Dysprosody in Parkinson's Disease: An Acoustic Study Based On Tonal Phonology and the INTSINT System

Karine Rigaldie, Jean Luc Nespoulous, Nadine Vigouroux

Laboratoire Jacques Lordat, Toulouse
Institut des Sciences du Cerveau, Toulouse
IRIT, UMR, CNRS, Université Paul Sabatier, Toulouse
{rigaldie; vigourou}@irit.fr; nespoulo@univ-tlse2.fr

Abstract

Many research programs in spoken communication have studied the prosody from an acoustic, phonological, syntactic, semantic or psycholinguistic perspective. As far as we know, very few are the studies that have approached prosodic alterations in parkinsonian patients taking into consideration, at one and the same time, the three following levels of analysis: phonetic, phonological (intonation groups) and linguistic (functional levels).

The INTSINT approach has been applied to a number of languages and not just to normal speech but also pathological speech. The aim here is to study the relevance of this alphabet for the prosody of the dysarthric speech.

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. Context of the study

2.1. Dysprosody

Based on an earlier proposition by Critchley [4] has 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 signals, 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 in 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 subject [3].

2.2. Pharmalogical treatment : Levedopa

A number of acoustics studies have found that patients with PD (unmedicated or off medication) have impaired speech prosody [7]. Nevertheless, prosody and acoustic parameters could be improved by L-dopa treatment. Currently the standard medication for treatment of PD is a combination of levedopa and carbidopa, in the form of Sinemet [8].

We propose a synthesis of the studies concerning the variations of the fundamental frequency in OFF state (off medication). Then, we will report characteristics of PD accompanying initiation of Levedopa treatment (ON state), and accompanying Levedopa-related fluctuations (ON versus OFF state).

2.2.1. Speech prosody in OFF State

According to Canter [9] patients with PD have been shown reduced fundamental frequency range and variability during speaking task. Canter notes decrease of F0 range during syllable production, and a number of researchers have found decreased F0 range/variability during reading. While normal speakers on average 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. In addition to F0 variability, Le Dorze [10] observes that a decrease of F0 changes to mark the difference between question and statement with parkinsonian subjects.

2.2.2. Speech prosody in ON State

Compared to results obtained from unmedicated PD patients, improvement in speech production and intelligibility have been found after initiating levedopa treatment in PD [11].

Wolfe [12] examined the speech characteristics of PD patients before starting levedopa, and again after a stable motor response to the drug was achieved. Based upon perceptual ratings of a reading passage, improvements in pitch variation (improved prosody) were found.

2.2.3. OFF versus ON

Lagrue [13] observes that the tonal characteristics of the voice differ between treated parkinsonian subjects and untreated ones. He concludes that the antagonistic results in perception and production confirm Darley hypothesis [3], knowing that the parkinsonian “dysprosody” would come from peripheral neuro-engine dysfunction affecting the larynx motor activity.

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 protocol [14].

3.1. Patients

Currently, 8 subjects (in OFF vs. ON state L-dopa treatment) underwent the linguistic protocol. 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 control population is also defined.

3.2. Levedopa 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".

3.3. The Stimulus

The Parkinsonian subjects had to repeat the interrogative pattern “Vous avez appris la nouvelle?” (in english: "You heard the news?"), three times: at the beginning, in the middle, and in the end of the protocol. This timing was determined in order to evaluate the effects of tiredness and the influence of other stimuli during the protocol.

4. Methods

The purpose of this study is to give an account of the prosodic disorders of the parkinsonian subjects at a phonetic and a phonological levels according to the INTSINT system [15].
It means observing more accurately the variations of the fundamental frequency on the interrogative patterns in ON and OFF medication state.

Our work use tonal phonology [16] which has as a basis : the definition of two tones (Top and Low), phonematic segments, intonative units segments (accented groups), and intonative units (intonatif groups). This approach held our attention because it offers *a priori* a good theory of formal representativeness of the prosodic structure, which is materialized by tonal gauges [16]. The stimulus is an interrogative sentence marked by a significant rise of the voice at the end of the utterance, especially when sentence structure is of enunciative type, as is the case in the present study.
“The way of formalizing melody contours makes it possible to propose general features and eliminate individual characteristics” [17]. That was the objective of some phonetists. Delattre [18] and Rossi [19] proposed a formalization of the intonative achievements in basic melody patterns. For results interpretation, we will take the interrogative intonation models [18] (the medium towards acute at the end of the sentence) as theoretical framework and interpretative parameters.

4.1. INTSINT SYSTEM

INTSINT (International Transcription System for Intonation), describes intonation with a limited set of abstract tonal symbols. It proposes to distinguish four levels of representation: the physical level, the phonetic level, the surface phonological level and the underlying phonological level. The deep phonological level provides an encoding of linguistically significant prosodic functions. The input to the INTSINT system is a serie of target points, which is estimated by low-level F0 modeling technique called MOMEL. The MOMEL algorithm aims to analyse and synthesise F0 curves automatically [20].

According to [21] “these are macroprosodic components, consisting of a continuous smooth curve (represented as quadratic spline function) corresponding to the linguistic function of the contour. There is also a microprosodic component consisting of deviations from the macroprosodic curve caused by the nature of the phonematic segments (voiced/unvoiced obstruent, sonorant, vowel etc)”. In INTSINT, abstract symbols are defined to represent target points derived from MOMEL procedure.

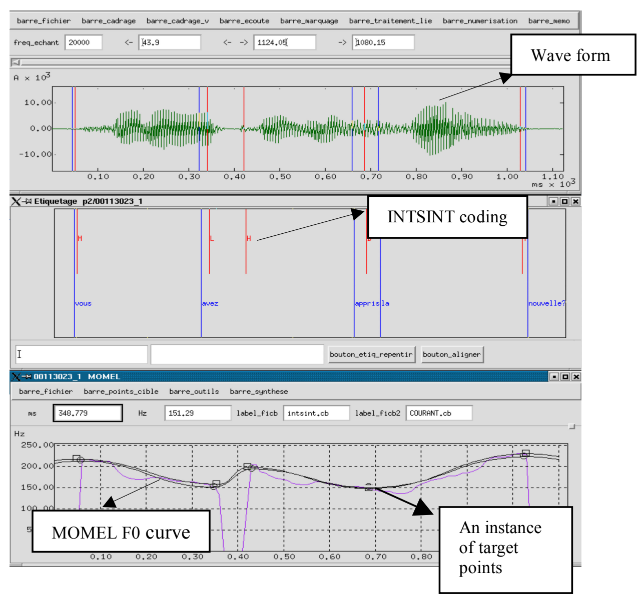

Figure 1: Wave form (Top), Intsint code (middle) and quadratic spline stylisation (bottom) for the French sentence “vous avez appris la nouvelle?”.

These are T, M, B, H, S, L, U, D, which stand for Top, Mid, Bottom, Higher, Same, Lower, Upstepped, Downstepped respectively. Among these symbols, tones (T, M, B) are regarded as absolute tones which refer to the speaker’s overall pitch range; tones (H, S, L, U, D) are relative with respect to the value of preceding target point. The relative tones are further distinguished between non iterative (H, S, L) and iterative (U, D) tones.

4.2. Software

The speech signal is analyzed using 20 kHz sampling. We employ the peigne algorithm to detect F0. We use basic orthographical annotation and the SAMPA transcription. MES (Motif Environment for Speech [22]) provides an automatic coding program which generates a set of INTSINT labels from a set of target points. For each target points, we can extract the F0 values as well as the precise moment when this value is measured (time scale).

When tools such as fundamental frequency detection are applied to a segment (prosody process), additional files are created and added to the segment folder.

The statistical values of the INTSINT labels are stored in a file **Intsint. stat**. Absolute symbols (T,M,B) are represented by their mean value and standard deviation. These statistical values together can be used for PSOLA resynthesis. Indeed the modelled curve can be manipulated manually by creating, destroying or moving target points. See [23] for more details.

4.3. INTSINT Application

INTSINT coding is completely related to F0 values, it does not appears to be necessarily linked to syllables or other linguistic units. The INTSINT documentation does not state how the presence of a target point is determined [7].

The aim of this paper is to observe how the INTSINT system is used as a phonological tool to characterize parkinsonian's speech. The INTSINT system was applied on speech recorded both in OFF and ON Levedopa treatment

As we observe (Figure 2 and 3) in OFF state; the target points (red marks labelled B and T) corresponds respectively to the [u] vowel and to the end of sentence. In ON state, the first target B is located at the same phoneme [u], but the second label "U" is marked on the vocalic kernel [E].

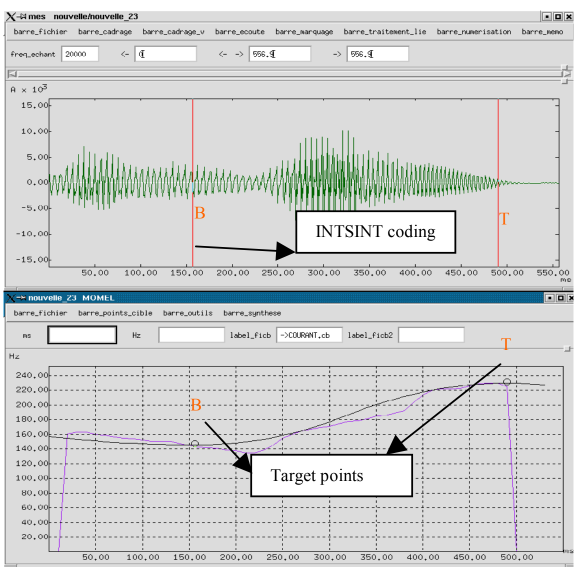

Figure 2*: Target points for "la nouvelle?" in OFF state.*

The difficulty comes from the fact that we cannot directly compare the "target points", which are not the same in the ON and OFF state. Some of these points can fall on a vocalic kernel as well as on a pause or an absence of signal, which makes any rigorous comparison impossible.

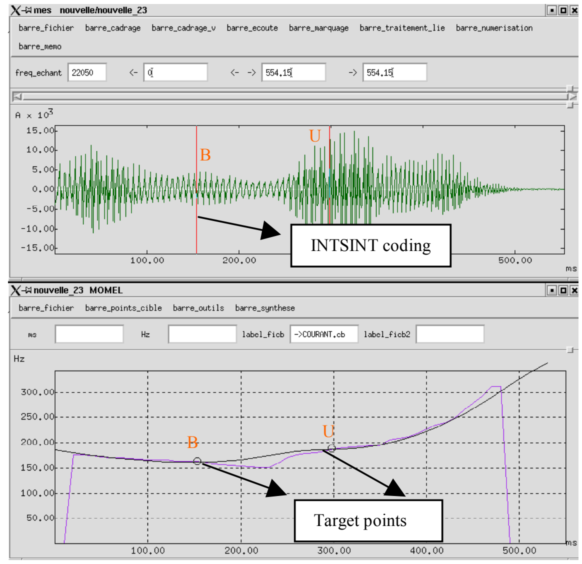

Figure 3*: Target points for " la nouvelle?"in ON state.*

5. First observations

To date, we observed 8 parkinsonian subjects in state OFF and ON (2 females and 6 men). We can already determine if the F0 values will be decreasing between the first, the second, and the third interpretation, at the level of distribution of the target points. That is, the number of target points corresponding to a raising or a lowering of the frequency. This allows us to observe the prosodic strategy of each speaker.

5.1. T, M, B interpretation

If we compare the frequency values linked to T, M, B, between the OFF and the ON state on the three productions, the fundamental frequency is more significant for 7 patients. The second fact is that, in OFF sate, the third production is the most relevant for 4 patients. In ON state, the same fundamental frequency increasing is observed for two patients.

5.2. Mean F0

If we observe the main F0 calculated for the last interrogative production pattern, there is only one patient for whom the last realization is better and this, in ON state. If we compare the first realization with the second one, in OFF state, the second realization is better for half of the patients. Always in OFF state, the last realization is better for only 2 patients. In ON state the second realization is better for 7 patients. Always in ON state, the last realization is better than the 2 first for only 2 patients.

6. Discussion

According to INTSINT coding, principles of the stimuli should start on the level of the average register of the speaker (M) and finish at the highest level (T). However, in reality there is a too great variability in interpretation of the target points. We study (among others) the variations through the highest and the lowest values of the sentence fundamental frequency. However these values can fall on a syllabe, on a vocal kernel, or an a word. Our main conclusion is thus that, due to some problems related to the automatically generated labelling provided by the software, the latter cannot be easily applied to the stydy of dysarthric speech.

In the state of this paper, INTSINT has been shown to be quite robust, it could analyse speech containing voiceless, obstruent, and discontinuous pitch, that is less problematic for other phonetic models. Since the INTSINT approach seeks target points representing level tone targets, it only needs accurate and complete pitch information around each target point [7]. This method encourages us to continue our data base exploitation by applying our protocol on the remaining subjects, and comparing parkinsonian subjects performances to the control subjects. The target points give us some phonological and prosodic informations, our principal perspective is to interpretate more carefully these target points and the pausal strategy of the speaker.

7. Aknowledgments

We are gratefull for the sugestions and technical help of Mr Robert Espesser , Mr Alexander Goberman, and Jean Léon Bouraoui who provided helpfull insights for the preparation of this paper.

8. References

[1] Meynadier, Y., Lagrue, B., Mignard P., Viallet., F.1999 Effect of L-Dopa treatment on the production and perception of Parkinson vocal intonation. In Procceedings of the 13th International Congress on Parkinson's Disease, Vancouver Canada.

[2] Darley, F.L., Aronson, A.E., & Brown, JR., 1969. Differential diagnostic patterns of dysarthria. *Journal of speech and hearing research*, 12, 249-269.

[3] Gentil, M., Pollack, P., J.Perret, J., 1975. La dysarthrie parkinsonienne, Revue Neurologique, 151(2), 105-112.

[4] Critchley, E.M.R., Speech disorders of parkinsonism.J Neurol Neurosurg Psychiatry,44, 751-758.

[5] Benke, T.H., Hohenstein, C., Poewe, W., B Buterworth, B., 2000. Repetitive speech phenomena in Parkinson's disease. J Neurosurg Psychiatry, 69, 319-325.

[6] Carmichael, L., 2002. Modelling Prosody: Different Perspectives. University of Washington Department of Linguistics. http://students.washington.edu/lesley/projects.html.

[7] Goberman, A., 2000. Acoustic characteristics of Parkinsonian speech before and after morning medication : The on and off states.

[8] Simuni, T., Hurtig, H., 2002. Levodopa: 30 years of progress. In Parkinson's Disease: Diagnosis and clinical management, S. Factor & W. Weiner (Eds.), New York: Demos Publishing.

[9] Canter G.J., 1963. Speech characteristics of patients with Parkinson's disease: Intensity, pitch and duration. Journal of Speech and Hearing Disorders, 28 (3), 221-229.

[10] Le Dorze, G., Ouellet, L., Ryalls, J., 1994. Intonation and speech rate in dysarthric speech. Journal of Communication Disorders, 27, 1-17.

[11] Mawdsley, C., Gamsu, C., 1971. Periodicity of speech in Parkinsonism. Nature, 231, 315-316.

[12] Wolfe, V., Garvin, J., Bacon, M., Waldrop, W., 1975. Speech changes in Parkinson's Disease during treatment with L-Dopa. Journal of Communication Disorders, 8, 271-279.

[13] Lagrue, B., Mignard, P., Viallet, F., Gantcheva, R., 1999. Voice in Parkinson's disease : A study of pitch, tonal range and fundamental frequency variations. In Proceedings of the 13th International Congress of phonetic sciences, San Fransisco, vol 9, 1811-1814.

[14] Vigouroux, N., Laur, D., Nespoulous, J.L., 1999. Etude phonétique de la dysarthrie dans la maladie de Parkinson. Rapport d'avancement.

[15] Hirst, D., Di Cristo, A., 1998 (eds), Intonation Systems : A Survey of Twenty Languages. Cambridge University Press.

[16] Di Cristo, A., Hirst, Daniel., 1993. Prosodic regularities in the surface structure of French questions. Proceedings ESCA Workshop on Prosody. (Lund, Septembre 1993), 268-271.

[17] Guimbretière E.,1994. Phonétique et enseignement de l'oral, Didier Hatier.

[18] Delattre P., 1966. Les dix intonations de base du français. In French Review, 40, American Association of teachers of French, Illinois, 1-14.

[19] Rossi M. et al, 1981, L'intonation de l'acoustique à la sémantique, Paris, Klincksieck.

[20] Hirst, D.J., Espesser, R., 1993. Automatic modelling of fundamental frequency using a quadratic spline function. Travaux de l'institut de phonétique d'Aix, 15, 71-85. http://www.lpl.univ-aix.fr/~hirst/software.html

[21] Hirst, D.J., Di cristo, A., 1986. Modelling French micromelody : analysis and synthesis. Phonetica, 43, 11-30.

[22] Espesser, R., 1996. MES : Un environnement de traitement du signal. In Actes of the XXIe Journées d'Etude sur la Parole, p.447.

[23] Espesser R, Hirst D , Nicolas P., 1995. User guide to prosody tools, Rapport Multext, LRE 62-050, Prosodic labelling tools. http://www.lpl.univ-aix.fr/projects/mes_signaix