INTERSPEECH 2016
September 8–12, 2016, San Francisco, USA

The production of intervocalic glides in non dysarthric Parkinsonian speech

V. Delvaux[1,2], V. Roland[1], K. Huet[1], M. Piccaluga[1], M.C. Haelewyck[1], B. Harmegnies[1]
[1] Institut de Recherche en Sciences et Technologies du Langage, UMONS, Belgium
[2] FNRS, Belgium
veronique.delvaux@umons.ac.be

Abstract

In the context of a research project aiming at investigating the relationships between speech disorders, quality of life and social participation in Parkinson's Disease (PD), we report here on an acoustic study of glides and steady vowels by non dysarthric parkinsonian and control speakers. Our specific aim is to explore the dynamics of supra-laryngeal articulators in PD. Results suggest that non dysarthric Parkinsonian speakers maintain an accurate production of glides in VC[glide]V pseudo-words at the expense of articulatory undershoot in the surrounding vowels, and some asymmetry between the V1-to-glide and glide-to-V2 articulatory movements. We discuss how these results both support and challenge the accuracy-tempo trade-off hypothesis (Ackermann and Ziegler, 1991).

Index Terms: Parkinson's Disease, glides, speech production

1. Introduction

The study reported here has been carried out in the context of a larger project aiming at investigating the relationships between speech disorders, quality of life and social participation in Parkinson's disease (PD). PD is a neurodegenerative disease associated with basal ganglia motor loop dysfunction and impairment of the dopamine pathway. It is mainly characterized with the progressive loss of dopaminergic neurons. The core symptoms may include akinesia as well as bradykinesia, rigidity and/or resting tremor, which may all contribute to a wide variety of speech disorders usually regrouped under the label of 'hypokinetic dysarthria'.

Hypokinetic dysarthria manifests in all aspects of speech production, including respiratory, phonatory and articulatory processes, at both segmental and suprasegmental levels. Classical perceptual studies [1,2] and more recent acoustic studies [3,4,5] have repeatedly shown that Parkinsonian speakers display voice quality disorders (hoarseness, breathiness, etc.) as well as reduced overall loudness, limited variation in intensity and fundamental frequency (monotony of pitch and monoloudness), speech dysfluencies including longer, unappropriate pauses and word/syllable repetitions, unappropriate speech rate (mainly: short rushes of speech), and reduced stress.

On the articulatory level, imprecision of consonant production is one of the most reported impairment in individuals with PD who suffer a hypokinetic dysarthria [6,7,8]. Stops, affricates and fricatives are most distorted (in the direction of softening, e.g. via spirantization), presumably due to limited range and reduced force of articulatory movement. Actually, Ackermann and colleagues [6,9] have hypothesised that PD patients reduce the amplitude of articulatory movement in order to preserve speech tempo, which results in articulatory undershoot. However, physiological studies have yielded mixed findings in terms of amplitude and velocity of jaw, tongue and lip movements (and associated muscle activity) in Parkinsonian speech production (for a recent review, see [10]). For example, Mcauliffe *et al.* [11] evidenced perceived undershooting of Parkinsonian consonant production, but could not find an associated pattern of reduced tongue-palate contact on EPG examination. Wong *et al.* [8] even found an increased range of lingual movement (mostly in the release phase of velar and alveolar consonants) in dysarthric PD individuals. Obviously, more studies are needed to fully apprehend the dynamics of supra-laryngeal articulators in PD.

Interestingly, "resonatory" properties of speech production are presumably preserved - but rather understudied - in PD [12], although vowels, diphtongs and approximants certainly need accurate execution of motor plans involving jaw, tongue and lips. The study of vocoids may be of great interest to research on PD speech, particularly if steady vowels are compared with dynamic vocalic productions (i.e. glides), since it allows to investigate the speakers' ability to control their resonators in maintaining stable articulatory configurations vs. in producing accurate and properly-timed dynamic gestures.

In this paper, in line with prior exploratory research in our laboratory (on palatal French glides in PD speakers: [13]), we report on an acoustic study of the production of glides and steady vowels by non dysarthric PD and control speakers[1]. Our aim was to explore the dynamics of supra-laryngeal articulators in vocoids, and to address specifically the hypothesis that when dysarthria is subclinical, Parkinsonian speech may be characterized by a preservation of the tempo, somewhat at the expense of the accuracy of articulatory movements (in line with [6,9]).

2. Material and method

2.1. Speakers

Two groups of speakers participated in the study. The first group was made of 9 (6 male, 3 female) speakers with PD (middle stages on the Hoehn and Yahr scale: [14]). They were Belgian French native speakers aged 52-77 (mean: 65), with an average disease duration of 10 years. All PD participants had been receiving medication for several years at the time of the experiment. Only one of them had benefited from deep brain stimulation 5 years earlier and still underwent speech therapy. The second group of participants was made of 10 control subjects (5 male, 5 female) with no speech or language pathology by self-report. All participants were administered self-assessment questionnaires on voice disorders (VHI: [15]), quality of life (PDQ-39: [16]) and social participation

[1] This paper is the full version of a preliminary report presented at LabPhon15 (Ithaca, NY, 2016).

http://dx.doi.org/10.21437/Interspeech.2016-349

(MHAVIE 4.0: [17]). Concerning VHI, the results of the PD speakers ranged from mild (3 speakers) to severe (4 speakers) passing by moderate (2 speakers) voice handicap, mostly on the functional and emotional subscales. However, none of the parkinsonian speakers made any articulatory complaint.

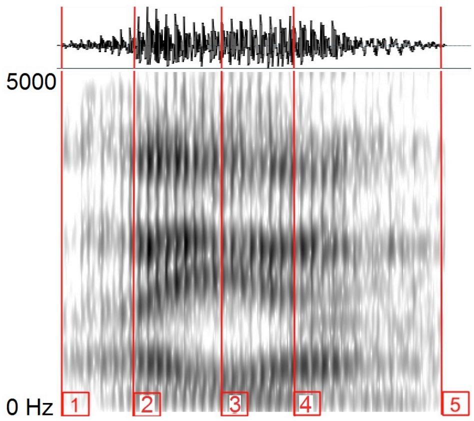
2.2. Speech data collection

All participants undertook a variety of speech tasks including: (i) the production of sustained oral vowels [a,i,u]; (ii) the production of V1C[glide]V2 pseudo-words in which V1=[a,u], C=[j,w] (/ɥ/ was not included because it has merged with /w/ in the Belgian French dialect) and V2=[a,i,u]; (iii) the repetition of CV(C)CV pseudo-words; (iv) the reading of a short text. The present paper focusses on an acoustic analysis of the first two tasks. Both tasks concern productions made in isolation (3 repetitions): carrier sentences were dismissed because of the overall tendency to hypoarticulation that has been evidenced for PD speakers in long utterances [18].

2.3. Data processing

For the sustained oral vowels, acoustic measurements included overall duration and formant frequencies (F1, F2) taken at the middle point of the vowel. For V1CV2 pseudo-words, based on waveforms and spectrograms each production was annotated with 5 labels using Praat [19] (Fig.1a): (1) V1 onset, (2) V1 offset=glide onset, (3) "F2 inflection", i.e. the time point when F2 reaches its extreme (minimal or maximal) value within the glide, (4) V2 onset=glide offset, (5) V2 offset. Acoustic measurements included duration and formant measurements.

(a)



(b)

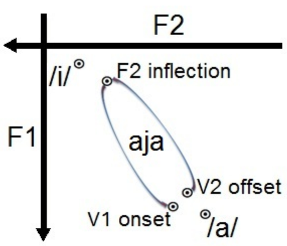


Figure 1. *(a) Annotations on the VCV pseudo-words: [aja], PD male speaker (b) Topological analysis of formant frequencies measured in VCV pseudo-words and sustained vowels*

Duration measurements consisted in: V1 duration (1)-(2), C duration (2)-(4), V2 duration (4)-(5), total duration (1)-(5), duration of the time interval between V1 onset and F2 inflection (absolute duration: (1)-(3), as well as relative-to-total duration: (1)-(3)/(5)), duration of the time interval between F2 inflection and V2 offset (absolute duration: (3)-(5) as well as relative-to-total duration: (3)-(5)/(5)). Formant frequencies (F1, F2) were taken at (1), (3) and (5). Mean rates of F2 frequency changes over the V1-C and C-V2 portions of the VCV pseudo-word were computed as F2(1)-F2(3)/(1)-(3) and F2(5)-F2(3)/(5)-(3).

Formant frequencies were mainly analysed from a topological perspective (illustrated in Fig.1b). The collected data were used to compute a variety of euclidean distances in the F1/F2 plane. We focus here on two types of such distances: (i) distances documenting the range of vowel quality changes within the VC[glide]V pseudo-word (go path from V1 onset to F2 inflection (1)-(3); return path from F2 inflection to V2 offset (3)-(5)); (ii) distances expressing how each speaker produced a given VCV pseudo-word with respect to his/her corresponding sustained oral vowels (e.g. in Fig.1b, distance from V1 onset to sustained [a], from F2 inflection to sustained [i] and from V2 offset to sustained [a]).

2.4. Vowel spaces

The productions of the sustained vowels [a,i,u] were used to assess the vowel spaces of the participants. Built using Cédric Gendrot's "triangle vocalique" Praat script [20], Fig.2 plots individual vocalic productions as well as associated ellipses in the F1/F2 plane, contrasting productions from PD vs. control speakers. Fig.2 illustrates the fact that vowel productions are more scattered for PD speakers. Individual triangle areas were also computed. A t-test for independent samples revealed that mean areas were not significantly different for PD vs. control speakers ($t(17)=-0.229$, $p=0.82$). These data suggest that, even if interindividual variation in the production of sustained vowels is larger among PD speakers, their vowel *spaces* do not differ substantially from those of healthy speakers.

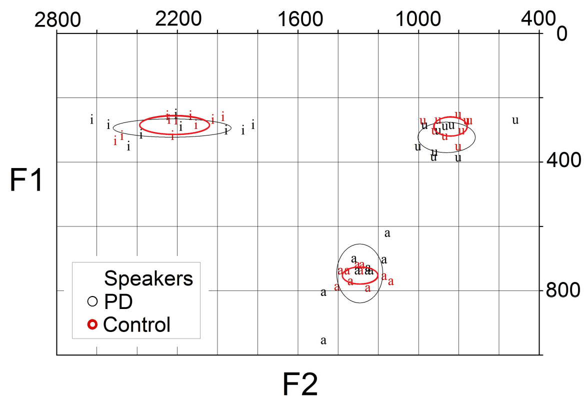


Figure 2. *Individual [a,i,u] productions and associated ellipses in the F1/F2 plane [Hz] for PD vs. control speakers (sustained vowels)*

2.5. Changes in vowel quality within VC[glide]V

The range of changes in vowel quality within the VCV pseudo-words was compared across the two groups of participants. A MANOVA was carried out with the V1 onset-F2 inflection (go path) and the F2 inflection-V2 offset (return path) euclidean distances in the F1/F2 plane as dependent variables, and Group of speakers (PD vs. controls) as well as Pseudo-word as independent variables. The statistical analysis revealed that both independent variables yielded significant differences in the go path distances (Pseudo-word: $F(4,85)=38.203$; $p<0.001$; Group: $F(1,85)=22.728$; $p<0.001$) as well as in the return path distances (Pseudo-word: $F(4,85)=32.575$; $p<0.001$; Group: $F(1,85)=14.764$; $p<0.001$). No significant interaction was found.

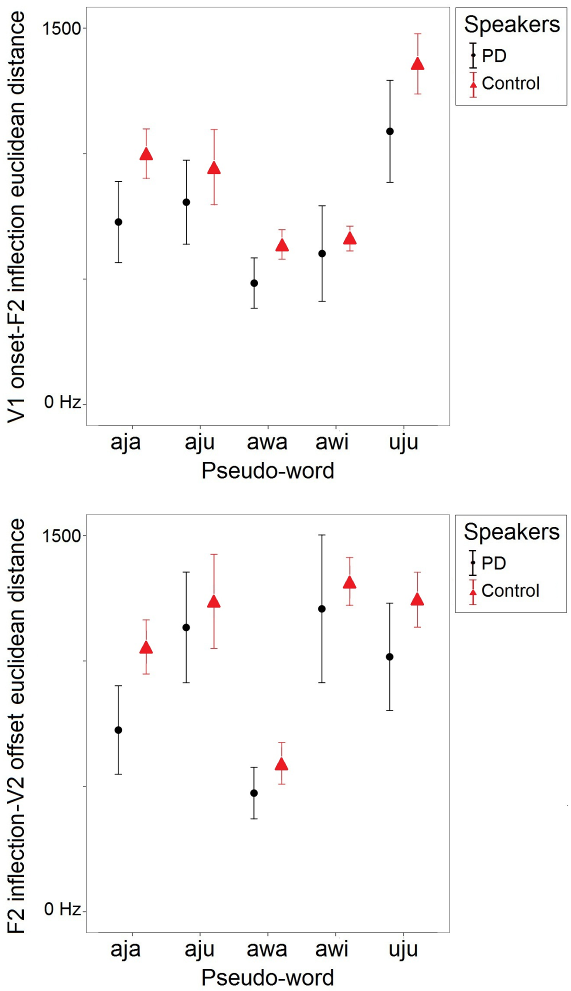


Figure 3. *Error bars (Mean, SD) representing euclidean distances in the F1/F2 plane [Hz] as a function of Pseudo-word for PD vs. control speakers: top: V1 onset-F2 inflection (go path); bottom: F2 inflection-V2 offset (return path)*

Fig.3a&b illustrate these effects. They show that both the go and the return paths are sensitive to the nature of the pseudo-word, but more importantly in the context of the present study, they are always smaller in parkinsonian speech.

2.6. VC[glide]V with respect to sustained vowels

PD vs. control speakers were also compared in terms of how they produced a given VCV pseudo-word with respect to the corresponding reference oral vowels. A MANOVA was carried out with V1-to-reference, C-to-reference and V2-to-reference euclidean distances in the F1/F2 plane as dependent variables, and Group of speakers (PD vs. controls) as independent variable. The statistical analysis revealed that PD speakers had significantly larger V1-to-reference ($F(1,93)=12.428$; $p<0.05$) and V2-to-reference ($F(1,93)=8.732$; $p<0.05$) distances than control speakers. However, there was no significant difference between PD and control speakers in terms of C-to-reference distances ($F(1,93)=2.013$; $p=0.159$) (Fig.4). These results indicate that in V1CV2 pseudo-words, PD speakers maintain a production of the glide which is close to controls' production, i.e. close to the vowel quality of the reference vowel in terms of formant values, but that they do so at the expense of the neighbouring vowels V1, V2, which are subjected to undershoot.

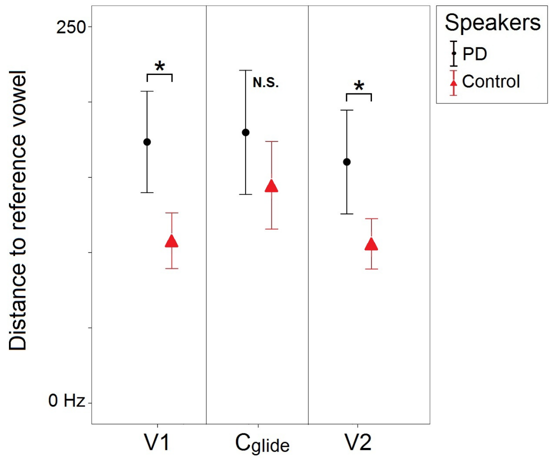


Figure 4. *Error bars (Mean, SD) representing V1-to-reference, C-to-reference and V2-to-reference euclidean distances in the F1/F2 plane [Hz] for PD vs. control speakers*

2.7. Durations in VC[glide]V

Durations within VCV pseudo-words were compared across the two groups of participants. A MANOVA was carried out with all duration measurements detailed above (see 2.3) as dependent variables and Group of speakers (PD vs. controls) as independent variable. The statistical analysis revealed that there was no significant difference between PD and control speakers in terms of total VCV duration ($F(1,93)=0.73$; $p=0.395$) and many other duration measurements not detailed here. However, compared to control speakers, PD speakers had significantly shorter relative-to-total duration of the time interval between V1 onset and F2 inflection ($F(1,93)=8.84$; $p<0.05$), and significantly longer relative-to-total duration of the time interval between F2 inflection and V2 offset ($F(1,93)=8.84$; $p<0.05$) (Fig.5).

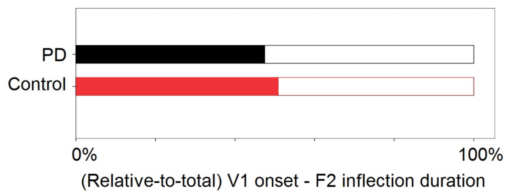


Figure 5. *(Relative-to-total) duration of the time interval between F2 inflection and V2 offset [%] for PD vs. control speakers*

These results suggest that PD speakers reach earlier the acoustic target for the glide (i.e. the extreme F2 value), then move slowlier to the following vocalic target. Note that the mean rates of F2 frequency change did not significantly differ between PD and control speakers.

3. Discussion

In this paper, we have reported on an acoustic study of the production of glides and steady vowels by PD vs. control speakers. Our first aim was to explore through the acoustics the dynamics of supra-laryngeal articulators in parkinsonian speech, focussing on the - understudied - vocoids of Belgian French. Our second aim was to address specifically the hypothesis that when dysarthria is subclinical, Parkinsonian speech may be characterized by a preservation of tempo, somewhat at the expense of articulatory precision (as proposed earlier by [6,9]).

Results showed that the vowel spaces of the parkinsonian group did not differ substantially from those of the control group (although interindividual variation is larger among PD speakers), which indicates that their articulatory range is preserved when they produce static sustained vowels. However, the acoustic analysis of the VC[glide]V pseudo-words suggests differences in articulatory control across the two groups of participants. Indeed, the range of changes in vowel quality within the V1CV2 pseudo-words (as evidenced by euclidean distances between V1, C and V2 in the F1/F2 plane) proved systematically smaller for PD speakers, which suggests articulatory undershoot. In fact, PD participants maintained a production of the glide which was close to the vowel quality of the reference vowel in terms of formant values (as was the case for control speakers), but they did so at the expense of the neighbouring vowels V1 and V2.

The acoustic data reported here provide evidence in favour of the hypothesis of a trade-off between speech tempo and articulatory precision, since VCV total duration was similar in PD and control speakers whereas the amplitude of articulatory movements (as indexed by changes in vowel quality) was reduced in parkinsonian speech. However, articulatory precision was only selectively dispensed with, because the Parkinsonian speakers maintained an accurate production of glides in terms of formant target.

Interestingly, timing was somewhat different in Parkinsonian speech, in that PD speakers reached earlier the acoustic target for the glide (i.e. the extreme F2 value), then moved more slowly to the following vocalic target. The fact that the mean rates of F2 frequency change did not, however, significantly differ between PD and control speakers points to the necessity to assess, in future work, the evolution of such rates over time. Indeed, glides are by nature *dynamic targets*, which may challenge the very notion of a trade-off between articulation rate and precision.

4. Conclusion

In the acoustic study reported here, the Parkinsonian speakers maintained an accurate production of glides in VC[glide]V pseudo-words at the expense of articulatory undershoot in the surrounding vowels, and some asymmetry between the V1-to-glide and glide-to-V2 articulatory movements. These results shed light on the articulatory reorganization that may take place when dysarthria is (still) subclinical in Parkinson's disease.

5. References

[1] Darley, F. L., Aronson, A. E., and Brown, J. R. *Motor Speech Disorders*, Philadelphia: W.B. Saunders Company, 1975.

[2] Logemann, J. A., Fisher, H. B., Boshes, B. and Blonsky, E. R. "Frequency and cooccurrence of vocal tract dysfunctions in the speech of a large sample of Parkinson patients", *Journal of Speech and Hearing Disorders*, 43, 47–57, 1978.

[3] Hammen, V. L., and Yorkston, K. M. "Speech and pause characteristics following speech rate reduction in hypokinetic dysarthria", *Journal of Communication Disorders*, 29, 429–445, 1996.

[4] Gamboa, J., Jimenez-Jimenez, F. J., Nieto, A., Montojo, A., Orti-Pareja, M., Molina, J. A., *et al*. "Acoustic voice analysis in patients with Parkinson's disease treated with dopaminergic drugs", *Journal of Voice*, 11, 314–320, 1997.

[5] Cheang, H. S., and Pell, M. D. "An acoustic investigation of Parkinsonian speech in linguistic and emotional contexts", *Journal of Neurolinguistics*, 20, 221–241, 2007.

[6] Ackermann, H., and Ziegler, W. "Articulatory deficits in Parkinsonian dysarthria: An acoustic analysis", *Journal of Neurology, Neurosurgery, and Psychiatry*, 54, 1093–1098, 1991.

[7] McRae, P., and Tjaden, K. "Spectral properties of fricatives in Parkinson's Disease", *J. Acoust. Soc. Am.* 104, 1998.

[8] Wong, M. N., Murdoch, B. E., and Whelan, B.-M. "Lingual Kinematics in Dysarthric and Nondysarthric Speakers with Parkinson's Disease", *Parkinson's Disease*, Article ID 352838, 8 pp., 2011.

[9] Ackermann, H., Hertrich, I., and Hehr, T. "Oral diadochokinesis in neurological dysarthrias", *Folia Phoniatrica et Logopaedica*, 47, 15–23, 1995.

[10] Walsh, B., and Smith, A. "Basic parameters of articulatory movements and acoustics in individuals with Parkinson's disease", *Mov Disord,* 27, 843-850, 2012.

[11] McAuliffe, M. J., Ward, E. C., and Murdoch, B. E. "Speech production in Parkinson's disease: I. An electropalatographic investigation of tongue-palate contact patterns", *Clinical Linguistics & Phonetics*, 20, 1-18, 2006.

[12] Goberman, A. M., and Coelho, C. "Acoustic analysis of parkinsonian speech I: speech characteristics and L-Dopa therapy", *Neuro Rehabilitation*, 17, 3, 237–246, 2002.

[13] Couvreur, N., Bruyninckx, M., and Harmegnies, B. "Effects of parkinsonian symptoms on voiced palatals", *Proceedings of 14th International Congress of Phonetic Sciences*, 1, 831-834, 1999.

[14] Hoehn, M., and Yahr, M. "Parkinsonism: onset, progression and mortality", *Neurology,* 17, 5, 427–442, 1967.

[15] Jacobson, B. H., Johnson, A., Grywalski, C., Silbergleit, A., Jacobson, G., Benninger, M. S., and Newman, C. W. "The Voice Handicap Index (VHI)Development and Validation", *Am J Speech Lang Pathol*, 6, 3, 66-70, 1997. doi: 10.1044/1058-0360.0603.66

[16] Auquier P., Sapin C., Ziegler M., Tison F., Destée A., Dubois B., Allicar M. P., Thibault J. L., Jenkinson C., and Peto V. "Validation en langue française d'un questionnaire de qualité de vie dans la maladie de Parkinson: le Parkinson's Disease Questionnaire - PDQ-39", *Revue neurologique*, 158, 1, 41-50, 2002.

[17] Fougeyrollas, P., Noreau, L., and St-Michel, G. "Guide de l'utilisateur « Instrument de mesure des habitudes de vie » (MHAVIE 2.1) et « Instrument de mesure de la qualité de l'environnement »", *Réseau International CIDIH*, 9, 1, 6-19, 1997.

[18] Sauvageau, M., Roy, J. P., Cantin, L., Prud'homme, M., Langlois, M., and Macoir, J. "Articulatory Changes in Vowel Production following STN DBS and Levodopa Intake in Parkinson's Disease", *Parkinson's Disease*, Article ID 382320, 2015.

[19] Boersma, P. "Praat, a system for doing phonetics by computer", *Glot International,* 5, 9/10, 341-345, 2001.

[20] Gendrot, C. and Adda, M. "Analyses formantiques de corpus radiophoniques multilingues", in *Actes de la conférence MIDL, Paris, France*, 2004.