Dysprosody in Parkinson's disease : Musical scale production and intonation patterns analysis

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Abstract

This article aims to acquire a better knowledge of prosody disturbances in Parkinson disease via an acoustic analysis. The investigation of the patients' vocal productions by the way of acoustic analyses should indeed allows two things. Firstly, to identify phonetic and prosodic parameters that are specific of such a pathology. Secondly, to study the effect of a pharmacological treatment (based on dopamine) on these patients' speech production. In order to determine the effect of dopamine, oral productions of 8 parkinsonian patients of the akinetic type have been collected, in the OFF and ON states, and have then been compared to those of control subjects. The specific aim of this study is (a) to examine the ability of patients to handle the variations in fundamental frequency of their voice as well as to master the rise in frequency required by the task (i.e. production of the musical scale and intonation patterns) and (b) to measure the palliative effects that can be induced, at least partly, in the management of frequency by a treatment based on L-Dopa.

1. Introduction

Parkinson's disease (PD) is commonly characterized by a reduction in motor activity, and at the speech production level, by a "dysprosody" [1]. The speech disorders occurring as a result of PD are a form of hypokinetic dysarthria. Darley [2] explains the origin of the parkinsonian dysarthria by the execution limitation of respiratory movements, due to a weakness of muscular rigidity.

The disorders would thus affect speech production and in particular the handling of fundamental frequency (F0). The fact that voice can't correctly be used depends on various factors, mainly of physiological nature (defect of the vocal cords vibrations for example). Gentil [3] affirms that the F0 of parkinsonian subjects is conventionally associated with global increase in pitch and reduction in range likely due to a greater stiffness and a hypokinesia of the muscle controlling the tension of the vocals folds.

2. Dysprosody

Critchley [4] classified the speech disorders of parkinsonian with Parkinson's disease into an akinetic, rigid, hyperkinetic, and iterative (or repetitive) forms of dysarthrophonia. This symptomatic classification suggests that the two main elements of Parkinson's disease, bradykinesia and rigidity, exert an influence on the motor speech system. The equivalents of hypokinesia or rigidity has been described as monopitch, reduced stress, imprecisely produced consonants, breathless voice, monoloudnesss and inappropriate silences [5], [3].

Prosody pervades all aspects of a speech signal, both in terms of a raw acoustics outcomes and linguistically meaningful units from the phoneme to the discourse unit. It can be defined as the phrase, accent, and tone structure of speech. It is carried out the suprasegmental features of fundamental frequency, loudness and duration [6]. Measurements of fundamental frequency, and its variation providing statistical data related to the defect of the melody, is a dominant feature of parkinsonian subjects [3].

3. Speech and subject data base

We use medical data, neurological and speech bases constituted in collaboration with the Purpan Hospital within the framework of a project granted by the INSERM (French Institute of Health and Medical Research). The data base contains several kinds of stimuli according to the experimental protocol [7].

3.1. Patients

Currently, 8 subjects (in OFF vs. ON state L-dopa treatment) underwent the linguistic protocol (4 females and 4 men between the stage II and IV towards Hoehn and Yahr scale [8]). The parkinsonian patients selected are all of the akinetic type. They are all French, aging from 60 to 75 years old, and showing evidence, in all cases, of speech (phonetic) disturbances on the basis of a first-level perceptual analysis. In order to free us from the aging of the speaker subjects, a control population is also defined. Eight participants were chosen as controls. The age and gender characteristics of these participants were matched as closely as possible with the participants with PD.

Table 1: Patients Clinical table

Participants	Gender/ PD age (control age)	Years post diagnosis	Hoehn and Yhar scale
PD 1	F/79 (75)	6	2,5
PD 2	F/65 (61)	7	2.5
PD 3	F/ 72 (69)	10	4
PD 4	F/77 (74)	12	4
PD 5	M/74 (70)	12	4
PD 6	M/67 (68)	7	3
PD 7	M/75 (73)	18	4
PD 8	M/80 (75)	15	3

3.2. Levodopa administration

The patients are convened the day before the investigation, and are hospitalized for 24 hours. They stop their antiparkinsonian treatment 16 hours after their arrival. They are observed the next morning in period of "freezing, without any treatment". At the end of this first exercise series, they receive their usual antiparkinsonian treatment and can have a rest. As soon as they are unfreezed, they repeat exactly the same procedure as previously (series of phonetic exercises) so to evaluate their production in phase "ON".

A number of acoustics studies have found that patients with PD (undedicated or off medication) have impaired speech prosody [9]. Nevertheless, prosody and acoustic parameters could be improved by L-dopa treatment. Currently the standard medication for treatment of PD is a combination of levodopa and carbidopa, in the form of Sinemet [10].

4. Methods

The three main stages of our study are the phonetic annotation of the signal, extraction of the prosodic parameters, and statistical analyses.

4.1. Data recording / Analysis

Speech signal is annotated at orthographic and phonetic levels according to the visualization of the frequency curves, of formant transitions and intensity obtained by the signal editor "Winsnoori" (1994-1997 by S.Q.L.A.B).

The speech signal is analysed using a 22 kHz sampling. The F0 and intensity values are computed each five milliseconds using the LPC algorithm.

4.2. The Stimuli

We are here studying the diatonic scale. The patients must ascend the diatonic scale : DO, RE, MI, FA, SOL, LA, SI, DO (english: C, D, E, F, G, A, B, C) going from the gravest to the acutest. Thus, the patients' voice quality should be observed.

Indeed, the aim here is to test the capacity of the patients to vary the fundamental frequency of their voice as well as to control rise in frequency. Our hypothesis is that, in such a task, speech production should be phonetically affected for parkinsonian patients and improved by L-Dopa treatment.

We finally make the hypothesis that musical scale production would be an indicator of the subjects' capacity to produce intonation schemas according to a given instruction: subject evidencing difficulties in ascending the scale would similarly have problems in handling adequately intonation patterns in language production. So, they had to repeat the interrogative pattern "Vous avez appris la nouvelle?" (in english: "You heard the news?"), "Je fais le marché le mardi et le samedi". (in english : "I go to the market on Tuesday and Saturday").

5. Results

Table 2 : Mean F0 values of each stimulus participants with PD in their OFF, ON and the control participants. Fundamental Frequency values are listed in Hz.

Female	OFF	ON	CS
Musical scale	259, 84	261, 29	251,56
Market	186, 64	186, 72	202,85
News	208, 77	212,93	212,83
Men			
Musical scale	127, 53	125, 52	137,39
Market	108, 29	115, 28	118, 06
News	115, 26	120,48	130,29

5.1. Musical scale

We find 3 profiles at the level of the realization of F0 curve, in OFF and ON state: rising, flat and descending realization. We calculated the mean values of F0 for each vowel of the stimulus. The aim is to observe the evolution of the oral realization according to the drug intake. (P1, P4, P6 and P7) have a rising realization, whether in OFF or ON state. Among them, only P4 has a better realization after the dopamine intake.

In OFF state, we observe that for 2 patients P2 and P8 a flat realization. In this state, the fundamental frequency between the different notes don't vary. The musical scale is then produced like a monotonous sentence, "recto tono". However, for these two patients, the average obtained on the level of F0 is better in ON state than in OFF state. In ON state, only the patient P8 has a "flat" realization whereas it becomes rising after the L-dopa intake for P2. These results can mean that the treatment generates a certain stability in the production.

Descending realization: In OFF state, two patients P3, and P5 have a descending realization. For P3, the values of F0 are initially rising, then a stage (pause) is produced. Next, the values of frequency drop. Two patients have descending achievements, whether OFF or ON state. Besides, they do not manage to make the fundamental frequency of their voice varying, whether it is in OFF or ON state.

All the control females subjects have rising realizations between first C and last C, but the mean of each note is lower than among the Parkinsonian Disease Females (PDF), whether in OFF or ON state (**OFF**: 259.84Hz; **ON:** 261.29Hz; **Control**: 251.56 Hz). (Table 2).

Among the control subjects men, S7 and S8 have a completely flat realization, and the mean of the range for these subjects is higher than for the patients (**OFF**: 127.Hz ; **ON**: 125.52Hz; **Control**: 137.39Hz).

The aim of this work is to examine the acoustic characteristics of the prosody for parkinsonian subjects in

OFF and ON state of drug intake, during the musical scale production. Our paramount objective is to determine if the subject is able to make the frequency of his voice varying between each note and thus to carry out a rising scale[1]. Our specific goal is to determine if the mean of the notes, and more precisely of the final vowels, improved after the dopamine intake.

Our results show that the prosodic disorders are partly reduced, for some of the patients, thanks to the administration of L-dopa. In fact, the dopamine seems to have an obvious effect among 3 patients (P2, P4, P8) with regard to the mean of F0 on the stimuli musical scale. The 5 others have a higher mean in OFF.

5.2. Assertions and question patterns

Concerning the realization of the intonation patterns of the interrogative type all the PDF manage to go up finally on "the news", whether in OFF or ON state (table 2). Remind that the syntactic structure of this stimuli "you heard the news?" (and not “did you hear the news?") had been selected to check if the subjects could carry out a rising intonation, notably finally.

Among men, only one patient manages to go up in frequency finally and this in ON state.

With regard to the intonation patterns of the affirmative type, let’s observe the ranges of variation of the values of fundamental frequency. Among females, there is a variation of frequency for 3 of them, both in ON and OFF state. Furthermore, P3 subject’s realization is completely flat after the dopamine intake.

Among men, only one patient, P7, manages to make the frequency of his voice vary on this stimuli, the 3 others produce it without any intonation. The melody lines of P5, P6, P8 are always flat. This actually validate our starting hypothesis: the subject that presents some difficulties for rising the range, does not manage to make the melody line of his voice varying (P5, P8).

All control subjects manage to produce an assertion pattern with variations of F0. It is as true for “news” (they all succeed to go up in frequency on the level of "the news") as for “the market”. There is a variation of the values on the level of the intonation.

With regard to the mean of F0 among females, the mean of “I do the market” is higher for the control subjects than for the parkinsonian ones: (**OFF**: 184.64 Hz, **ON**: 186.72 Hz; **control subjects**: 202.85 Hz.) With regard to "you heard the news?" the mean from F0 is OFF: 115.26 Hz; ON: 120 Hz, control subjects:130 Hz.

The mean F0 for the two stimuli is better for the whole patients after the dopamine intake. Among the 3 female patients only one, P3, does not improve its productions. It is besides about same which did not manage to produce a rising scale and of which the values of the musicale scale were not improved in OFF state.

[1] However, we want specify, whether the subject is "parkinsonian" or not, he does not necessarily “sing" correctly: each one speaker/singer can carry out, according to cases, a rising, flat or descending scale.

Among men the mean F0 for the two stimuli are better for control subjects, (**OFF**: 108.29 Hz; **ON**: 115.28Hz; **control subjects** 118.06 Hz.

The P5 subject has a better realization in OFF with regard to the musical scale. His productions improved after the dopamine intake on the assertion patterns.

P6 does not manage to improve any of his productions.

5.3. Intensity observation

Table 3: Mean intensity values of each stimulus for participants with PD in their OFF and ON state and the control participants. Intensity values are listed in dB.

Female	OFF	ON	CS
Musical scale	49,9	52,95	55,94
Market	29,3	33,66	29,68
News	32,94	31,98	28,90
Men			
Musical scale	60,22	59,35	54,75
Market	29,71	30,35	31,89
News	30,18	28,42	30,48

Concerning intensity, we formulate the fallowing hypothesis : the patients would hide their deficit of their vocal cords vibration by increasing energy. It would be thus a palliative strategy. It would allow to get round their deficit, whether this one results from a pathology or a from a “deteriorated” situation. With regard to the musical scale production our hypothesis is checked among 5 patients.

The mean F0 values is lower in ON state compared to the OFF state OFF. On the other hand, the values of intensity are higher in ON state. (Table 3).

The hypothesis also checked on the realization of the assertions and questions patterns.

The frequency values of the PD male are definitely worse than those of the control subjects. Nevertheless the intensity values of the PD in the two state tend to approach those of the control subjects (**market OFF**: 29.71dB; **ON**: 30.35 dB, **control**: 31.89 dB; **news OFF**: 30.18 dB; **ON**: 28.42 dB, **control**:30.48 dB).

Among females, the energy values are better on patients in ON state compared to the control subjects (**market OFF**: 29.30 dB; **OFF**; 33.36 dB; **control**: 29.68 dB, **news OFF:** 32.94 dB; **news ON**: 31.98 dB; **OFF**: 31.98 dB; **control**: 28,90 db); whereas the control subjects have better results on the frequency. We suppose that the dopamine has an effect on energy values, indeed these are more homogeneous.

6. Conclusion

The purpose of this study was to examine the acoustic characteristics of speech prosody in participants with PD before and after taking medication.

Previous studies have found a reduction in speaking F0 variability in subjects with PD compared to controls [11,12,]. In addition to F0 variability, individuals with PD

demonstrate decreased use of F0 changes particularly in assertion pattern [13].

Our Parkinsonian population confirmed deficits in speech prosody compared to age-matched controls. The participants with PD demonstrated increased mean F0 values on the musical scale production. After taking medication, analysis revealed improvements in mean F0 values on the assertions and questions (interrogatives) patterns. However while control speakers typically demonstrate a high F0 range and variability during speaking tasks, the decrease in F0 variation in individuals with PD may reflect a prosodic deficit, corresponding to the perceptual feature of monotone speech [11]. We still observe in a recent study [14] that the musical scale production is phonetically affected for parkinsonian patients compared to control subjects. In this study, the PD do not present some difficulties to produce interrogative patterns. Nevertheless the patients have some problems in handling adequately assertion patterns. Effects relating to the L-dopa administration diverge according to the patients, the year post diagnosis and the Parkinson's disease severity degrees .

Compared to our control population, our parkinsonian subjects present prosodic disorders, in particular on the level of the fundamental frequency management. This dysfunction would come from the akinesy, the breathing deficit and the problems of vocal cords vibration. These results confirm in part Darley hypothesis [2], knowing that the parkinsonian "dysprosody" would come from a peripheral neuro-engine dysfunction affecting the larynx motor activity.

7. Perspectives

Intensity is the most difficult parameter to identify, which is certainly due to its correlations with F0 values [15].The weakening of the intensity can go until whisper. It can settle from the start or only at the end of production and it can be accompanied by a deceleration of the articulation rate [16].

In this study one of our hypothesis is that the patients would hide their deficit of vocal cords vibration by an increase in energy. It would be thus a palliative strategy. Our hypothesis is checked in particular among the females.

These results reinforce the importance of examining the palliative strategy adopted by the subject to hide their vocal cords deficit, that's why we will observe and compare the duration, the percent pause time and the pauses strategy. We also observe the phonological disturbances.

Indeed, actually we will create a specific "diacritic" alphabet to describe the Parkinson's dysarthria. The aim of these diacritics is to describe the phenomenon of lengthening, diphthongization of the vowel, resumptions of breath, breathlessness, quavering, freezing, husky devoicing.

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9. References

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