

 <p><b>UniSR</b> Università Vita-Salute San Raffaele</p>	<p><b>APPLICATION TO ACT AS SUPERVISOR AND RESEARCH PROJECT PROPOSAL</b></p>	<p><b>MO 20-5</b> ed. 02 of 16/01/2026 PO 20 Page 5 of 11</p>
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**PROJECT**

**Supervisor:**

Dr. Silvia Basaia

**Title:**

Network-Based modeling and multimodal biomarkers to personalize treatment in Parkinson's Disease

**Curriculum:**

Cognitive and Behavioural Sciences

Link to the personal page of the University or relevant hospital site website:

<https://research.hsr.it/en/institutes/institute-of-experimental-neurology/neuroimaging-of-neurodegenerative-diseases/silvia-basaia.html>

**Description of the Project (max 3,000 characters including spaces)**

**Background/gap of knowledge**

Parkinson's disease (PD) is a progressive neurodegenerative disorder characterized by motor impairment and marked inter-individual variability, likely driven by network-level alterations beyond dopaminergic deficits. Rehabilitation combined with non-invasive neuromodulation, such as transcranial direct current stimulation (tDCS) and transcutaneous spinal direct current stimulation (tsDCS), is promising, but treatment response remains heterogeneous. Network diffusion models (NDM) can describe disease progression as a network-mediated process linked to longitudinal MRI-derived atrophy. In parallel, digital biomarkers from inertial sensors, electromyography (EMG), and functional Near-Infrared Spectroscopy (fNIRS) provide complementary measures of gait, neuromuscular activation, and cortical engagement. However, integrated approaches remain limited, restricting data-driven personalization and adaptive rehabilitation.

**Rationale and hypothesis**

PD progresses as a network-level neurodegenerative process, and subject-specific NDM models may capture individual disease trajectories. Combined with inertial sensors, EMG, and fNIRS features, these biomarkers may explain inter-individual variability and predict treatment response, enabling personalized neuromodulation.

**Objectives and specific aims**

To implement MRI processing pipelines to obtain regional atrophy maps across longitudinal timepoints in PD patients.

To build subject-specific NDM models in PD patients who will subsequently undergo the treatment, by fitting different parameters on the pre-intervention interval and deriving biomarkers of natural-history neurodegeneration trajectories.



To validate NDM-derived on an independent PD cohort, with no treatment intervention, estimating population-level parameter distributions and using them as reference for disease trajectory modelling.

To generate NDM-based predictions of expected atrophy in PD patients after treatment from the pre-intervention NDM fit and quantifying subject-specific deviations from the natural progression trajectory.

To develop a multimodal signal processing pipeline, integrating inertial sensors, EMG, and fNIRS and linking these to NDM-derived parameters of the pre-intervention interval to quantify how baseline neurodegeneration dynamics constrain brain plasticity and neuromodulation responsiveness.

### **Expected outcomes**

NDM fitted on pre-intervention MRI is expected to provide natural-history biomarkers that stratify patients by network-level degeneration dynamics, benchmarked against an independent PD cohort.

Post-treatment NDM predictions are expected to quantify deviations from expected atrophy trajectories and relate them to inertial sensors, EMG, and fNIRS.

Combining NDM biomarkers with inertial sensors/EMG/fNIRS features is expected to yield predictors of response and retention, supporting personalized stimulation and future adaptive neuromodulation.

### **Skills that the student should acquire** (max. 600 characters including spaces):

The student will acquire interdisciplinary skills in clinical/technical and translational neuroscience, including the design of ecological experimental paradigms for gait assessment. He/she will gain expertise in multimodal data acquisition using wearable technologies (EMG, inertial sensors, and fNIRS) and in signal processing with MATLAB/Python. The student will also develop competencies in MRI processing and connectome construction for computational disease modelling.

### **References** (max. 15)

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- Sarasso E, et al. J Neurol 2021; 268(9):3144-3179
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