Acoustic speech markers for tracking changes in hypokinetic dysarthria associated with Parkinson's Disease

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Contents

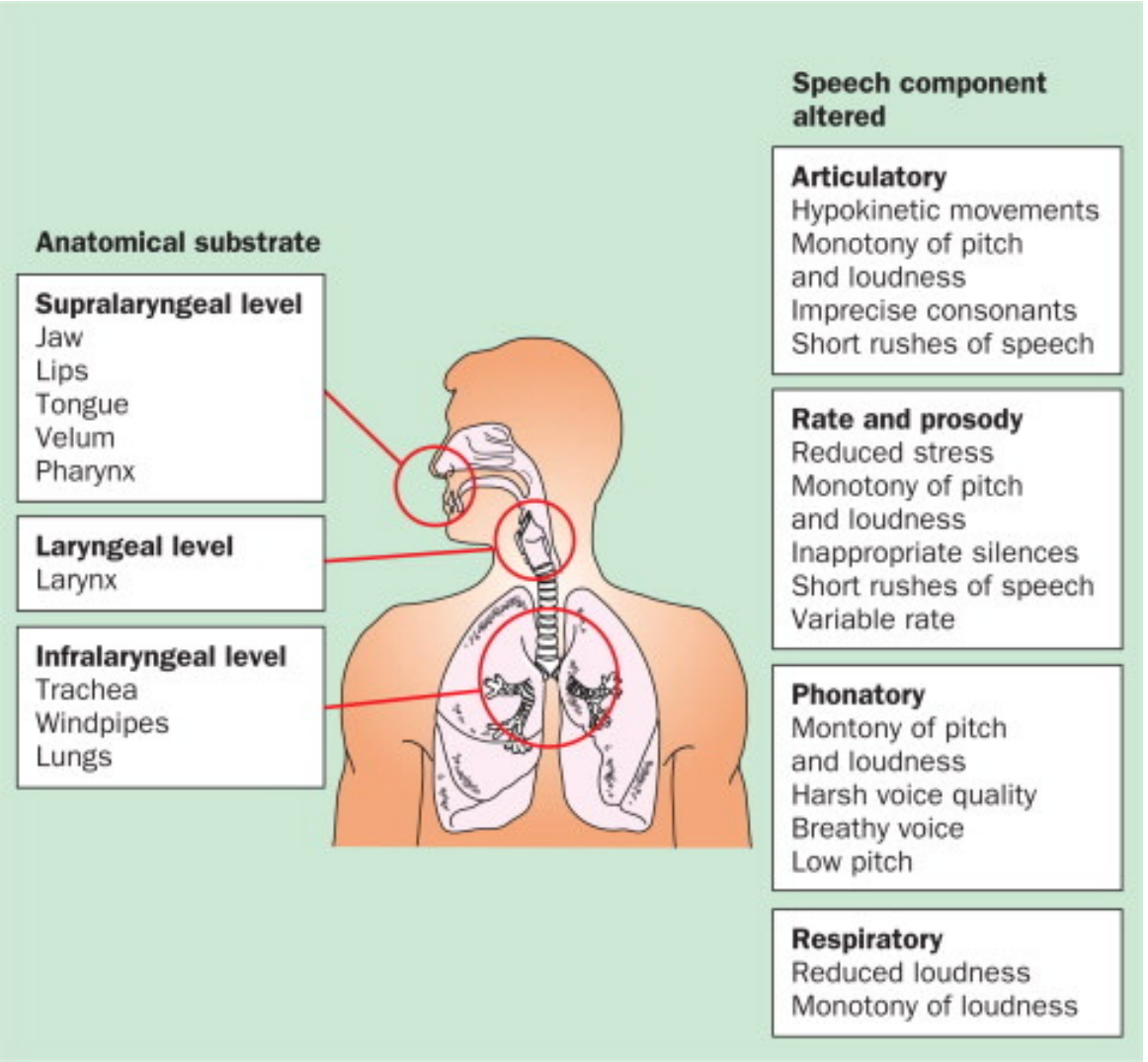
Introduction: Dysarthria

- Motor Speech Disorder – affects respiration, phonation, articulation and velopharyngeal control.
- Unintelligible speech; timing and accuracy disturbances.
- Listeners describe speech as having imprecise articulation, slow speaking rate, voice disturbances, and reduced prosodic variation. Often characterized as having rhythmic disturbances but not the focus of most research.

Introduction: Parkinson's disease (PD)

- Neuro degenerative syndrome resulting from damage to the basal ganglia.
- Parkinsonism is used to describe various types of PD including idiopathic PD (most common), secondary/ symptomatic PD and Parkinson-plus syndromes[1,2,3].
- Cardinal symptoms include bradykinesia, rigidity, and resting tremor.
- Speech and swallowing disorders are a typical consequence of PD[4].

Introduction: PD and hypokinetic dysarthria



Literature review

- Perceptual methods of analysis are easy to access and low cost, but they can be inaccurate[5].
- Acoustic analysis can balance this pitfall by providing a more quantifiable way of looking at speech production[6].
- Studies using acoustic analysis have found certain perceptual features present in hypokinetic dysarthria along with their acoustic correlates.
  - Acoustic markers that are robust for differential diagnosis may not be effective for tracking speech changes over time.
- Further studies are warranted to investigate whether acoustic parameters can capture changes in both perceptual speech features and changes in speech intelligibility – this is primarily addressed in my research.

Literature review

1. Some longitudinal studies have tried to identify speech features that are present over time that can be 'tracked'[7,8].

- One longitudinal study[7] found that F0 variation and voice onset time are consistently less than normal speech and showed deterioration over time.
  - This was a retrospective study and only used free speech which did not allow control over utterances.
  - Very small sample size.

1. Another longitudinal study[8] had variable lengths between data collection time points and therefore cannot conclude the trajectory of speech changes identified.

Research Questions

Global Research question:

Which acoustic parameters are able to capture speech changes in hypokinetic dysarthria associated with PD within a year?

Specific Research questions:

1) Which acoustic parameters can track perceptual changes in PwPD speech over time?
2) Which acoustic parameters can track changes in PwPD speech intelligibility over time?

Inclusion criteria for the PwPD group

- Aged 35 or over
- Fluent in English
- Diagnosed with PD in any stage of disease progression (whether on or off dopaminergic treatment)
- Displays deviant speech symptoms but do not need to be formally diagnosed with hypokinetic dysarthria

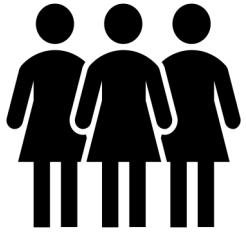
Exclusion criteria for the PwPD group

- Any cognitive or mental health condition (such as dementia or depression) that is associated with PD symptomatology or otherwise
- Diagnosis of a speech or voice disorder prior to PD or after PD that is not dysarthria

Data collection

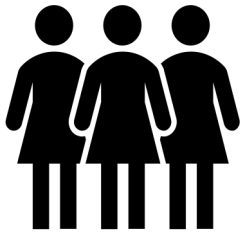
Recording with Squadcast

Repeated after six months



63 PwPD

45-93 years (Mean = 69; SD = 8.4), with 20F and 43M



47 Control

35-86 years (Mean = 64; SD = 12.2), with 30F and 17M

GORILLA™ [9]

SLT severity ratings

- Two speech and language therapists rated 30s speech samples across 7 speech dimensions:
- pitch, loudness, voice quality, resonance, respiration, prosody, and articulation.
- Speech samples were rated after T1 and T2 respectively.

SLT ratings – results

- Analyses of the ratings showed Voice quality, Articulation and Prosody were rated as most severely affected categories. These three categories were the focus of acoustic analysis. Voice quality and prosody are discussed today.
- Perceptual features within each category rated as 3 “marked” or 4 “severe” deviant were isolated and their acoustic correlates identified.

Speech subsystem	Acoustic parameter	Speech task	Description
Voice	Jitter	Sustained phonation	Variability of the fundamental frequency from one cycle to the next.
	Shimmer	Sustained phonation	The maximum amplitude of each vocal fold vibration from one cycle to the next.
	HNR	Sustained phonation	The amplitude of noise relative to tonal components.
	CPP	Reading passage	The measure of cepstral peak amplitude normalized for overall amplitude.
Prosody	Speech rate	Reading passage	The number of syllables over the total duration of speech after the removal of pauses.
	Mean intensity	Reading passage	The average sound pressure over the total duration of speech after pauses are removed.
	IntSD	Reading passage	The standard deviation of the speech intensity contour of voiced segments.
	F0SD	Reading passage	The standard deviation of the fundamental frequency contour.

Acoustic analyses in Praat[10]

- Two analyses were conducted to answer each of the specific research questions:

1. Perceptual Feature Rating (PFR) analysis
   - Used the results of the SLT ratings to identify participants who were rated 3 or 4 on the most deviant speech features. These were further divided into sub-groups based on whether SLT ratings changed between T1 and T2.
   - The analysis also investigated if acoustic correlates were able to differentiate between PwPD and controls.
2. Intelligibility Groups (IG) analysis
   - Created sub-groups based on overall intelligibility rating and whether these ratings changed between T1 and T2.

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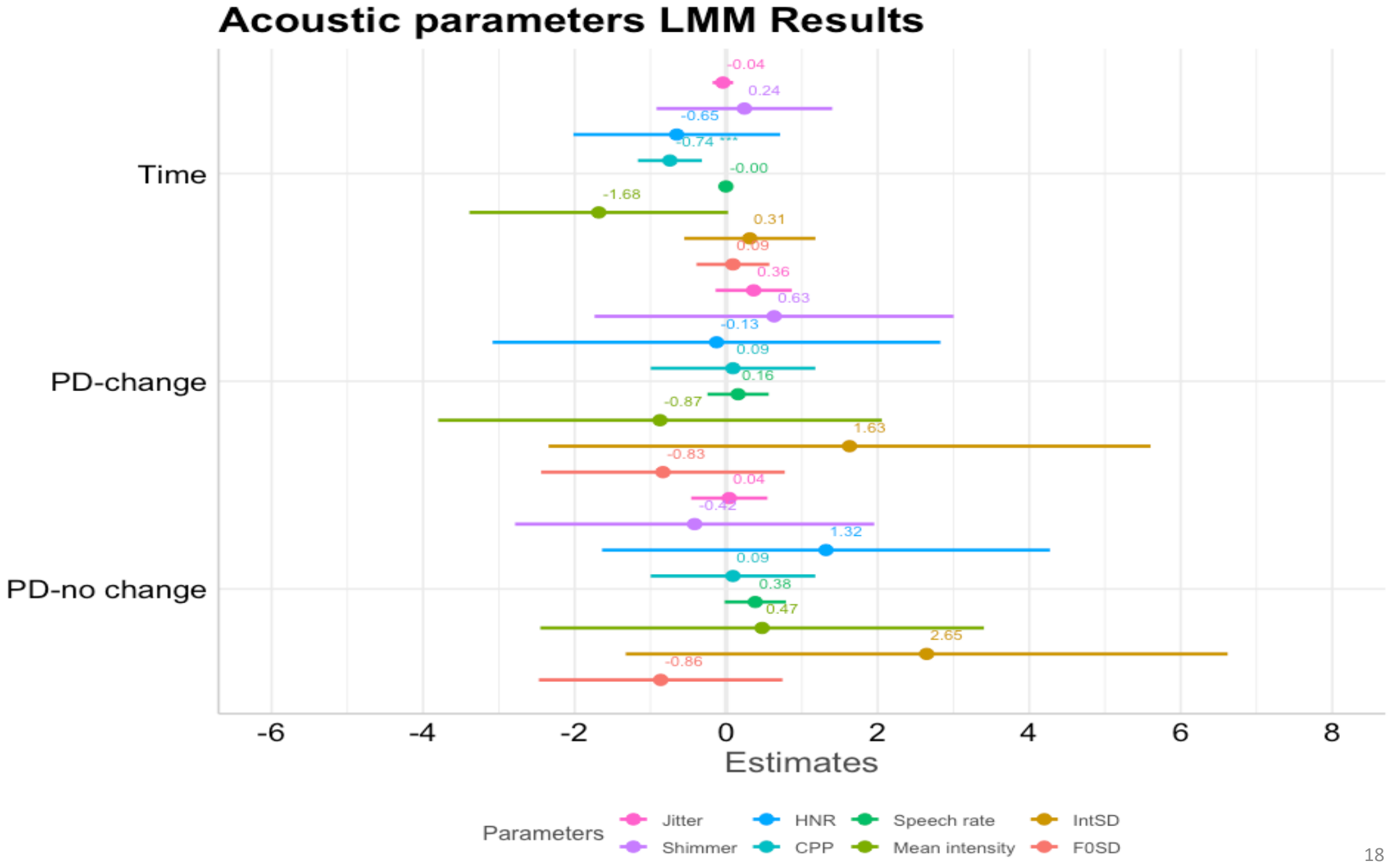
Participant demographics

PFR Groups	Number of participants	Age range (years)	Mean age (years)
PwPD-change	N= 21(M = 15; F = 6)	50-93	69
PwPD-no change	N= 21; M = 13; F = 8	56-84	71
Control	N= 10; M = 5; F = 5	51-82	70

Statistical Analysis

- Linear Mixed Effects Models (LMMs) on R Studio[11]
- Each LMM formula: acoustic parameter ~ time + group + (1|participant)


Acoustic parameters LMM Results
Time
PD-change
PD-no change
-0.04
0.24
-0.65
-0.74 ***
-0.00
-1.68
0.31
0.09
0.36
0.63
-0.13
0.09
0.16
-0.87
1.63
-0.83
0.04
-0.42
1.32
0.09
0.38
0.47
2.65
-0.86
-6
-4
-2
0
2
4
6
8
Estimates
Parameters
Jitter
Shimmer
HNR
CPP
Speech rate
Mean intensity
IntSD
F0SD

Voice Quality Results

Fixed Effects:						
Acoustic parameter	Predictor	Estimate	Std. Error	df	t-value	p
Jitter	(Control, T1)	0.63	0.21	51.66	2.97	<0.01*
	T2	-0.04	0.07	51.00	-0.63	0.54
	PwPD-change	0.36	0.25	49.00	1.43	0.16
	PwPD-no change	0.04	0.25	49.00	0.16	0.87
Shimmer	(Control, T1)	7.94	1.03	57.61	7.73	<0.01*
	T2	0.24	0.59	51.00	0.41	0.68
	PwPD-change	0.63	1.19	49.00	0.53	0.59
	PwPD-no change	-0.42	1.19	49.00	-0.35	0.73
HNR	(Control, T1)	15.69	1.27	56.67	12.32	<0.01*
	T2	-0.65	0.69	51.00	-0.95	0.35
	PwPD-change	-0.13	1.49	49.00	-0.09	0.93
	PwPD-no change	1.32	1.49	49.00	0.89	0.38
CPP	(Control, T1)	4.93	0.46	54.46	10.65	<0.01*
	T2	-0.74	0.21	51.00	-3.49	0.001**
	PwPD-change	0.09	0.55	49.00	0.17	0.87
	PwPD-no change	0.09	0.55	49.00	0.16	0.87

Prosody Results

Fixed Effects:						
		Estimate	Std. Error	df	t-value	p
Speech rate	(Control, T1)	4.05	0.17	50.72	23.931	< 0.001**
	T2	-0.00	0.04	51.00	-0.073	0.94
	PwPD-change	0.16	0.20	49.00	0.771	0.44
	PwPD-no change	0.38	0.20	49.00	1.885	0.07
Mean intensity	(Control, T1)	73.27	1.29	61.14	56.873	< 0.001**
	T2	-1.68	0.86	51.00	-1.955	0.06
	PwPD-change	-0.87	1.48	49.00	-0.592	0.56
	PwPD-no change	0.48	1.48	49.00	0.322	0.75
IntSD	(Control, T1)	10.49	0.49	54.03	21.59	< 0.001**
	T2	0.12	0.32	45.89	0.37	0.71
	PwPD-change	1.00	0.56	45.44	1.79	0.08
	PwPD-no change	1.12	0.56	45.12	1.99	0.06
F0SD	(Control, T1)	5.74	0.68	52.23	8.470	< 0.001**
	T2	0.09	0.24	51.00	0.369	0.71
	PwPD-change	-0.83	0.81	49.00	-1.029	0.31
	PwPD-no change	-0.86	0.81	49.000	-1.066	0.29

Discussion

- Voice quality – CPP significant for *time* – increased dysphonia in T2.
  - Change observed across all groups
  - Might not see a significant diff. in minor severity.
- Prosody – no parameters significant.
- Results suggest a correlation of various perceptual features.
- Results could indicate speech change is independent of PD stage.

Limitations

- Controls not age and sex matched to PwPD group
- Age range of the two groups are variable
- All PwPD participants were on dopaminergic treatment and cannot isolate the baseline influence of the medication on speech.
- Online data collection limitations on some acoustic measures.

Future studies

- See if the results generalise to other speech data collected – minimal pairs, spontaneous speech.
- More data collection points to see if the deterioration is linear or not.

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