VOICE AND PARKINSON'S DISEASE: A STUDY OF PITCH, TONAL RANGE, AND FUNDAMENTAL FREQUENCY VARIATIONS

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ABSTRACT

In this preliminary study, we tested the comprehension and the production of tonal events in a group of parkinsonian patients with and without pharmacological treatment in comparison with control subjects. Significant differences were found in the production task only: pitch, tonal range, and fundamental frequency variations in the parkinsonian group were reduced.

1. INTRODUCTION

Muscular rigidity and decreased motor activity are two characteristic features of Parkinson's disease that are mirrored at the speech production level by prosodic disturbances. Our study focuses on the tonal level, i.e. the fundamental frequency (F0) variations produced by the laryngeal activity. The parkinsonian dysprosody has often been described as a mere neuro-motor disturbance [1, 2]. But a few works suggest that its origin is to be found at a more central level of processing [3]. In order to verify this hypothesis, we tested both the comprehension and the production of pitch parameters in a group of parkinsonian patients. The influence of traditional anti-parkinsonian treatments (L-DOPA) was also studied to determine whether improved performances occur.

2. METHODS

2.1. Subjects

Ten male patients with idiopathic Parkinson's disease, free from cognitive degradations (MMS>25) or hearing disorders volunteered for the recordings, in two clinical conditions – with (ON) and without (OFF) treatment. Six male subjects without neurological, speech, or hearing disorders served as a control group (CTR).

	Number		**Age**		**Years of disease**	
	R	*S*	*R*	*S*	*R*	*S*
OFF / ON	10	7	57,4 *(8,9)*	57 *(9,0)*	10,9 *(4,2)*	9,3 *(3,0)*
CTR	6		61,0 *(6,7)*		-	

Table 1. Number of subjects, with age and years of disease (mean and standard deviation) for both spontaneous (S) and reading (R) tasks.

2.2. Perception tests and production tasks

The aim of the first perception test (test 1) was to assess the ability of the subjects to discriminate between two opposing falling / rising final F0 contours (15 pairs of affirmative / interrogative sentences). The two other tests aimed at evaluating the subjects' ability to detect pitch prominences: identification of the word carrying an emphatic stress within a sentence (test 2: 30 stimuli), and detection of the number of words carrying emphatic stresses within a sentence (test 3: 21 stimuli).

The production tasks consisted in the reading aloud of a passage (171 words) as well as the recording of one minute of spontaneous speech (monologue on a free subject).

2.3. Fundamental frequency measures

For every subject, F0 data from both production tasks were collected (reading: all data; monologue: same duration as reading). In order to analyze the distribution of F0 data on the speakers' pitch-range, four frequency regions were defined: the global region (GR) includes 100% of the data and corresponds to the overall voice compass of a speaker; the central region (CR) includes 70% of the data around the median; the lower and upper regions (LR and UR) include 15% of the data on either side of the central region (see Figure 1).

The F0 distribution was analyzed with a series of statistical indices. Five of them correspond to pitch-position parameters within each frequency region: mode, mean, median, minimum, and maximum (Min and Max correspond to the 1st and 99th percentiles within the global region, and to the 5th and 95th percentiles within the central, lower, and upper regions). Three other indices correspond to pitch-range parameters within each frequency region: the overall pitch-range corresponds to the frequency span between Min and Max, the usual pitch-range corresponds to the interquartile distance, and the average pitch-range corresponds to long-term fundamental frequency variations around the mean and is calculated from the coefficient of variation.

2.4. Statistical analysis

We used post-hoc PLSD Fisher tests for the comparison of the pitch parameters between the control group and the parkinsonian patients in OFF and ON conditions, and repeated measures ANOVA tests for the comparison of the pitch parameters between OFF and ON (the level of significance being 5% for both methods).

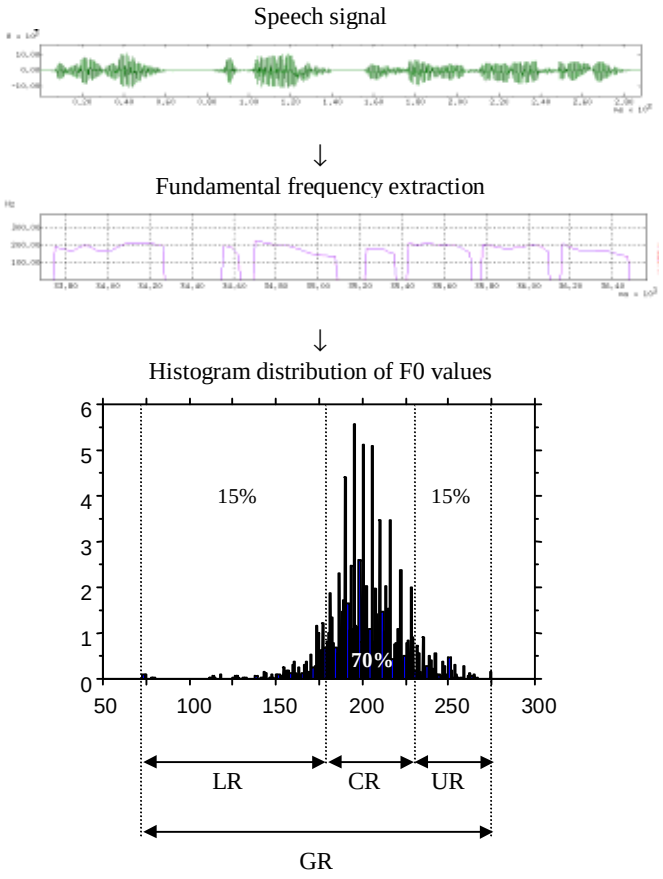

Figure 1. F0 data processing.

3. RESULTS

3.1. Pitch Perception

The results in Table 2 show that the percentage of correct answers from the control subjects is always higher than that of the parkinsonian subjects. Among the parkinsonians, The ON subjects have a higher proportion of correct answers. But there is no statistically significant differences between the three groups.

	Parkinsonian patients		Control subjects
	OFF	ON	
Test 1	94,1 *(4,2)*	96,5 *(2,0)*	97,3 *(1,5)*
Test 2	92,2 *(7,6)*	94,1 *(4,7)*	96,0 *(3,7)*
Test 3	78,0 *(10,6)*	80,1 *(3,9)*	86,7 *(6,2)*

Table 2. Mean *(and standard deviation)* of percentages of correct answers for the three groups to the perception tests

3.2. Production

3.2.1. Spontaneous speech vs. reading. The results from the spontaneous speech task are too variable among subjects: no systematic cross-group tonal differences emerge. On the contrary, the reading task, which is a more stereotyped task, seems to be best suited for the comparison of pitch parameters between OFF, ON, and CTR groups: when there is a significant difference between OFF and ON, OFF is always lower than ON (except for the Min parameter). CTR generally does not distinguish from OFF, and rarely does from ON.

3.2.2. Frequency regions. The information provided by the global and central regions is always redundant. The pitch parameters which best distinguish all the groups are related to the central and upper regions (see Table 3). Only the central region makes it possible to differentiate the groups according to all the pitch parameters we used. Thus, as the observation focuses on a speaker's central region, i.e. on his usual pitch-range, the differences between the groups appear. On the contrary, the lower region does not seem to reflect cross-group differences.

3.2.3. Pitch-position parameters. In all the frequency regions, the median is significantly higher for ON and CTR than for OFF (ON < CTR: non significant trend). This discrepancy can be explained by a larger proportion of high F0 values: CTR > ON > OFF. This phenomenon occurs together with the presence of more extreme frequencies (Max and Min parameters) within the central and upper regions. Thus the Max parameter in the central region (roughly equivalent to the lowest frequencies in the upper region) is the only parameter significantly distinguishing every group. Moreover, the pitch parameters relative to the values above the median are the only ones distinguishing the control subjects from the parkinsonians in OFF condition.

3.2.4. Pitch-range parameters. The pitch-range measured within the central region is the only parameter which is significantly wider for the control group than for the OFF parkinsonian subjects. The widening of the pitch-range in the central region between OFF and CTR and between OFF and ON may be explained by two concomitant phenomena: a larger span between the most extreme values in this frequency region (see Max and Min), and a higher proportion of extreme values for CTR and ON (see usual pitch-span). The last remark also applies to the upper region for the difference between OFF and ON. Finally, the average pitch-range is the only parameter that significantly increases between OFF and ON and between OFF and CTR.

4. INTERPRETATION

The antagonistic results found in perception and production confirm that the parkinsonian dysprosody does not have its origin in a cognitive disorder affecting the abilities to process prosodic information, but rather in a neuro-motor dysfunction affecting laryngeal activity. Thus, in the reading task, the opposition between control subjects and parkinsonian subjects without treatment emphasizes a significant influence of the disease upon pitch height and range. The results are less obvious for the opposition between control subjects and parkinsonian subjects with treatment. The vocal pitch characteristics are different between OFF and ON. This opposition shows the effect of the treatment on the tonal dimension of voice, and therefore on the motor activity responsible for the laryngeal movements.

The parkinsonian group seems to be qualitatively divided into two diverging categories regarding the effect of the treatment

F0 Region	Task	Pitch-position parameters					Pitch-range parameters		
		Minimum	*Median*	*Mode*	*Mean*	*Maximum*	*Overall*	*Usual*	*Average*
UR	***R***	ctr < **on** < **off**	**off** < **on** < ctr		**off** < **on** < ctr	—	—	**off** < **on** < ctr	—
	S	—	—		—	—	—	—	—
CR	***R***	ctr < **on** < **off**	**off** < **on** < ctr	—	**off** < **on** < ctr	**off** < **on** < ctr	**off** < **on** < ctr	**off** < **on** < ctr	**off** < **on** < ctr
	S	**on** < ctr < **off**	—	—	—	—	—	—	—
LR	***R***	—	**off** < **on** < ctr		**off** < **on** < ctr	—	—	—	—
	S	—	—		—	—	—	—	—
GR	***R***	—	**off** < **on** < ctr	—	**off** < **on** < ctr	—	—	**off** < **on** < ctr	**off** < **on** < ctr
	S	—	—	—	—	—	—	—	—

Table 3. Fisher LDPS post hoc tests results from pitch parameters between CTR, OFF, and ON (significantly different groups are underlined) and from repeated measures ANOVA tests between OFF and ON (in bold character if significantly different). No significant difference was found whenever "—" occurs.

upon pitch production. For 50% of the patients (group A) there is a noticeable increase in pitch height, average pitch-range, and usual pith-range (respectively 10%, 10%, and 3 %); for the second half of the patients (group B), these three parameters do not significantly increase (respectively 0%, 0%, and 10%). However this contrast between these two groups cannot be explained on the basis of age (same mean for A and B = 57.4), or motor examinations (Hoehn & Yahr [4]: A = 2.9 *(σ = 1)* and B = 2.2 *(σ = 1.7)*; UPDRS: A = 31.8 *(σ = 15.7)* and B = 21.3 *(σ = 11.9)*), or even duration of the disease (A = 11.6 *(σ = 4.4)* and B = 10.2 *(σ = 3.8)*): both groups have very close means and are too heterogeneous. It is nevertheless a fact that two patient profiles emerge: the patients whose laryngeal motor activity seems to benefit from the treatment, and those whose pitch production disorders do not improve.

5. CONCLUSION

These preliminary results show that the perceptive processing of pitch information is not altered in the parkinsonians. On the contrary, their vocal production is characterized by a reduction in both pitch height and range. This reduction can be compensated by dopatherapy in only one half of the patients. But it is to be noticed that the parameters taken into account in the present study cannot distinguish the two emerging profiles, which can only be done through correlating our results with new parameters (such as OFF / ON UPDRS ratio) and through increasing the number of subjects.

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