Acoustic Assessment of Voice and Speech Disorders in Parkinson's Disease Through Quick Vocal Test

The disorders of voice and speech in Parkinson's disease (PD) result from involvements in several subsystems including respiration, phonation, articulation, and prosody.[1–3]

We investigated the feasibility of acoustic measures for the identification of voice and speech disorders in PD, using a quick vocal test consisting of sustained phonation, diadochokinetic task, and running speech. Various traditional and novel acoustic measurements have been designed in order to be gender independent, represent all speech subsystems, reduce the time required for voice investigation, and provide a reliable automated assessment in practice.[4]

Patients and Methods

A total of 46 Czech native participants were recruited. Twenty-four of them fulfilled the diagnostic criteria for PD and were examined before the symptomatic treatment was started: 20 men, 4 women; mean age (± SD), 60.9 ± 11.2 years; duration of PD symptoms, 31.3 ± 22.3 months (range, 6–84 months); H&Y stage, 2.2 ± 0.5 (range, 1–3); and UPDRS motor score, 17.4 ± 7.1 (range, 5–32); with UPDRS speech item = 0 in 13 patients and speech item = 1 in 11 patients. As a healthy control (HC) group, 22 persons with no history of neurological or communication disorders were included: 15 men, 7 women; mean age, 58.7 ± 14.6 years. Age distribution did not differ significantly between the groups.

Each participant was instructed to perform 3 vocal tasks: [VT1], sustained phonation at a comfortable pitch and loudness as constant and long as possible, at least 5 seconds on 1 breath; [VT2], diadochokinetic (DDK) task requiring rapid, steady /pa/-/ta/-/ka/ syllable repetition as constant and long as possible, repeated at least 5 times on 1 breath; and [VT3], running speech for approximately 80 seconds. For reproducibility of data, each task was repeated at least 2 times for every subject.

The extracted speech parameters were assessed using measures of *phonation* [VT1] including jitter, shimmer, noise-to-harmonics ratio (NHR), and harmonics-to-noise ratio (HNR)[5]; *respiration* [VT2] including sound pressure level decline (SPLD)[4]; *articulation* [VT2] including robust formant periodicity correlation (RFPC), and spectral distance change variation (SDCV)[4]; and *prosody* [VT3] including voice fundamental frequency variations (F0 SD).[6] Supporting Information Table 1 details the measurements used.

For every subject, average values (speech performances) for each acoustic measurement were calculated. Two-sided Wilcoxon rank-sum and Spearman rank tests were performed to find differences between groups and within-group correlations. Subsequently, an exhaustive search of all possible measure combinations was performed, and a predictive model was built using a kernel support vector machine (SVM) to find the best combination of measurements to differentiate PD from HC subjects. Cross-validation with the leave-one-out method was used to validate reproducibility of the SVM classifier.[7]

Results

In total, 116 vocal recordings were collected and used for classification. Significant differences between the 2 groups were found in all 8 measurements. In addition, from all performed correlations, statistically significant relationships were found between several measures of articulation and phonation and subscores of bradykinesia and rigidity (Supporting Table 2). The best classification performance of 85.0% ± 6.1% was reached in a combination of 4 measures that represent all PD-related affected speech subsystems, including the impaired ability to maintain sound pressure level (SPLD), increased noise components during phonation (NHR), lowered accuracy of articulation (RFPC), and reduced melody of speech (F0 SD); see Figure 1. The maximal classification accuracy using simple task was 81.3% ± 6.9% for running speech, 75.6% ± 8.3% for sustained phonation, and 71.4% ± 8.3% for DDK task; therefore, reduced melody in running speech appeared essential in characterizing the vocal impairment in PD.

Discussion

We have designed a quick 2-minute vocal test and investigated the potential of using acoustic analysis in detecting voice and speech disorders in PD. The method demonstrated that it can accurately differentiate PD patients from HCs. This could be of high clinical relevance as subtle abnormalities such as reduced melody in running speech were detectable from the early stage of PD. Admittedly, the study has certain limitations. Although the uneven gender representation of patients and controls could be offset by gender independence of designed acoustic measurement methods, our sample size remains rather small. Should our results be confirmed on a larger population sample, voice and speech disorders might be considered as early markers of the disease, and acoustic analysis might serve as a simple screening test in view of the expected advent of neuroprotective treatment. In a more

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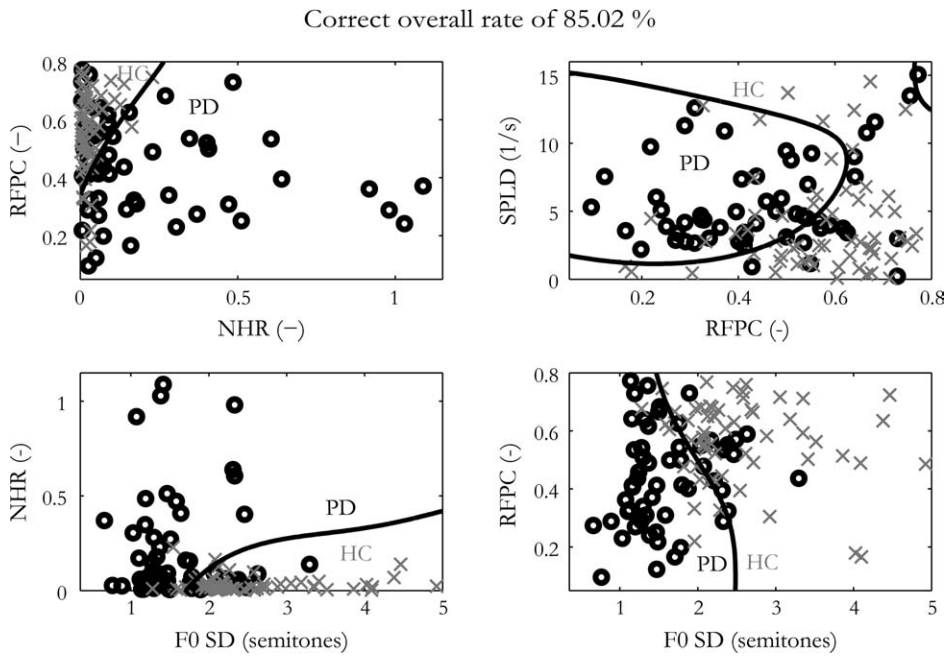

FIG. 1. The results of the SVM-based classifier for selected pairs of the measures combination with best classification accuracy. The "o" marks are for PD, the "x" marks are for HC, and the dark gray curves represent the SVM classification boundaries between both groups.

modest scope, the use of automated acoustic vocal tests can ease the clinical monitoring of voice and speech disorders progression as well as the effects of medication on speech production and can serve as feedback in voice treatment.

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