DEEP LEARNING IN OBJECTIVE CLASSIFICATION OF MOVEMENT OF PATIENTS WITH PARKINSON’S DISEASE USING LARGE-SCALE FREE-LIVING SENSOR DATA

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Objectives
- **Background**
  - Brady-hypokinesia and dyskinesia characterize movement in people with PD (PwP)
  - Motor fluctuations are the hallmark of later PD stages
  - Currently, the motor state is evaluated by a rater or the patient opening numerous paths to biased assessments
  - Ideally, the motor state could be detected using an objective assessment in free-living situations with sufficient temporal resolution
- **Deep learning has so far only been applied to data retrieved from PwP in test-based controlled setups, e.g. task-based**
- **To date, no objective detection of the motor state has been validated**
- **Commercially available mobile devices, such as smartphones or wristbands, carry motion sensors and can be imperceptibly worn over long time periods**

Challenges in working with PD motion data
- **Noisy Labels** (due to symptom changes within given rating time intervals)
- **High-Inter-Subject Variability**
- **Motion Interference** (due to voluntary motion)
- **Noisy Motion Data** (due to limited sensor quality)

Table 1 – PwP cohort
<table>
<thead>
<tr>
<th>Age [yrs]</th>
<th>± 10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hoehn &amp; Yahr stage</td>
<td>2 (2.2)</td>
</tr>
<tr>
<td>Disease dur. [yrs]</td>
<td>11 ± 5</td>
</tr>
<tr>
<td>MoCA [points]</td>
<td>26 ± 3</td>
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Methods
- **We obtained approval from the ethics committee of the TU Munich (Az. 234/16 S)**
- **We recruited 30 patients (see table 1) with PD and 8 age-matched healthy controls (HC)**
- **Patients were continuously clinically evaluated during the time they wore the sensor by a certified rater, which were >230 hours of recordings**
- **Clinical ratings included severity of bradyhypokinesia (MDS-UPDRS III.14) and dyskinesia (mAIMS)**
- **Sensor raw data (3D Acc, 3D Gyro) was recorded using a Microsoft band 2 (MS, Redmont, WA, USA) with a sampling frequency of 62.5 Hz running the STM LSM6DS2 Accelerometer / Gyroscope module**
- **Data was transferred to a storage device using a Bluetooth 4.1 interface, and analyzed off-line**
- **Data Augmentation methods as described in Um et al. were introduced for preprocessing**

Results
- **Difficult raw data patterns & their classification**
  - (a)
  - (b)
  - (c)
  - (d)

Discussion
- **Sensor data from low-cost devices are effective to detect the motor signals from healthy controls and people with Parkinson’s disease**
- **Relevant technical issues have to be addressed before the data can be analyzed**
- **Deep Learning proves to be a powerful instrument to classify motion data**
- **The temporal and manifestation resolution of the achieved classification is unprecedented.**
- **Generalization can be a hard task: Individual Calibration will be key (Precision Approach)**

Conclusions
- **We describe a novel approach for the objective classification of the PD motor state, the core characteristic of the disease, using Deep Learning and a low-cost commercially available sensor device**
- **This method is not limited to a controlled test setup, but can be applied in free-living situations and thus potentially allows for full seamless integration of the IoT technology into the daily lives of patients**
- **The precision and temporal resolution of the measurements is unprecedented, and could be used for numerous clinical indications**
- **Individual models will enable more accurate monitoring of the PD motor state**

Literature
- Kubota et al. (2016) Machine learning for large-scale wearable sensor data in PD, MDJ
- Shokal et al. (2016) Complex human activity recognition using smartphone and wrist-worn motion sensors. SENSORS
- Sanchez-Ferro et al. (2016) New technologies for the assessment of Parkinson’s, MDI
- Dal Din et al. (2016) Free-living monitoring of Parkinson’s disease: lessons from the Fall, MDI
- Sama et al. (2012) Dyskinesia and motor state detection in PD. IEEE EMBC
- Um et al. (2017) Data Augmentation of Wearable Sensor Data for Parkinson’s Disease Monitoring using Convolutional Neural Networks