Effects of Pharmacological versus Electrophysiological Treatments on Parkinsonian Dysprosody

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Abstract

Dysprosody represents an essential part of the lack of speech intelligibility in Parkinson disease. To date, patients' management has been based on two therapeutic interventions: L-DOPA medication and/or sub-thalamic nucleus (STN) stimulation. Herein, we studied speech production in two groups of ten patients (one group for each treatment), by means of three prosodic parameters: pitch, intensity, and duration.

The results of this study show a clear effect only on the pitch parameter (mean F_0 and F_0 standard deviation) with either treatment: L-DOPA or STN stimulation. No significant change was obtained on either intensity or duration with these treatments

1. Introduction

Apart from the segmental aspects of speech production, the acoustic parameters of prosody represent an essential part of speech intelligibility.

During the course of pathological states, such as Parkinson disease, the progressive loss of speech intelligibillity may considerably impair the quality of life, and hence aggravate the motor and cognitive consequences of the disease.

To date, this aspect of patient management is increasingly important in the assessment of therapeutic intervention, such as L-DOPA medication or the more recently developped sub-thalamic nucleus stimulation (STN) with surgically implanted electrodes.

In general, speech impairment is correlated with overall motor status in Parkinson disease: within the motor part of the Unified Parkinson Disease Rating Scale (UPDRS) [1], speech assessment is restricted to a sole item among 15 others, whereas its specific weight represents only 4 out of 108 points.

Currently, it is possible to assess the prosodic dimension of speech production both automatically and easily, and to consider its different elements, i.e. pitch (fundamental frequency F_0), intensity (SPL), and duration [2].

A such, it is of interest to consider the impact of different therapeutic strategies in Parkinson disease, via these new assessment tools. We use them, first, for the evaluation of L-DOPA administration, when comparing patients' performance while "on" versus "off" drug intake. Secondly, we use such measurements for the evaluation of the STN stimulation effects, when comparing patients (without any drug intake) during "on" and "off" stimulation.

The rationale of such a study relies on the comparison of a pharmacological versus an electrophysiological therapeutic action in parkinsonian patients with special attention paid to their common effects but also to their differential influences on speech prosody.

2. Method

2.1. Patients

Two groups of 10 male parkinsonian patients participated in the study. Their characteristics are outlined in detail in parts A (L-DOPA group) and B (STN group) of Table 1. Their mean ages were respectively 57.4 years and 60 years; disease duration were respectively 10.6 years and 12.6 years. Their cognitive status was considered as unimpaired according to their MMSE and/or the Mattis dementia rating scale. Their mean UPDRS motor score during on and off states were 36.5 vs. 20.5 respectively for the L-DOPA group and 48.5 vs. 19.8 for the STN group.

Table 1 - a: Patients' characteristics (L-DOPA group)

Patient	Age	Disease duration	Total motor score (UPDRS)		Speech score (UPDRS)	
			ON	OFF	ON	OFF
1	57	12	22	60	2	2
2	43	11	10	26	0	0
3	47	10	16	28	1	1
4	67	20	46	61	3	3
5	61	13	27	34	3	3
6	70	13	29	38	2	2+
7	68	10	20	36	1	2
8	55	3	11	24	0	1
9	58	10	10	28	0	1+
10	48	4	14	30	1	1+

Table I - b: Patients' characteristics (STN group)

Patient	Age	Disease duration	Total motor score (UPDRS)		Speech score (UPDRS)	
			ON	OFF	ON	OFF
1	49	10	27	58	1	2
2	64	12	13	42	0	1
3	70	13	35	75	2	3
4	63	11	13	47	1	2
5	70	22	24	41	2	2
6	50	13	11	26	2	1
7	46	14	12	38	0	1
8	65	10	27	65	0	2
9	55	12	16	34	1	1
10	68	09	20	59	1	3

2.2. Analysis of the speech prosody

We used an EVA system [3], developed for the evaluation of the pathological states, the diagnosis aid and the therapeutic follow-up of speech and voice illnesses. More recently, a specific software application developed on the EVA 2 version was dedicated to the evaluation of prosody [2].

The corpus of this study was constituted by the reading of a reference text of about one minute duration (mean time for a normal speaker). We took three prosodic parameters into account into account: pitch, intensity, and duration.

The F_0 is computed with an Average Mean Difference Function (AMDF) method for 30 ms each 10 ms after a voiced-unvoiced detection. The F_0 variation curve, thus obtained, is modelized with the MOMEL method proposed in [4]. It is based on target points detection, linked by a quadratic spline interpolation (Fig. 1).

The intensity is given by the RMS value of the speech sound pressure level signal, with a 10 ms time constant.

The durational data were given by the measure of silent pauses, defined as silent intervals (i.e. above noise level) longer than 200 ms.

2.3. Statistical analysis

As the purpose of this study was to compare the difference between the readings of the same subjects in ON and OFF conditions, statistical analyses were conducted by means of two-tailed *Student t-tests* on dependent samples. For the L-DOPA group on the one hand and for the STN group on the other, the following dependent variables were tested successively: mean F_0 (Hz), standard deviation of the F_0 distribution (in Hz and semitones; a coefficient of variation was calculated as well), mean intensity (dB), standard deviation of the intensity distribution (dB), cumulated silent pause duration (sec.), cumulated signal duration (sec.), the total reading duration (sec.) which includes both cumulated silent pauses and signal duration, the mean silent pause duration (sec.), the mean signal duration (sec.), the proportion of pausing time and the number of silent pauses.

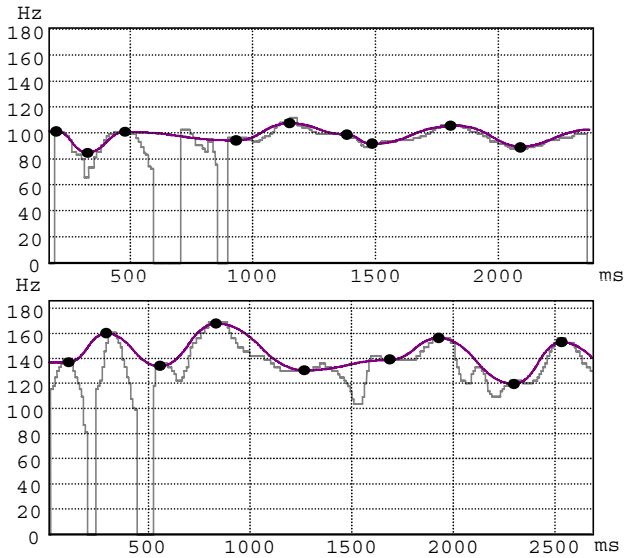

Figure 1: *Two instances of the beginning of the reference text ("Monsieur Seguin n'avait jamais eu de bonheur…") read by the patient J.D., OFF stimulation (above, http://www.lpl.univ-aix.fr/sp2002/papers/sounds /viallet/OFF.wav) and ON stimulation (below, http://.../ON.wav).*

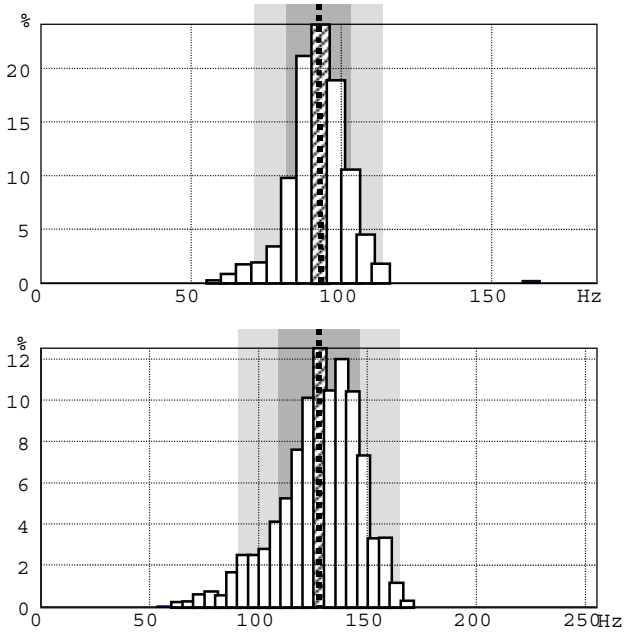

Figure 2: F_0 histograms for the complete readings for the patient J.D.: OFF stimulation (above) and ON stimulation (below). Dotted line: mean; dashed interval: mode; dark grey area: ± 1 SD; light grey area: ± 2 SD.

Table 2: F_0 parameters for the complete reading of the reference text by the patient J.D. OFF and ON stimulation

	OFF stimulation	ON stimulation
Mean	92.3 Hz	127.4 Hz
Mode	[90.0–95.0] Hz	[125.0–130.0] Hz
SD	10.6 Hz	18.5 Hz
Coef. of Var.	11.5 %	14.5%
Min	56.2 Hz	60.0 Hz
Max	163.8 Hz	167.7 Hz
Range	107.6 Hz	107.8 Hz

3. Results

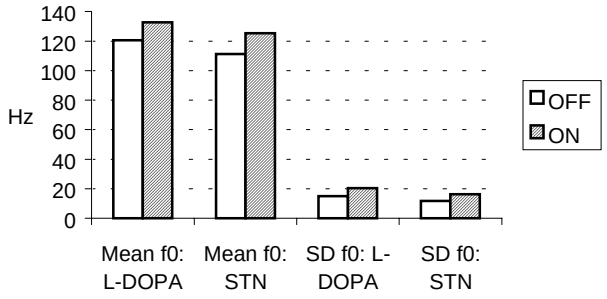

Figure 3: Mean F_0 and SD of F_0 distribution for the L-DOPA and STN groups. Dashed bars refer to patients in ON condition (either drug or stimulation) and blank bars to patients in OFF condition (either drug or stimulation).

The analysis was focused on mean F_0 values (in Hz) and standard deviations (in Hz). Results are presented in Fig. 3. In both groups, there were statistically significant improvements of the mean F_0 (L-DOPA group: t = -3.732, df = 9, p = .0047, mean difference = -12.23 Hz; STN group: t = -3.002, df = 9, p = .0149, mean difference = -14.15 Hz) and of the tonal range (L-DOPA group: t = -4.35, df = 9, p = .0019, mean difference = -5.59 Hz; STN group: t = -3.487, df = 9, p = .0069, mean difference = -4.51 Hz). The difference between the standard deviations in semitones was also significant with p = .0002 for the L-DOPA group and p = .0175 for the STN group; the difference between the coefficients of variation was also significant with p = .0004 for the L-DOPA group and p = .0275 for the STN group). When comparing L-DOPA effects to those of STN, the extent of the improvement was similar. Fig. 1 illustrates some of the tonal changes induced by STN stimulation. In this example, the same subject read aloud the beginning of the reference text, without stimulation (above) and, afterwards, with stimulation (below). It shows that in OFF condition the F_0 average level is lower than in ON condition. In addition, F_0 exhibits a considerable narrowing of the tonal variation. These observations are confirmed when examining data from Table 2 and distributions of F_0 in Fig. 2 for reading of the entire passage by the same patient OFF stimulation (above) and ON stimulation (below).

Despite the numerical differences, there were no statistically significant differences when comparing "on" versus "off" states, in either treatment group, for either intensity or the temporal variables analysed.

4. Discussion

Both groups of patients benefited clinically from treatment, whether L-DOPA medication (eventually with dopamine agonists) or STN stimulation, as confirmed by the UPDRS motor scores which showed a dramatic decrease during ON states. The pharmacological action of these therapies is well established in neurological studies; indeed L-DOPA sensitivity provides a clear-cut diagnosis of idiopathic Parkinson's disease [5]. The benefit of the electrophysiological action of STN stimulation was more recently demonstrated in a large series of studies [6], and clearly confirmed in many neurological centres and in France in particular.

The respective effects of these therapeutic interventions on speech production are less documented [7]. Only a few studies have examined the effects of L-DOPA therapy in detail. They indicate that in some speakers, there can be only modest changes to phonatory function [8], or to speech intelligibility. However, the gains with L-DOPA are not as significant for speech as they are for limb symptoms [9], [10]. Recent data show that STN stimulation can have a similar effect as L-DOPA in ameliorating parkinsonian symptoms [11]. However, even if control of oral movement is improved in parkinsonian patients after STN stimulation [12], the benefit on speech disorders still remains difficult to qualify, either better or worse, on the basis of voice intelligibility and prosodic assessment [7].

The results obtained in this study emphasize the clear effect on mean F_0 and on tonal variation (assessed through the standard deviation) with L-DOPA as well as STN stimulation. A more detailed analysis previously reported with L-DOPA effects [13], indicates that it can restore the upper part of the tonal range, thus increasing the mean value of F_0. This effect could be attributed to the restoration of the phasic components of the laryngeal muscular activity, which would in turn enable tone elevation during speech production. It remains to be demonstrated that in the STN group, this effect on F_0 is as homogeneous and regular as that observed in the L-DOPA group.

In contrast with what was observed on pitch, there were no pharmacological or electrophysiological effects

on either intensity or duration. To explain this at first sight surprising result, it need be outlined that during a reading task, the text and its punctuation constitute a frame of reference that facilitates a normalised performance. More specifically, concerning the rhythmic segmentation, it would certainly be more relevant to consider not only the global distribution of pauses during the entire text recording, but also the more detailed segmentation within the breath groups.

5. References

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