TWO-MINUTE VOCAL TEST AND ACOUSTIC ANALYSIS REVEAL VOICE AND SPEECH DISORDERS IN EARLY UNTREATED PARKINSON'S DISEASE

Jan Rusz[1,2], Roman Čmejla[2], Hana Růžičková[1], Jiří Klempíř[1], Veronika Majerová[1], Jana Picmausová[1], Jan Roth[1], Evžen Růžička[1]

[1]Charles University in Prague, First Faculty of Medicine, Department of Neurology and Centre of Clinical Neuroscience, Czech Republic
[2]Czech Technical University in Prague, Faculty of Electrical Engineering, Department of Circuit Theory, Signal Analysis Modelling and Interpretation Group, Czech Republic

BACKGROUND and AIMS

Disorders of voice and speech in Parkinson's disease (PD) affect all subsystems including respiration, phonation, articulation, and prosody [1-3]. Quick vocal test consisting of sustained phonation, fast syllable repetition, and running speech was designed in order to be gender independent [4]. Main aim of this study was to separate early untreated PD from healthy control (HC) participants based upon automated acoustic analysis [5].

PATIENTS and DATA

24 PD speakers (20 men & 4 women)
- examined before the symptomatic treatment was started
- age 60.9 ± SD 11.2 years
- duration of PD symptoms 31.3 ± 22.3 months
- H&Y stage 2.2 ± 0.5
- UPDRS III motor score 17.4 ± 7.1

22 HC speakers (15 men & 7 women)
- no history of neurological or communication disorders
- age 58.7 ± 14.6 years

Table I: Summary of the speech data. For reproducibility of data, each task was repeated at least 2 times.

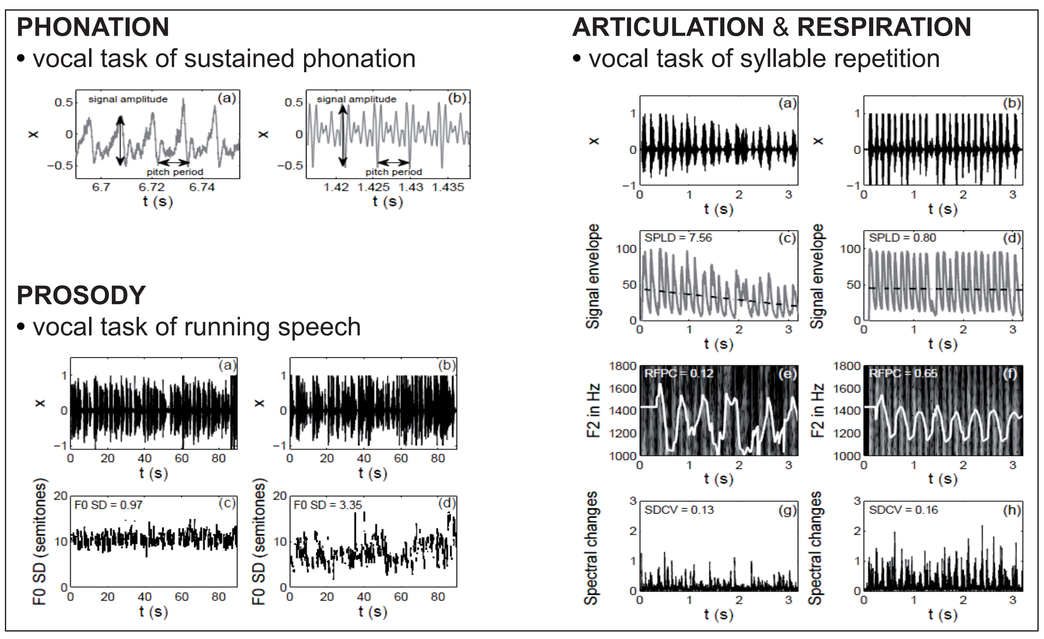
Task no.	Speech data
[VT1]	Sustained phonation on one breath at a comfortable pitch and loudness as constant and long as possible, at least 5-sec.
[VT2]	Rapid steady /pa/-/ta/-/ka/ syllables repetition, called diadochokinetic (DDK) task, on one breath as constant and long as possible, repeated at least 5-times.
[VT3]	Running speech, at least approx. 80-sec.

METHODS

Table II: Overview of the measurement methods used.

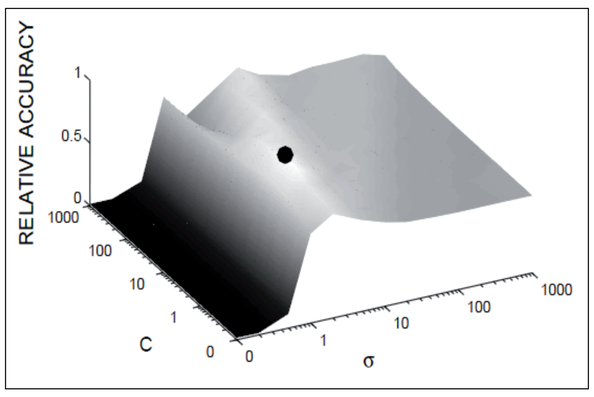
Determined from task	Acoustic measurement	Acoustic measurement description
[VT1]	Jitter	Regular or irregular variations of glottal cycle duration, the average absolute difference between a period and the average of it and its four closest neighbours, divided by the average period.
[VT1]	Shimmer	Regular or irregular variations of amplitude maxima in subsequent glottal cycles, the average absolute difference between the amplitudes of consecutive periods, divided by the average amplitude.
[VT1]	NHR	Noise-to-Harmonics-Ratio, the amplitude of noise relative to tonal components.
[VT1]	HNR	Harmonics-to-Noise-Ratio, the amplitude of tonal relative to noise components.
[VT2]	SPLD	Sound Pressure Level Decline, the robust linear regression of the signal envelope.
[VT2]	RFPC	Robust Formant Periodicity Correlations, the first autocorrelation coefficient of F2 contour.
[VT2]	SDCV	Spectral Distance Change Variations, the variations of spectral distance changes in spectrum.
[VT3]	F0 SD	Variations of fundamental frequency (F0) in semitones, the variations of vibration rate of vocal folds.

Figure 1: Details of measures used for subsequent analysis. The left panels are for a person with PD, the right panels are for a HC subject.



Statistics
- predictive model was built using a kernel support vector machine (SVM)
- exhaustive search of all possible measure combinations and optimal SVM parameters (C, σ)
- cross-validation with the leave-one-out method was used to validate reproducibility
- best combination of measurements was found to differentiate PD from HC subjects

Figure 2: Optimal SVM parameters.



RESULTS

- 116 vocal recordings were used for classification (56 for PD/60 for HC)
- relationships between measures of articulation & phonation and subscores of bradykinesia & rigidity

- best performance of 85.0 ± 6.1% in combination of four measures that represent all PD-related affected speech subsystems
- 81.3 ± 6.9% for running speech
- 75.6 ± 8.3% for sustained phonation
- 71.4 ± 8.3% for DDK task

Figure 3: The results of SVM-based classifier.

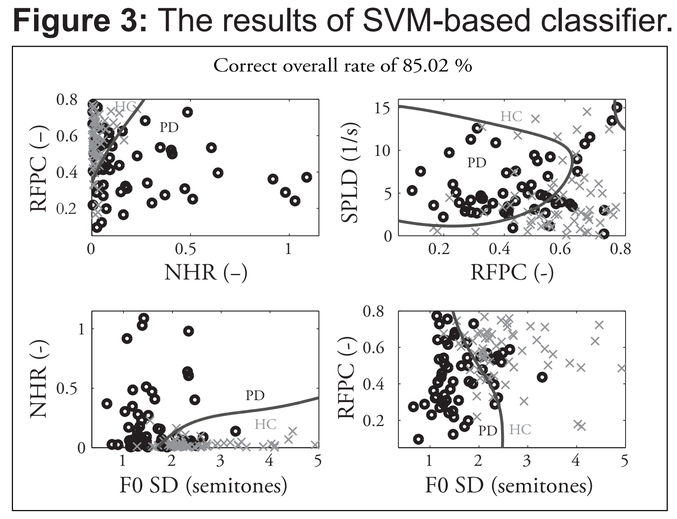
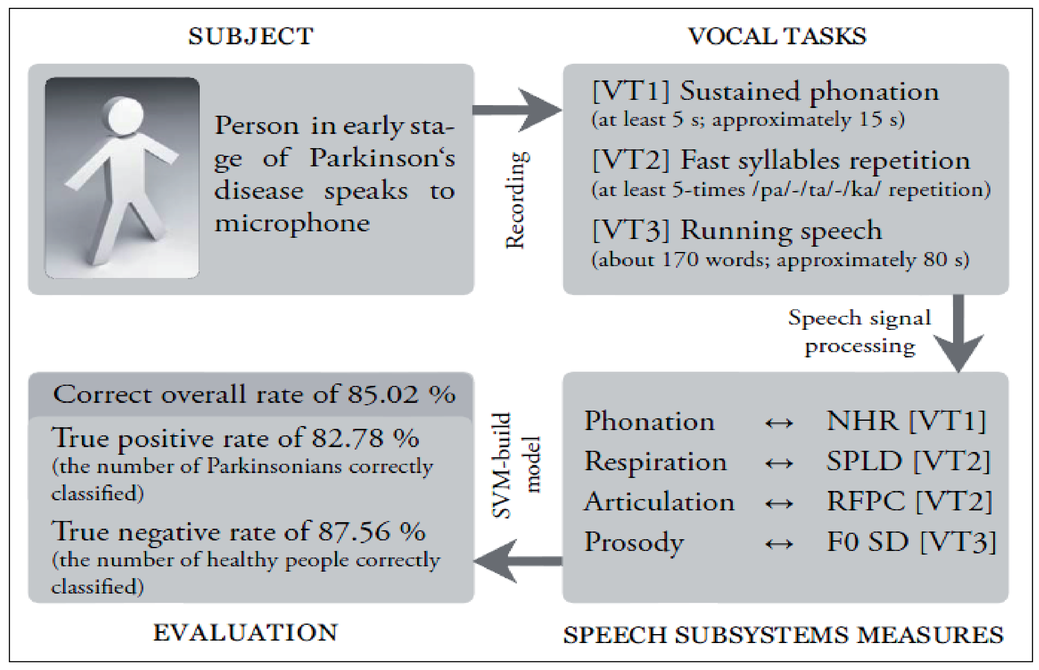


Table III: Result of the speech examination.

Measurement	Subjects PD Mean	PD (SD)	HC Mean	HC (SD)	Differences between groups	Correlation between PD patients' speech performances and UPDRS III total score		A composite UPDRS III subscore of Bradykinesia		PIGD		Rigidity	
[VT1] Sustained phon.													
Phonation													
Jitter (%)	0.91	0.68	0.33	0.21	***P* < .001**	*R* = .31	*P* = .14	***R* = .42**	***P* < .05**	*R* = .21	*P* = .32	*R* = .24	*P* = .25
Shimmer (%)	8.57	4.60	3.25	1.57	***P* < .001**	*R* = .28	*P* = .18	*R* = .33	*P* = .12	*R* = .01	*P* = .95	*R* = .35	*P* = .09
NHR (-)	0.22	0.25	0.04	0.03	***P* < .001**	*R* = .36	*P* = .08	***R* = .43**	***P* < .05**	*R* = .21	*P* = .33	*R* = .39	*P* = .06
HNR (dB)	14.05	6.01	22.55	4.28	***P* < .001**	*R* = -.40	*P* = .05	***R* = -.44**	***P* < .05**	*R* = -.14	*P* = .52	***R* = -.42**	***P* < .05**
[VT2] DDK task													
Respiration													
SPLD (1/s)	5.68	2.99	3.85	3.01	***P* < .05**	*R* = -.12	*P* = .59	*R* = -.19	*P* = .38	*R* = -.37	*P* = .08	*R* = .16	*P* = .46
Articulation													
RFPC (-)	0.43	0.14	0.58	0.10	***P* < .001**	*R* = -.33	*P* = .12	*R* = -.18	*P* = .40	*R* = -.13	*P* = .55	*R* = -.23	*P* = .28
SDCV (-)	0.14	0.03	0.17	0.03	***P* < .01**	*R* = -.40	*P* = .05	***R* = -.44**	***P* < .05**	*R* = -.28	*P* = .19	*R* = -.28	*P* = .18
[VT3] Running speech													
Prosody													
F0 SD (semitones)	1.52	0.43	2.62	0.75	***P* < .001**	*R* = .12	*P* = .56	*R* = .14	*P* = .53	*R* = .26	*P* = .22	*R* = .19	*P* = .37

Figure 4: Schematic diagram depicting the recording of the PD speakers.



CONCLUSIONS

- **method demonstrated that it can accurately differentiate PD patients from HCs**
- **subtle abnormalities such as reduced melody in running speech were detectable from the early stage of PD**
- **acoustic analysis may serve as a simple screening test in view of the expected advent of neuroprotective treatment**
- **acoustic vocal tests can be used for clinical monitoring of speech progression, effect of medication on speech production, and feedback in voice treatment**

REFERENCES

[1] Darley FL, Aronson AE, Brown JR. Differential diagnostic patterns of dysarthria. J Speech Hear Res 1969;12:246-269.
[2] Goberman AM, Coelho C. Acoustic analysis of Parkinsonian speech I: Speech characteristics and L-dopa therapy. Neurorehab 2002;17:237-246.
[3] Skodda S, Schlegel U. Speech rate and rhythm in Parkinson's disease. Mov Disord 2008;23:985-992.
[4] Rusz J, Čmejla R, Růžičková H, Růžička E. Quantitative acoustic measurements for characterization of voice and speech disorders in early untreated Parkinson's disease. J Acoust Soc Am 2011;129:350-367.
[5] Rusz J, Čmejla R, Růžičková H, Klempíř J, Majerová V, Picmausová J, Roth J, Růžička E. Acoustic assessment of voice and speech disorders in Parkinson's disease through quick vocal test. Mov Disord 2011;26:1951-1952.

ACKNOWLEDGEMENT

This research was partly supported by the Czech Science Foundation, project GACR 102/08/H008, Czech Ministry of Health, projects NT 11331-6/2010 and NT 12288-5/2011, Grant Agency of the Czech Technical University in Prague, project SGS 10/180/OHK3/2T/13, and Czech Ministry of Education, projects MSM 0021620849 and MSM 6840770012.