

Quantification of upper limb motor symptoms of Parkinson's disease using a smartphone

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Objective

The aim of this study is to develop and evaluate methods for quantifying motor symptoms in Parkinson's disease (PD) using combined upper limb motor test data, collected during tapping and spiral drawing tasks by a smart phone.

Background

PD is a multidimensional and complex disorder affecting motor and non-motor functionalities. Assessments of PD symptoms are usually done by clinical rating scales. One of them is the Unified PD Rating Scale (UPDRS), developed to provide comprehensive, efficient and flexible means to monitor PD-related disability and impairment. It has been the most commonly used rating scale. It is composed of four main parts where the third part is designed for rating of motor symptoms. However, UPDRS has relatively poor inter-rater reliability [1, 2]. Another scale that is used to grade motor function of patients is Treatment Response Scale (TRS)[3, 4]. A limitation is that there is no general agreement on which parts of the symptomatology should be included in the TRS score [5]. However, the scales have low intra- and inter-rater reliability and their use is limited, as they are only used during in-clinic observations [6].

Methods

Participants

Nine-teen patients diagnosed with PD and 22 healthy controls were recruited in a single center, open label, single dose clinical observational study in Sweden. Simultaneous clinical- and smartphone-based measures were collected up to 15 times following a single levodopa/carbidopa morning dose (50% over normal to induce dyskinesias).

Clinical assessment

Subjects were asked to perform standardized motor tests in accordance with UPDRS and were videotaped. The videos were blindly rated by three movement disorder specialists. The ratings were given based on Treatment Response Scale (TRS) ranging from -3 = 'Very Off' to 0 = 'On' to +3 = 'Very dyskinetic', three UPDRS motor items (item 23, Finger Taps; item 25, Rapid Alternating Movements of Hands; item 31, Body Bradykinesia and Hypokinesia), and dyskinesia score. Means of the three specialists' assessments per time point on these scales were used in subsequent analysis.

Smartphone-based data collection

On each test occasion, the subjects performed upper limb motor tests (tapping and spiral drawings), using a smartphone (Figure 1) [7]. The subjects were instructed to perform the tests using an ergonomic pen stylus with the device placed on a table and to be seated in a chair. During tapping tests, the subjects were asked to alternately tap two fields (as shown in the screen of the device) as fast and accurate as possible, using first right hand and then left hand. Each tapping test lasted for 20 seconds. During spiral tests, the subjects were instructed to trace a pre-drawn Archimedes spiral as fast and accurate as possible, using the dominant hand. The spiral test was repeated three times per test occasion. The smartphone recorded both position and time-stamps (in milliseconds) of the pen tip.

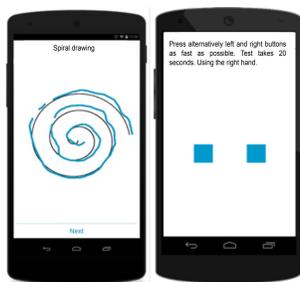


Figure 1. Spiral drawing and Tapping tests on the smartphone.

Data processing and analysis

The raw tapping and spiral data were processed with time series analysis methods, including both time- and frequency-domains methods. Nineteen and 22 spatiotemporal features were extracted from spiral and tapping data, respectively. Features were calculated to represent various kinematic quantities during the motor tests such as acceleration, speed, time delay, and distance. The features from both tapping and spiral data were used in a Principal Component Analysis and 7 principal components (PCs) were retained, which in turn were used as inputs to a Support Vector Machines (SVM) to be mapped to mean clinical ratings. The analysis were performed with a stratified 10-fold cross-validation. Test-retest reliability of the spiral tests were assessed after calculating correlations between the first PCs for the three spiral tests and then calculating the mean of all possible correlations.

Results

The correlation coefficients between SVM predictions and mean clinical ratings were as follows: 0.59 for TRS, 0.6 for dyskinesia score, 0.52 for item 23 of UPDRS (finger taps), 0.47 for item 25 of UPDRS (rapid alternating movements of hands), and 0.57 for item 31 of UPDRS (body Bradykinesia and Hypokinesia). The spiral test had a good test-retest reliability with a coefficient of 0.84, indicating that spiral scores are stable and consistent over time. When assessing the ability of the PCs to distinguish between patients and healthy controls the means of 3 out of 7 PCs (PC1, PC2 and PC4) were different between the two groups ($p < 0.005$). Figure 2 shows clinical and predicted scores for two representative patients.



Figure 2. Results of methods' predictions versus actual clinical rating scores for two random patients (patient A, first column; patient B, second column)

Conclusions

The upper limb motor tests of the smartphone were able to capture important and relevant symptom information of the clinical rating scales. The methods for quantifying the upper limb motor symptoms of PD patients:

- Had adequate correlations to clinical ratings
- Were able to differentiate between movements of patients and healthy controls, and
- (Spiral tests) had good test-retest reliability.

References

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