



# Motor speech and non-motor language endophenotypes of Parkinson's disease

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To cite this article: Michelle Magee, David Copland & Adam P. Vogel (2019): Motor speech and non-motor language endophenotypes of Parkinson's disease, Expert Review of Neurotherapeutics, DOI: [10.1080/14737175.2019.1649142](https://doi.org/10.1080/14737175.2019.1649142)

To link to this article: <https://doi.org/10.1080/14737175.2019.1649142>



Accepted author version posted online: 25 Jul 2019.



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**Table 1:** Distinguishing clinician and patient reported findings in dysarthria. (Adapted from

VOICE DEFICIT	SUBSYSTEM AFFECTED	STIMULI	ACOUSTIC FEATURE	DEFINITION	OBSERVATION	REF
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49)

SPEECH CHARACTERISTICS	ORAL-MOTOR FUNCTION	PATIENT OBSERVATIONS
Monopitch* Monoloudness* Reduced stress* Short phrases* Variable rate* Short rushes of speech* Imprecise consonants* Increase rate in segments Inappropriate silences Breathiness (continuous) Low pitch Hypernasality Hoarseness	Masked Facies Tremulous jaw, lips, tongue Reduced range of movement Weak cough or coup Dysphagia Drooling	Reduced loudness Rapid rate Mumbling Stuttering Difficulty initiating speech Stiff lips

\* Perceptual speech features defined as most unique to hypokinetic dysarthria (12, 13)

**Table 2:** Summary of main speech and voice deficits found in early Parkinson's Disease prior to symptomatic treatment

DYSPHONIA	Phonation	Sustained phonation /i/ /a/	Jitter	The variability of the fundamental frequency of speech from one cycle to the next	↑	54, 68
		Sustained phonation /i/ /a/	Shimmer	The sequence of maximum extent of the signal amplitude within each vocal cycle	↑	54, 68
		Sustained phonation /i/	NHR	The amplitude of noise relative to tonal component	↑	54
		Sustained phonation /i/	HNR	The amplitude of tonal relative to noise components	↓	54
IMPRECISE VOWEL	Articulation	DDK /pa/-/ta/-/ka/	DDK rate	Number of /pa/-/ta/-/ka/ syllable vocalizations per second	↓	54
ARTICULATION		DDK /pa/-/ta/-/ka/	RIRV	Relative intensity range variation	↓	54
		DDK /pa/-/ta/-/ka/	RRIS	Robust relative intensity slope	↑	54
		DDK /pa/-/ta/-/ka/	RFPC	first autocorrelation coefficient of F <sub>2</sub> contour	↓	54
		DDK /pa/-/ta/-/ka/	SDCV	the variations of spectral distance changes in a signal spectrum	↓	54
		Sentence repetition, monologue	tVSA	triangular vowel space area	↓	85
		Sentence repetition, monologue, reading passage	F <sub>2i</sub> /F <sub>2u</sub>	Measurement of vowel articulation based on ratio of F <sub>2</sub> frequencies of corner vowels /i/ and /u/	↓	85
		Sentence repetition, monologue, reading passage	F <sub>2u</sub>	F <sub>2</sub> frequencies of corner vowels /u/	↑	85
		Sentence repetition, monologue	VAI	Vowel articulation index	↓	85
DYSPROSODY	Prosody	Reading passage, monologue	F <sub>0</sub> SD	Standard deviation of fundamental frequency in Hz	↓	54, 68, 70, 86
		Reading passage, monologue	Intensity SD	Standard deviation of speech loudness	↓	54
		Reading passage, monologue	No. pauses	Number of all pauses	↑	54
		Monologue	F <sub>0</sub>	Mean fundamental frequency related to the entire speech task in Hz	↑	70

NHR = noise-to-harmonics; HNR = harmonics-to-noise; RIRV = Relative intensity range variation; RRIS = Robust relative intensity slope; RFPC = Robust Formant Periodicity Correlation; SDCV = Spectral Distance Change Variation; tVSA = triangular vowel space area; VAI = vowel articulation index; F<sub>0</sub> SD = fundamental frequency variation; F<sub>0</sub> fundamental frequency.

PARTICIPANT COHORT	UPDRS III	STIMULI	ACOUSTIC FEATURE	DEFINITION	CHANGE OVER TIME	CORRELATE WITH UPDRS	REF
PD 65.5 ± 7.5 years old T <sub>0</sub> : 7.61 ± 4.01 years disease duration 2 sessions, interval: 24 months “ON” state  Tested 60 min after L-dopa	T <sub>0</sub> 22.5 ± 13.5 T <sub>1</sub> 27.5 ± 12.7	Sustained phonation /a/ Sustained phonation /e/ Sustained phonation /i/ Sustained phonation /o/ Sustained phonation /u/	APQ FLUF PPQ	Micro-perturbations in intensity of voice Aperiodicity of voice using fraction of locally unvoiced frames Micro-perturbations in frequency of voice	↑ /e/ /i/ /u/ ↑ /e/ /i/ /o/ /u/ ↑ /o/ /u/	NO YES /e//o/ NO	89
HC vs PD 40-80 years old T <sub>0</sub> 1-20 years disease duration 2 sessions, interval: 12-88 months “ON” state  Tested 60-90 min after morning meds	T <sub>0</sub> 20.1 ± 11.0 T <sub>1</sub> 19.6 ± 8.3	Sentence repetition Sustained phonation /a/	Shimmer NHR  Speech rate VAI  % pauses	Maximum extent of the signal amplitude within each vocal cycle The amplitude of noise relative to tonal component  Syllables per second related to net speech time Vowel articulation index  Pause time percentage of total speech time	↑ ↑  ↓ ↓  ↓	    YES (H & Y)	86
HC vs PD 40-80 years old T <sub>0</sub> 1-20 years disease duration Stratified by sex 2 sessions, interval: 12-88 months “ON” state Tested 60-90 min after morning meds	T <sub>0</sub> Males 19.5 ± 10.7 Female 18.2 ± 11.0 T <sub>1</sub> Males 19.1 ± 8.3 Female 19.2 ± 8.6	Reading task	VAI  tVSA	Vowel articulation index  Triangular vowel space area	↓ (males & females) ↓ (females)	YES (gait)	88
HC vs PD 58-80 years old T <sub>0</sub> 1-20 years disease duration 2 sessions, interval: 12-88 months “ON” state	T <sub>0</sub> 20.0 ± 10.3 T <sub>1</sub> 19.5 ± 8.8	DDK	COV <sub>5-20</sub> %PA	Stability of pace of the utterances Comprehensive measure of pace acceleration	↑ ↑	NO NO	87
HC vs PD	T <sub>0</sub> Males	Reading task	F <sub>0</sub> SD	Standard deviation of F <sub>0</sub> in Hz	↓ (females)	NO	73

43-80 years old	19.7 ± 10.0	F <sub>0</sub> VR	Difference between minimum and maximum F <sub>0</sub> in Hz	↓ (females)	NO
T <sub>0</sub> 1-20 years disease duration	Female 18.9 ± 11.2 Males 18.2 ± 9.1	TSR	Syllables per second related to total speech rate	↓ (males)	
Stratified by sex	Female 19.0 ± 9.8				
2 sessions, interval: 7-79 months “ON” state					

HC = healthy controls; PD = Parkinson’s Disease; APQ = amplitude perturbation quotient; FLUF = fraction of locally unvoiced frames; PPQ = period perturbation quotient; NHR = Noise to harmonics ratio; VAI = Vowel articulation index; tVSA = triangular vowel space area; COV =Relative coefficient of variation; %PA = pace acceleration; F<sub>0</sub>SD = Standard deviation of fundamental frequency; F<sub>0</sub>VR = Fundamental frequency variation range; TSR = total speech rate.

**Table 3:** Longitudinal assessment of acoustically derived speech parameters in Parkinson’s Disease

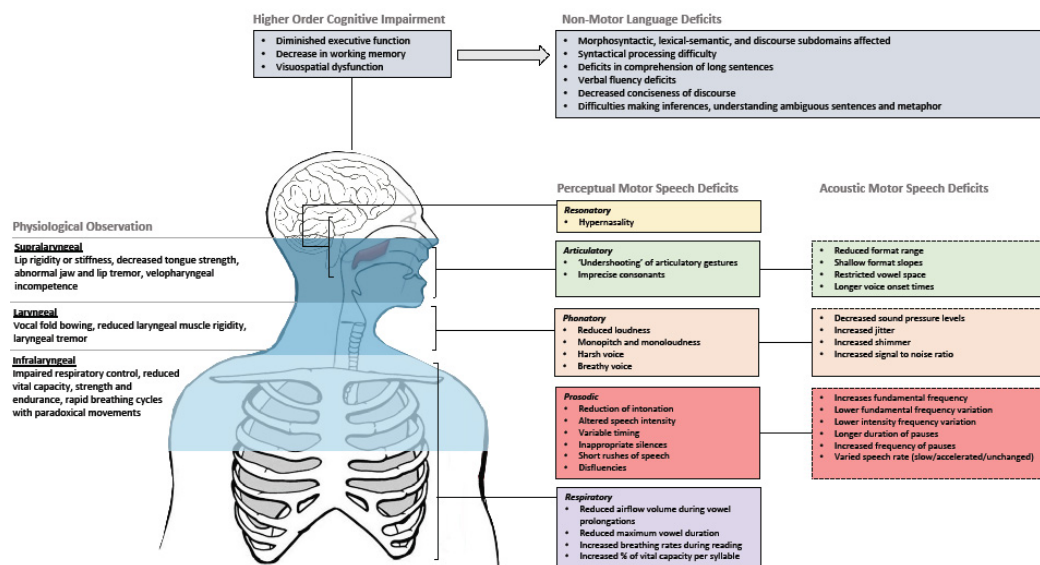


Figure 1