Musical scale production in Parkinson's disease

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ABSTRACT

The aim of this paper is to demonstrate the effect of L-Dopa treatment on the production of musical scale by Parkinsonian patients. In this preliminary study, we tested 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 also hypothesize that musical scale production would be an indicator of the subjects' capacity to produce intonation schemas according to a given instruction. If that is correct subject evidencing difficulties in ascending the scale would similarly have problems in handling adequately intonation patterns in language production (e.g. assertions, questions, etc.).

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]. Such a speech disturbance is traditionally interpreted as the consequence of the presence of a neuro-motor disorder [2] affecting language production. Darley [3] 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 variations 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). Darkins affirms that the F0 of parkinsonian subjects is conventionally associated with a 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 [4].

Although it represents considerable handicap for the speech communication, Parkinson dysartria is too often regarded as being a minor disorders of the disease.

This study should help us to better include/understand the parkinsonian dysprosody, and more precisely to better identify the linguistic units faded thanks to the orthographical, phonetic and intonative annotations proposed. The other aim of this research is to enable us to better determine the prosodic dysfunctions (controls variations of F0 and intensity).

From this point of view, we hope to validate and contribute to Darley's hypothesis, which is our starting point [3]. We will first propose a synthesis of the studies concerning the fundamental frequency. Then describe our experimental data base, our method on theoretical musical scale realization and FO measure and to conclude our first interpretation.

2. CONTEXT OF THE STUDY

The perfect correspondence between acoustic speech sounds measurements and the organs speech movements do not exist but one can deduce the motor deficits from the acoustic data, if the experimental protocol is suitable.

Perceptive studies constituted the first parkinsonian dysarthria descriptions. These studies were confirmed or cancelled thanks to acoustic studies. They contributed to a more precise evaluation of the deteriorations detected during the perceptive analyses. Complex functions like the prosody data can be evaluated accurately. In the same way, the comparisons with normal subjects are possible.

Parkinsonian speech was initially described according to the private clinic impressions of the observers. The generic term of "monotone" is often used to characterize the voice of the parkinsonian subjects [5].

Measurements of fundamental frequency of the voice, and its variations provide statistical data related to the defect of the melody, which is a dominant feature of the parkinsonian patients. The prosody being defined to provide linguistic and emotional information, like the use of the three acoustic parameters, height, intensity, and duration. Many authors observe that the dominant disorder of the parkinsonian speech is an aprosody.

What we propose is a synthesis of the studies concerning the variations of fundamental frequency in parkinsonian subjects.

A weak voice is frequently noticed [6], some authors speak

 ISBN 1-876346-48-5

about the tremor of the voice [7]. Deteriorations of the timbre voice, tone are mentioned in the literature. Generally, patients have difficulties in vary the height of their voice (the grave one towards the acute one. The results of the studies are conflicting. Ludlow [8] shows that F0 increases with the severity of the disorder. On the other hand, it would decrease according to Canter [9], observes a weak variation of F0 values leading to a monotonous speech. These latters authors observe a variation of the fundamental frequency much lower in parkinsonian subjects than in control subjects.

Studies conducted by Lagrue and Teston [10], [11], are more precise regarding to the methodology and the acoustic indices extraction. Lagrue [10] observes that the tonal characteristics of the voice differ between treated parkinsonian subjects and untreated ones. He concludes that these antagonistic results in perception and production confirms Darley hypothesis, knowing that the parkinsonian "dysprosody" would come from peripheral neuro-engine dysfunction affecting the larynx motor activity. More recently, a family of works initiated by Viallet [12] aim to compare the pharmacological treatment to the electrodes implantation in the subthalamic core (NST).

Viallet [12] evaluates effects of these two treatments on the prosody. The results clearly show an improvement of the fundamental frequency (average of F0 and standard deviation) with each treatment. However, no significant results have been obtained concerning intensity and duration.

3. SPEECH AND SUBJECTS DATA BASE

We use medical data, neurological and speech bases constituted in collaboration with the Purpan hospital (CIC Investigation Clinical Center) within the framework of a project financed by INSERM (French Institute of Health and Medical Research). The data base contains several kinds of stimuli according to the protocol [13].

In order to free us from the ageing of the speaker subjects, a control population is also defined. The selected patients are subjects devoid of any other neurological disease present dysarthric deficit perceptual.

Currently, 12 subjects (in the ON vs. OFF state of L-dopa treatment) and 12 control subjects undergo the linguistic protocols. 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.

4. METHODS

The various studies listed above revealed disorders of the speech in the Parkinson's disease on the level of the prosody. However, the results of the studies are sometimes contradictory, to the acoustic level as well to the perceptive level. Moreover, effects relating to the L-dopa administration diverge: patients did not react the same to L-dopa.

Our research aims to contribute to the installation of an observation platform of the parkinsonian dysarthria to the prosody plan. From this point of view, an analysis chain of the speech signal going to the acoustic and statistical processing of the prosodic parameters will be one of the results of the research. The three main stages of our study are annotation of the signal of word, extraction of the prosodic parameters, and statistical analyses. For this study, we chose to extract the following acoustic parameter likely to be markers of prosodic deteriorations of the parkinsonian subjects : fundamental frequency during the production of the musical scale.

Indeed, the aim of this study 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 acoustically affected for parkinsonian patients and improved by L-Dopa treatment.

4.1 THEORETICAL SCALE PRODUCTION

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.

Each element of the stimulus is theoretically separated from a tone or from an half, as illustrated in the table 1. For example the note "DO" and the not "Re" differ from a tone whereas the note "FA" is different from the "MI" note of a half tone.

Do	Ré	Mi	Fa	Sol	La	Si	Do
	1 T	1 T	½ T	1 T	1 T	1 T	½ T

Table 1 : Theoretical scale evolution

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" (1998-2000 Loria-Babel technologies). Figures 1 and 2 represent the orthographic and phonetic annotation of a scale production in a Parkinsonian Patient scale production in states OFF and ON.

ISBN 1-876346-48-5

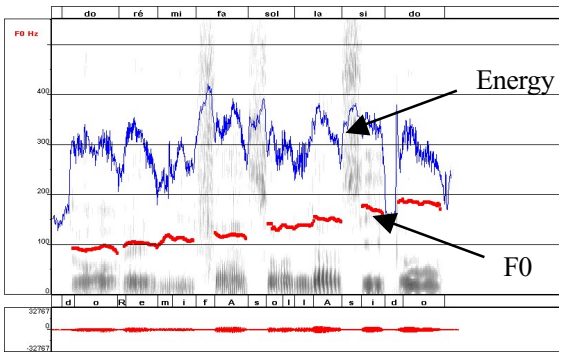

Figure 1 Scale production (OFF state)

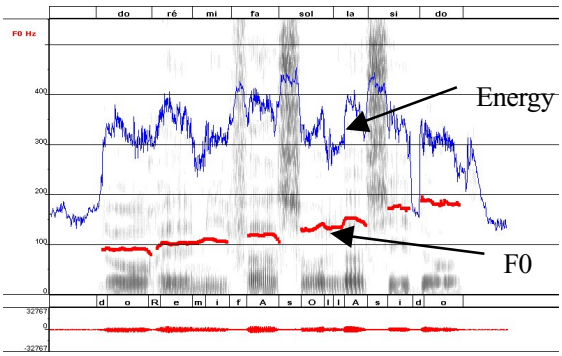

Figure 2 Scale production (ON state)

4.2 FUNDAMENTAL FREQUENCY MEASURE

The paper focuses on L-Dopa influence on musical scale production. In order meet the objectives of our study, we must determine the algorithm determining these values.. Several solutions are possible to complete that task.

To the acoustic level the vowel made up of several phases "establishment", "kernel", "coda". For this first study, the analysis relates to the stable part of the vowel, which corresponds to the "kernel" phase.

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

5. FIRST INTERPRETATIONS

To date, we observed 8 parkinsonian subjects in state OFF and ON patients (2 females and six men on stage III and IV towards Hoehn and Yahr scale [14]). Only one patient has better results with the treatment, Profile L1 in figure 3.

Four patients do not show any differences between OFF and ON state. Among these four patients, two adopt a strategy, constituting in realizing a "stage" on the level of the note "LA" to manage ascending the two last notes : Profile L2 and L3.

Finally the last three patients do not manage to vary the fundamental frequency of their voice that it is in OFF or in ON: Profile L4. After the intake of drugs, the patients can't manage to correctly handle the scale, there is practically no variation of F0, the musical scale is then produced as a "monotonous" sentence.

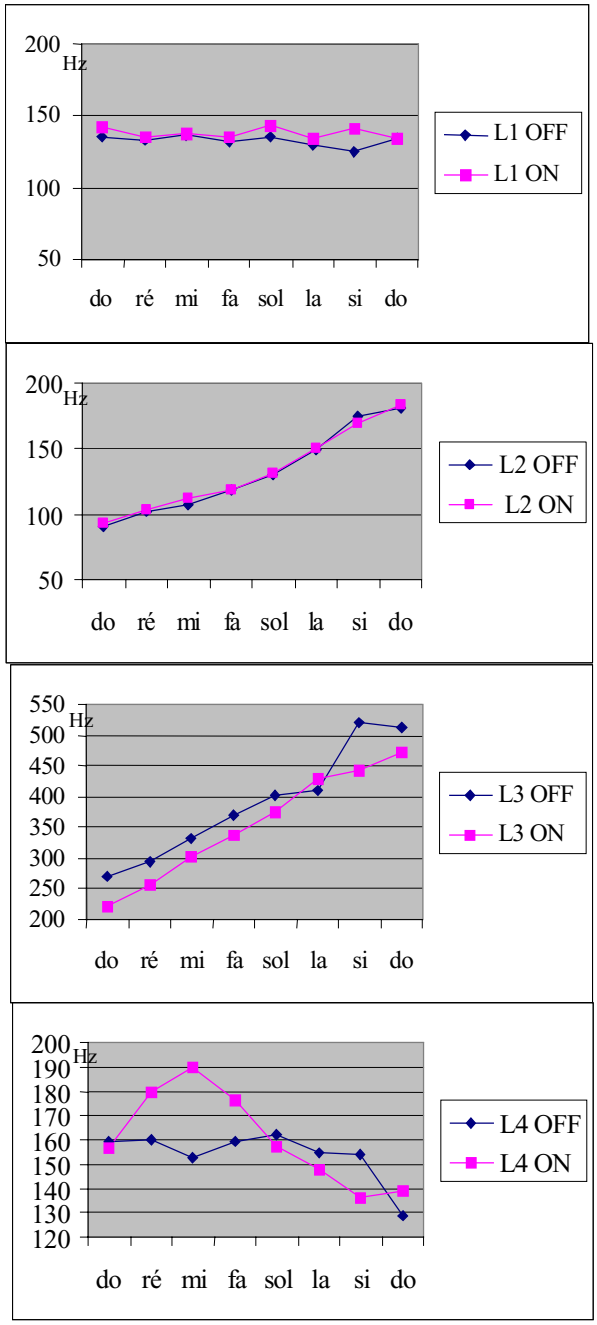

Figure 3: Observation of different profiles of musical

If we compare the difference of the F0 values between first and the last "DO", only half of the patients manage to go up in frequency. For the other half it is the opposite case, the value of the first "DO" is lower than the value of last "DO". It should be noticed that in the latter ones the results are better in state OFF than in state ON. We observe that the only patient, whose production of the scale is better in ON than in OFF, can not manage to go up in frequency from

ISBN 1-876346-48-5

first “DO” to the last “DO”: Profile 1.

In order to consider the variations inter note, we have studied more carefully the values of the frequency between each note. If we compare the transition or the passage from one note to another, we subtract the F0 value to the second note to the first one and so on. The results are rather variable, even if we noticed that patients tend to present some difficulties to vary in frequency between each notes. Some patients do realize a stage during the stimulus like profile L3 in state OFF (table 2).

Profile L3	F0 values State OFF	F0 values State ON
RE - DO	22,7	35,736
MI - RE	38,866	45,03
FA - MI	36,334	35,0528
SOL - FA	32,54	37,6422
LA - SOL	8,31	54,995
SI - LA	112,228	13,92
DO - SI	-9,838	28,2

Tableau 2 : F0 values of transition between notes

7. PERSPECTIVES

We will continue our data base exploitation by applying our protocol on the remaining subjects, and compare parkinsonian subjects performances to the control subject.

Then, we would like to compare the F0 values with intensity values. We think indeed that the patients would make up their deficit of F0 by an increase in energy. We will also compare the total duration of the range and of each note in state OFF and ON, it would seem that the achievements are longer in state ON. 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 (e.g. assertions, questions, etc).

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