NeurIPS 2026, Paris

Interpretable Machine Learning Evaluates Differential Therapy Effects in Parkinsonian Gait

Artur Chudzik Henryk Josiński Andrzej Przybyszewski

Objective therapy-response assessment from short-window gait dynamics

POLISH-JAPANESE ACADEMY OF INFORMATION TECHNOLOGY

Silesian University of Technology

Treatment response is difficult to measure

Parkinson's disease is progressive and currently has no cure.

Medication and deep brain stimulation can improve motor symptoms, but the response varies between patients and over time.

Clinical ratings provide snapshots. Gait adds objective evidence of treatment response.



Illustrative image

A within-patient therapy experiment

Within-patient comparisons across controlled therapy states

19

participants with Parkinson's disease

376

walking trials natural and fast

OFF / OFF

Medication off
DBS off

OFF / ON

Medication off
DBS on

ON / OFF

Medication on
DBS off

ON / ON

Medication on
DBS on

UPDRS-III total score (mean)

OFF / OFF	OFF / ON	ON / OFF	ON / ON
52.7	29.6	24.1	17.9

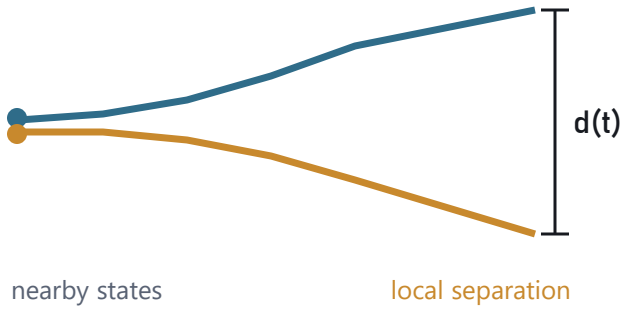
Lower scores indicate fewer motor symptoms.

Vicon motion-capture cameras, 100 Hz

Three views of gait dynamics

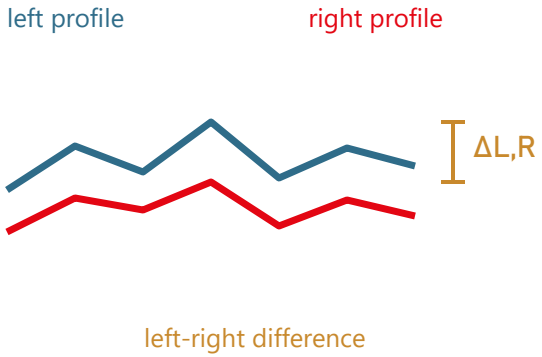
Short windows preserve when and where movement organization changes

01 Local divergence



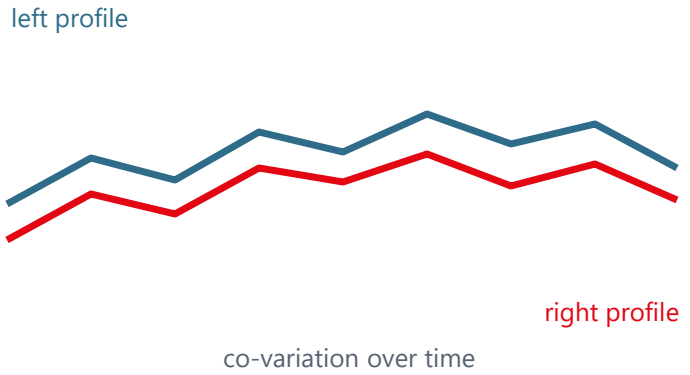
How quickly nearby gait trajectories separate within one-second windows

02 Asymmetry



How different the left and right local-divergence profiles are

03 Coupling



How the left and right profiles change together over time

From motion capture to local gait dynamics

We tracked four foot markers

LHEE (left heel)
LTOE (left toe)

RHEE (right heel)
RTOE (right toe)

The analysis uses their vertical trajectories.

1.0 s
sliding windows

100 Hz
motion capture



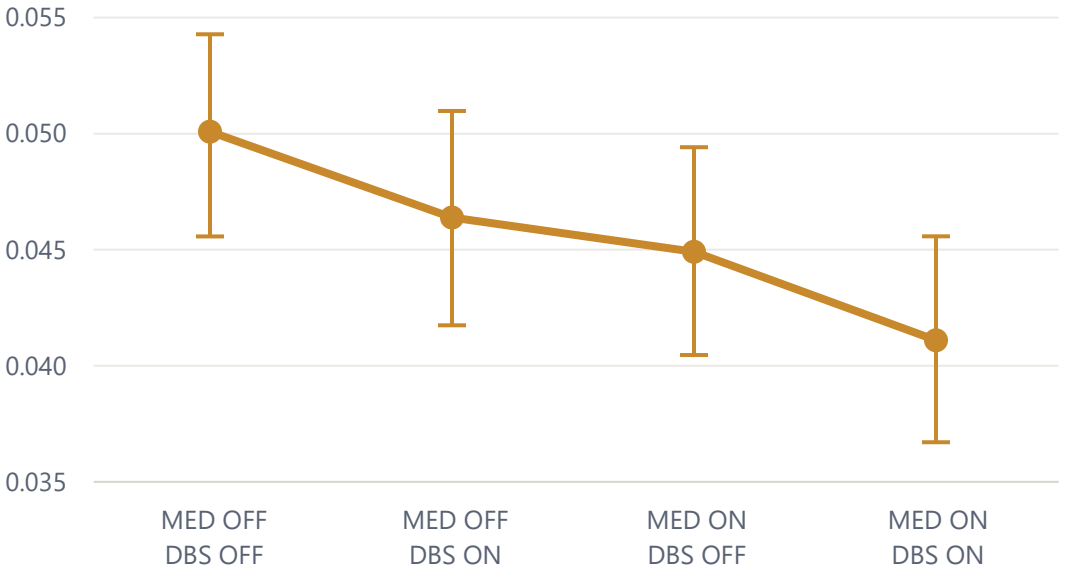
Illustrative motion-capture representation

Bayesian ML reveals complementary gait signatures

Natural walking, primary LLE variant, posterior means with 95% credible intervals

Overall LLE asymmetry

lower = less imbalance



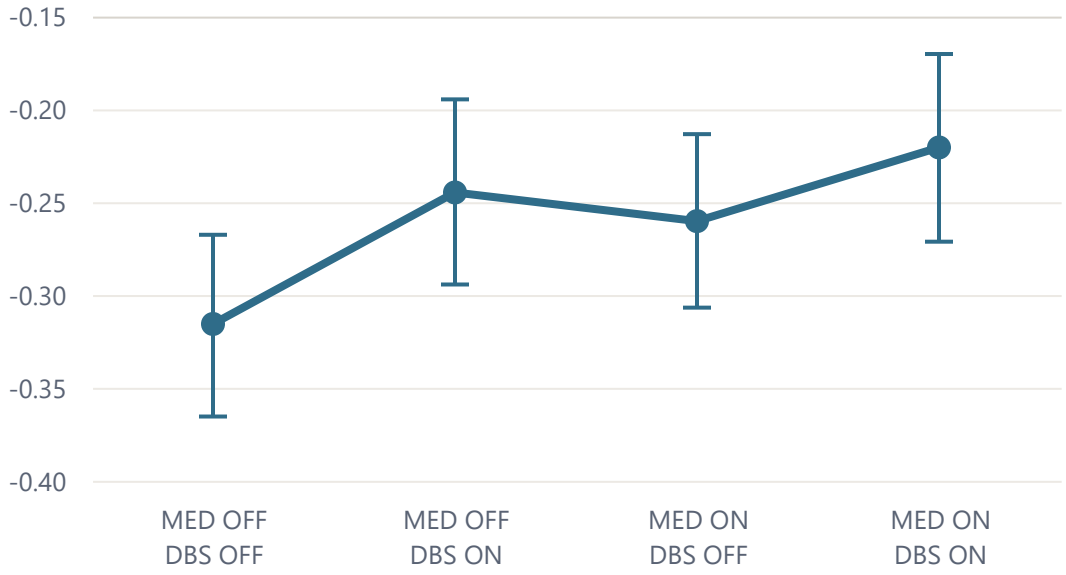
Paired OFF/OFF to ON/ON

Δ = −0.0103 dz = −0.83

less left-right imbalance

Toe LLE coupling

less negative = changed coupling



Paired OFF/OFF to ON/ON

Δ = +0.1270 dz = 0.86

changed bilateral coordination

Why these signatures matter

The endpoints answer different clinical questions

ASYMMETRY

A direct response marker

Captures the magnitude of left-right imbalance. The clearest paired changes appeared with medication and combined therapy.

COUPLING

A coordination marker

Captures how left and right local-divergence profiles change together. Factorial effects were strongest for stimulation.

Bayesian repeated-measures models include patient-specific baselines while estimating group-level therapy effects.

Initial convergence with UPDRS-III and standard gait measures supports complementary clinical relevance.

Take-home message

Short-window gait dynamics reveal complementary therapy-response signatures

Asymmetry captures lateralized improvement. Coupling captures treatment-related changes in bilateral coordination.

Next: larger prospective cohorts, external validation, and laboratory motion capture as a reference for scalable sensing.

Code and derived data: doi.org/10.5281/zenodo.23962355

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