response but are difficult to distinguish objectively. This study presents a machine learning-based classifier using functional near-infrared spectroscopy (fNIRS) recorded during upper-limb fine motor tasks. fNIRS data from 20 patients and 20 controls were preprocessed, and time- and frequency-domain features were extracted and selected using signal-processing procedures. Twenty-two classification models were evaluated in a multiclass setting. The Ridge Classifier achieved the best performance, with balanced accuracies of 75% in training and 83.33% in testing. These findings support fNIRS and machine learning for objective Parkinson's subtype classification.

Introduction: Parkinson's disease is classified into tremor-dominant and akinetic-rigid subtypes, which differ in symptom progression, underlying pathophysiology, and response to treatment. Accurate subtype identification is therefore essential for personalized clinical management. However, current classifications rely heavily on clinical scales and expert judgment, making them susceptible to subjectivity and inter-rater variability, particularly in early or mixed presentations¹. Functional near-infrared spectroscopy (fNIRS) offers a noninvasive approach to assess cortical hemodynamics during motor tasks, providing objective neurophysiological information². Combined with machine learning techniques, fNIRS may help improve subtype differentiation. This study investigates the feasibility of classifying Parkinson's subtypes and controls using fNIRS signals recorded during upper-limb fine motor tasks.

Methods: fNIRS data were acquired from 20 patients with Parkinson's disease and 20 healthy controls using the Brite MKII system during finger tapping tasks. Signals were processed using standard pipelines to remove low-quality channels, motion artifacts, and physiological noise². Optical density signals were converted to oxyhemoglobin (HbO), deoxyhemoglobin (HbR) and total hemoglobin (HbT) concentrations, and task-related hemodynamic responses were estimated using a general linear model. Fourteen features (12 time-domain and 2 frequency-domain) were extracted from 20 channels across three contrasts (HbO, HbR, and HbT), then centered and standardized. Highly correlated features were removed, and dimensionality was reduced using a genetic algorithm. Twenty-two machine learning classifiers were evaluated in a multiclass framework using stratified cross-validation, and the best-performing model was tested on an independent dataset.

Results: The Ridge Classifier yielded the highest multiclass performance, achieving balanced accuracies of 75% in training and 83.33% in the independent test set, demonstrating good generalization across classes. Performance metrics indicated effective discrimination between Parkinson's subtypes and healthy controls, with accuracy substantially exceeding chance level. These results suggest that fNIRS-derived features capture relevant neurophysiological differences associated with motor subtype expression.

Conclusion: This study demonstrates the potential of combining fNIRS and machine learning to achieve objective multiclass classification of Parkinson's disease subtypes. The proposed framework is designed to complement standard clinical evaluations by providing physiologically grounded information derived from motor task performance, thereby enriching the evidence base available for clinical decision-making. Although further validation in larger cohorts is required, these findings support fNIRS-based classification as a promising complementary tool for improving diagnostic precision and advancing personalized treatment strategies in Parkinson's disease.

References:

1 Khedr, EM et al. (2021). *Neurophysiol Clin* 51, 443–453

2 Guevara, E et al. (2024). *Neurophotonics* 11, 025004