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Prosodic aspects of parkinsonian speech: Effects of bilateral subthalamic nucleus stimulation

Danielle Duez, François Viallet, Ludovic Jankovski and Alain Purson

Laboratoire Parole et Langage

Prosody of Patients with Parkinson's disease (PD)

- Studies on the speech produced by patients suffering from Parkinson's disease (PD), a disease characterised by an impairment of basal ganglia (BG) function, have pointed out a certain number of **prosodic abnormalities**.
- "Prosodic insufficiency" (Darley et al.,1969), i.e. reductions in amplitude mean and range and anomalous restricted fundamental frequency (F0) range (e.g. Canter, 1963). F0 is among the first prosodic components affected by PD.
- The lack of variability in the F0 contours seems to correspond to a reduced efficiency of the laryngeal muscles, confirming a muscular rigidity (Weismer, 1984), especially in the cricothyroid muscles responsible for controlling pitch change (Aronson, 1990).

Temporal variables in PD speech

- Less agreement on temporal variables.
- Speech rate affected differently by PD: some patients accelerate while others speak more slowly than normal .
- Articulation rate faster (Hammen and Yorkston, 1996, Mac Rae et al. 2002) or about the same (Goberman et al., 2005; Nishio and Niimi, 2001).
- Pause time longer with shorter breath groups and longer, more frequent pauses in PD speech (Goberman et al., 2005; Hammen and Yorkston, 1996); No significant pause duration differences (Volkmann et al. 1992).
- Pause location. Pauses at syntactic boundaries (Canter and Van Lancker 1985). Pauses at inappropriate locations (Solomon and Hixon,1993).

Effects of STN Stimulation

- ***Contradictory results***
- ***Beneficial effects on F0 and duration of pauses***:
- patients varied intonation contour more easily and their speech sounded more normal and natural (Gentil et al., 2001)
- Longer maximal phonation time of sustained vowels and a reduction of the pauses in phrase repetitions for 30 s<=increase of vocal fold adduction and inspiratory and expiratory volumes (Gentil et al., 2001)
- ***Deleterious effects***:
- degradation of intelligibility with acceleration of speech rate, and less variability and more monotony in F0 (Rousseaux et al., 2004; Santens et al., 2003).

Importance of Prosody

- Degradation of prosody may have crucial consequences
- Prosody is a mould in which speech sounds take place
- Prosody is everywhere in speech (length of speech segment, tones, accentuation, rhythm and intonation)
- Prosody has a wide range of functions (Fonagy, 2003) : linguistic (lexical, syntactic, pragmatic) and communicative (emotional, attitudinal, identification).
- Some functions may be affected by PD , this can have a detrimential effect for intelligibility.(e.g. flattening of F0 may affect the emotional function of speech, Pell et al., 2006).
- ***How do the differents treatments affect prosody is a fundamental question: Do they improve or degrade it?***

Objectives of the study

- The present study deals with the F0 range and mean and the temporal variables (speech rate, articulation rate, pause time and pause location) of a **text read** by ten patients in two conditions of STN stimulation (ON and OFF).
- This analysis of these variables, in particular this of temporal organisation may give us an indirect although reliable understanding of the syntactic function of prosody.
- Three main objectives (1) to assess the *impact of STN stimulation on some* speech prosodic patterns, (2) to *evaluate individual responses to STN stimulation and (3) to see how PD affects prosodic patterns of PD speech by* comparing the results with those obtained for ten age-matched controls.

Procedure

- There were **two recordings of ten male patients in two STN stimulation conditions**. The first recording was with **stimulation on**. Then after thirty minutes the stimulation **was off**, the second recording started. Patients were without L-dopa
- Ten age-matched controls were also recorded
- These recordings are from the data-base of LPL initiated by F. Viallet and B. Teston)
- Before recording, the motor disability of each patient was assessed using the Unified Parkinson's Disease Rating Scale **(UPDRS)**
- **Degree of Dysarthria severity** as defined by item 18 (Fahn and colleagues, 1987) was evaluated.

Characteristics of patients

				OFF	**OFF**		**ON**	**ON**
	Diag-Age	Years Treatment	Age	UPDRS	Dysarthria Degree		UPDRS	Dysarthria Degree
P1	45	15	60	51	2		22	1
P2	31	15	46	36	1		12	0
P3	59	13	72	42	3		21	2
P4	46	11	57	60	2		18	1
P5	52	14	66	43	**2**		29	**2**
P6	52	8	60	43	**1.5**		23	**1**
P7	48	23	71	36	3		22	2
P8	54	15	69	49	**2**		23	**2**
P9	45	7	52	60	**2**		25	**2**
P10	48	21	69	37	1.5		8	0.5
Mean (SD)	48 (7.4)	14.2 (5.02)	62.2 8.7	45.7* 9	2* 0.6		20.3 6.18	1.35 0.7

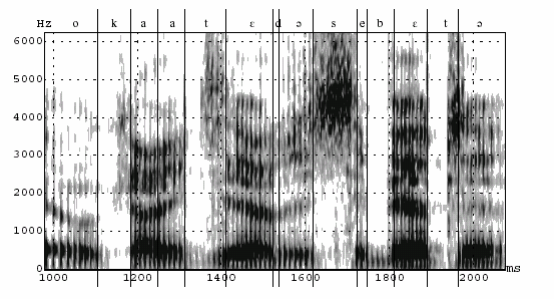
Corpus

- The read speech sample was a paragraph of “La chèvre de Monsieur Seguin” (the syntactic function of prosody is predominant in read speech, Vaissière and Michaud, 2005)
- Each subject was asked to read at his habitual speech rate. High-quality recordings were obtained in a sound-treated room of the Aix-en-Provence Hospital.
- The acoustic signal was transduced using an AKG C410 head mounted microphone and recorded directly onto a PC hard disk at a sampling rate of 20 KHz.

Labeling, segmentation and measurements

- Measurements were made on combined wideband spectrograms and oscillograms displayed on a screen, and by listening to selected segments of the waveform in regions of specific interest (with Praat)
- Segmention into pauses and sounded sequences; each sounded sequence was segmented into syllables in turn segmented into C’s and V’s whose limits were carefully marked using a set of consistent rules which utilise spectral changes and formant transitions.
- F0 mean extracted automatically for each vowel (script written by Gendrot)
- F0 minima and maxima were obtained manually for each sounded sequence

Sequence « au caractère de ses bêtes »



Analysis of variables

- ***F0 ranges*** : maximum F0-minimum F0 (in semi-tones)
- ***Silent-pause ratio:*** total duration of silent pauses/total speech time
- ***Mean pause duration***: total silent pause time/ the number of silent pauses.
- ***Mean duration of an articulated sequence***: articulation time (total speech time minus total pause time)/ the number of articulated sequences.
- ***Articulation rate :*** number of syllables of a sequence/ the duration of this sequence.
- ***Speech rate***: total number of syllables / total speech time***.***

Pause location

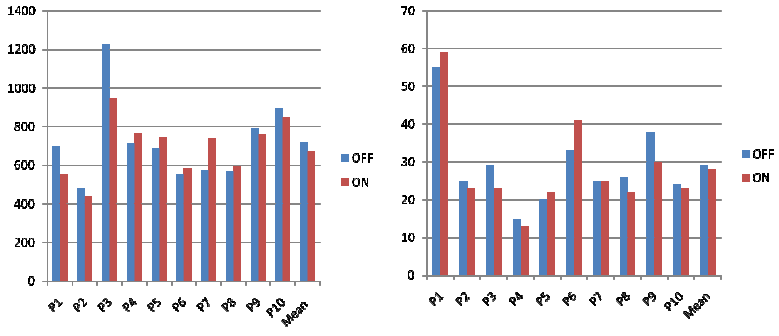
- ***Four types of syntactic pauses*** were considered:
- *(1) pauses* located between paragraphs;
- (2) pauses located between sentences, with a terminal contour;
- (3)pauses located between clauses (conjunctive, relative or independent);
- (4) pauses occurring between phrases as defined by Blanche-Benveniste et al. [39].
- ***Two types of non-syntactic pauses*** were examined
- (1) Pauses occurring within a phrase (e.g. between an article and a noun, a personal pronoun and a verb)
- (2) Pauses within a word (grammatical or lexical)

Temporal variables: overall results

	Speech rate	Pause %	Mean Pause D	Mean SS Duration	AR	Syll Duration
Control	4,12	24,12	575.98	1653	5,43	179,59
			(366,54)	(948)		(81,03)
Stim OFF	3,89	29,06	704,54	1544,58	5,49	185,3
			(442,84)	(868)		(90,12)
Stim On	3,91	26,58	663,5	1638,73	5,33	188,29
			(430,53)	(948)		(85,12)

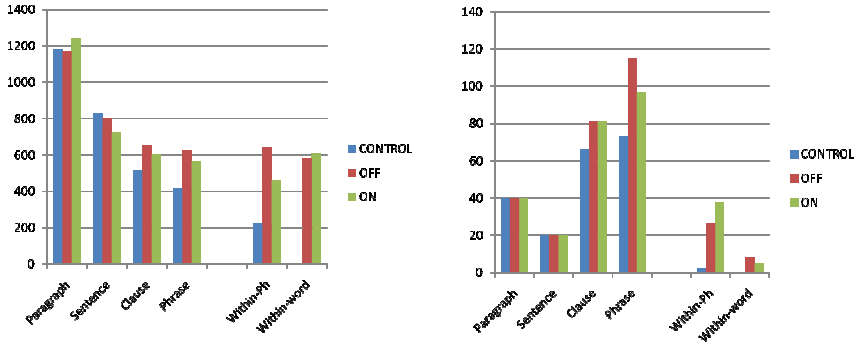
Speech rate is slightly more rapid in CS than in PS (about the same in both stim conditions).
This can be related to a shorter pause time and slightly less frequent pauses

Pause duration and number per subject and condition



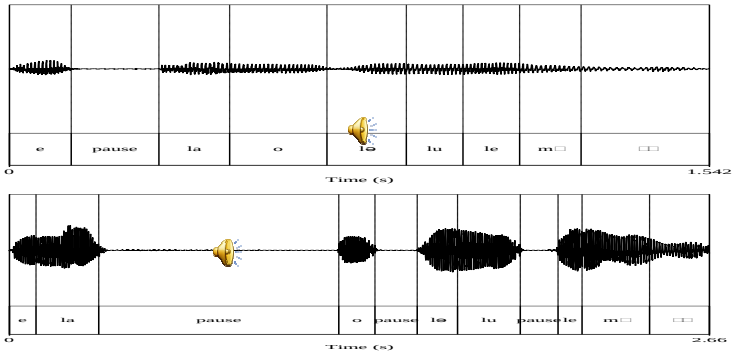
Slight decrease in mean pause duration and number in ON
High variability across subjects and different impact of STIM
D- and N-: P2,P3 (s.), P9,P10; D+ and N+: P5 and P6
D- and N+: P1; D+ and N-: P4 and P8; D+ and N=: P7

Duration and number of pauses/location

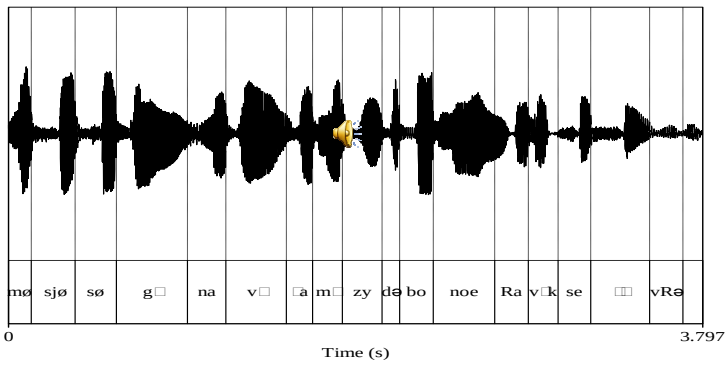


Correlation between the syntactic hierarchy of syntactic breaks and pause duration :***Preservation of the distributional scheme of pauses in Patients***
Non-syntactic pauses more frequent in ON (Off: 34; On:43)
P1,Off:12;ON:23; P5, OFF:1, On:5; P7: Off:1, On:3)
Tendencies to produce more pauses at clause and phrase boundaries in PS.

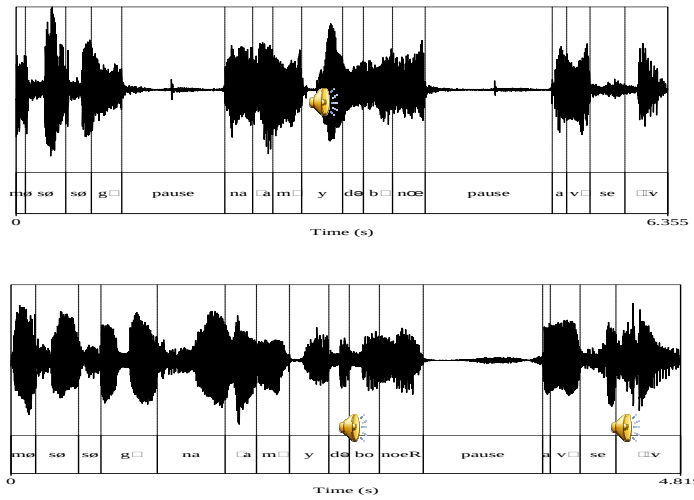
Sentence « la-haut le loup les mangeait » and up there the wolf eat them » produced by patient 1 (up: OFF, down: ON with a 910ms within-word pause)



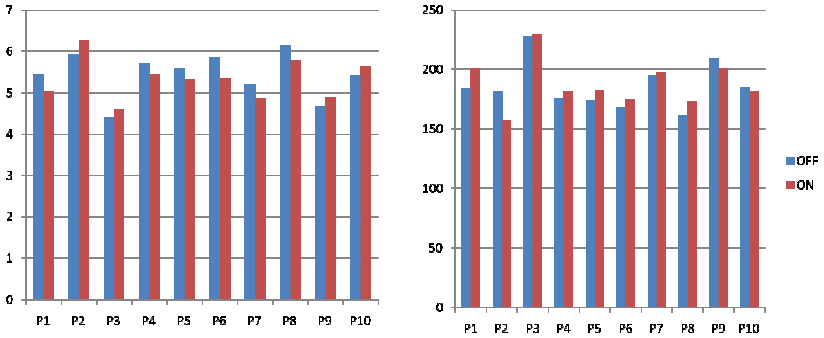
Sequence ’Monsieur Seguin n’avait jamais eu de bonheur avec ses chèvres » « Mr Seguin was never happy with his goats produced by a control (no pause)



The same sentence produced by a patient in STIM OFF and STIM ON



Articulation rate and duration per patient and condition



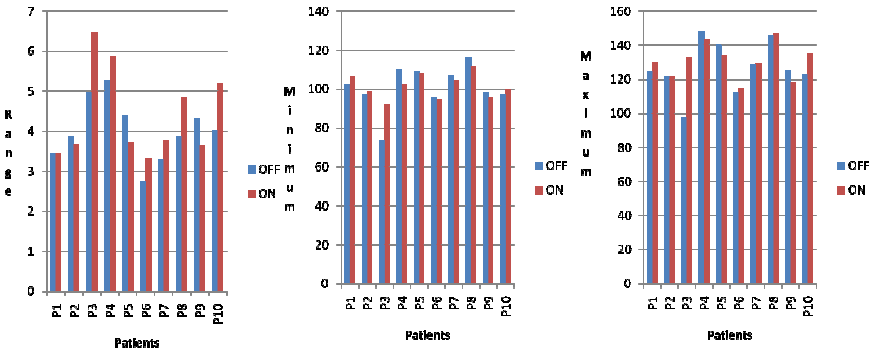
Again great variability across speakers : tendency to accelerate for P2, P3, P9 and P10; and to have a slower AR for the remaining.
This means a tendency to increase the duration of syllables. How does this impact the duration of consonants (which tend to be reduced in PS)?

F0 Values (Mean, Min and Max in hz, Range in semi-tones, SD in italics)

	Mean	Range	Min	Max
• **Cont**	133.8	9.1	102.2	172.8
	28.14	*3.1*	*19.7*	*33.7*
• **OFF**	114.7	3.9	100.2	125.2
	17.0	*1.7*	*14.0*	*15.1*
• **ON**	117.02	4.2	101.8	130.0
	13.8	*2.0*	*10.7*	*12.8*

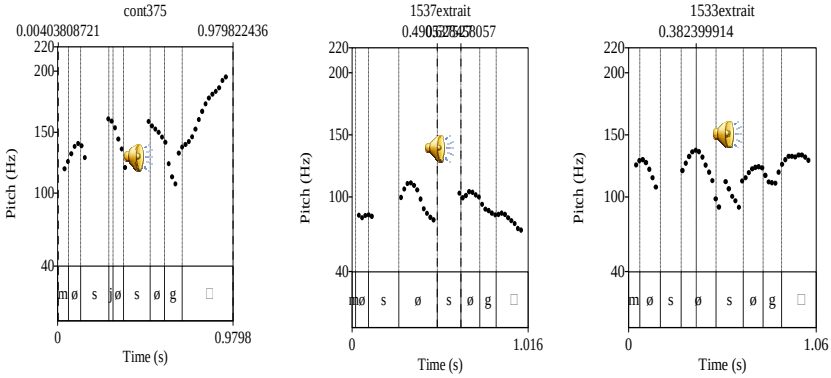
lower f0 means and values and smaller f0 ranges in PD speakers <significant lower maximum values and less variability=> HYPOMELODY

F0 ranges (in semi-tones) maximum and minimum (Hz) for STIMOFF and STIMON.



Variability across patients: Some decrease F0 ranges (P2, P5, P9), some increase ranges (P3*, P4, P6, P7, P8* and P10*
Increased F0 ranges are mainly due to higher maxima=> consequences for the realisation of contours at syntactic boundaries

Sequence « Monsieur Seguin » produced by a control and a patient in STIM-OFF and in STIM-ON



Concluding remarks (1)

- Relative perseveration of the pause pattern in agreement with the syntactic structure of the message across conditions: this suggests that the syntactic function of prosody is intact and that the syntactic function relies mainly on temporal parameters.
- Perserveration of flattened F0 (only three patients had a wider range
- This has implications for the different functions of prosody

Concluding remarks (2)

- Different impact of STN stimulation on the speech of patients (as shown in the literature for the different treatments)
- However, the present results do not allow us to draw conclusions on a possible improvement or degradation
  - Increase of F0 range and F0 maximum for a few patients suggests a better realisation of contours ;
  - Syllable lengthening may be due to a lesser shortening of C's
  - Less syntactic pauses may lead to a greater fluency
  - On the opposite, more non-syntactic pauses suggest a degradation of speech.
  - More acoustic and perceptual investigations are needed
- More generally, this confirms the difficulty to evaluate the impact of treatments

- Thanks for listening!