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Disfluency and speech management in Italian patients with early-stage Parkinson's Disease

Loredana Schettino[1], *Marta Maffia*[2], *Rosa De Micco*[3], *Alessandro Tessitore*[3]

[1]Interdepartmental Research Center Urban/Eco, University of Naples Federico II, Italy
[2]Dept. of Literary, Linguistics and Comparative Studies, University of Naples L'Orientale, Italy
[3]Dept. of Advanced Medical and Surgical Sciences, University of Campania Luigi Vanvitelli, Italy

loredana.schettino@unina.it, mmaffia@unior.it, rosita.demicco@gmail.com,
alessandro.tessitore@unicampania.it

Abstract

Parkinsonian speech has often been described as "disfluent". However, the specific nature of disrupted speech in Parkinson's Disease (PD) patients has not been well observed. Considering that pauses, fillers, repetitions and self-repairs are commonly used in spontaneous speech for managing and monitoring the own speech production, this study aims at investigating the characteristics of disfluency phenomena patterns in early-stage PD subjects. To reach this goal, the monological speech of 18 PD patients and 18 age- and sex-matched healthy subjects, all Italian native speakers, was annotated distinguishing between Forward-Looking Disfluencies, such as silent pauses, lexical and non-verbal fillers and prolongations, through which message delivery is suspended for planning, and Backward-Looking Disfluencies, such as repetitions, insertions, deletions and substitutions, used by the speaker to edit something already uttered. Pathological and healthy speech samples were compared with reference to four parameters: the number and frequency of disfluencies; their specific functions; the syntactic positioning of the items; the duration of silent pauses, filled pauses and lengthening. Results highlight the relevance of investigating the specific uses, types and characteristics of disfluency phenomena rather than just considering their frequency of occurrence to gain insight into the features of Parkinsonian speech, even at a very early stage.[1]

Index Terms: disfluencies, Parkinson's Disease, repairs, hesitations, functions

1. Introduction

Parkinson's Disease (PD) is a neurodegenerative disorder consisting of a deterioration of dopaminergic neurons in the basal ganglia and affecting more than 2-3% of the population over 65 years of age [1]. One of its early symptoms is hypokinetic dysarthria, caused by poor activation and coordination of the muscles involved in speech production. It includes a range of speech and voice impairments: reduced voice intensity, significantly narrower tonal range (monopitch), monoloudness, increased voice nasality, increased acoustic noise, imprecise consonantal articulation and reduced vowel space area, vocal tremor, harsh and breathy voice quality, impaired speech rate and rhythm, longer silent pauses (see, among others [2, 3, 4, 5]).

Although Parkinsonian speech is usually defined as "disfluent", still a detailed description of the specific characteristics of disrupted PD speech has not been provided [6]. Recent studies have focused on stuttering-like disfluencies in mild-to-severe PD patients, examined in different speech styles and compared to those produced by healthy speakers and by individuals with developmental stuttering [7, 8]. Results report greater disfluency percentages in PD patients than in the healthy control group, especially in the case of within-words disfluencies (stuttering occurring on part of a word; syllable repetitions, incomplete syllable repetitions, inaudible and audible fixed postures) and in the monologic speech task, thus supporting the relationship between stuttering-like behaviors in PD and impairment in the basal ganglia/dopamine system. A case study on a severely dysfluent PD patient also reported an effect of the speech task on the quantity and quality of disfluency phenomena: phonetic and syllabic dysfluencies appeared across all tasks, due to an impairment in motor planning of speech segments; however, lexical dysfluencies, reflecting linguistic planning, were found to be more frequent in spontaneous speech [9]. In another research, no differentiation in the speech disfluency severity between different speech styles produced by PD patients was found but a positive correlation between the frequency of disfluencies and the duration of the disease [10], as also observed for repetitive speech phenomena in [11]. The effect of Levodopa medication on disfluencies has also been observed, trying to support the so-called "excess dopamine hypothesis", according to which increased levels of dopamine should lead to the development of stuttering in PD, with controversial results [12].

More generally, speech errors and disfluencies have been demonstrated to be strong predictors of cognitive impairment in other pathologies, such as dementia and Alzheimer's disease [13, 14]. In fact, the very first classifications of the phenomena ascribable to the category of "disfluencies" [15] emerged in the strive to distinguish between disfluencies in typical and atypical speech [16] since the acknowledgement that typical speech also commonly includes phenomena like repetitions, pauses, self-repairs. Various studies on different languages have shown that human spontaneous speech is normally characterized by the occurrence of these phenomena (about 6 - 10 disfluency phenomena per 100 words, see [17]). In particular, it has been observed that some of the elements traditionally included in the heterogeneous class of disfluencies actually represent a useful tool for speakers to manage and monitor their own speech production either by gaining more time (e. g., through silences, the lengthening of segmental material, non-verbal or lexical fillers) for speech production or by editing something already uttered (e. g., through deletions, substitutions, insertions) [18, 19]. Hence, these speech management phenomena provide valuable information on speech planning and discourse structuring.

[1]This article is the result of the collaboration among the authors. However, for academic purposes, Loredana Schettino is responsible for sections 1, 2.2 and 3, Marta Maffia for sections 1 and 2.1. All the authors are responsible for section 4.

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In this light, the analysis of differences between the patterns of disfluency phenomena in PD and in typical speech can offer a unique opportunity to distinguish and examine acquired disfluencies of known neurogenic origin and associated with cognitive, linguistic, and motor deficits resulting from the damages in the central nervous system. Hence, the present study aims at describing the specific characteristics of speech disfluency phenomena produced by Italian subjects with early-stage PD.

2. Method

2.1. Participants and Data

The data for the present research were collected from 36 Italian native speakers residing in Campania region: 18 participants with idiopathic non-demented PD were involved (10 males, 8 females; 51–81 years of age, M= 65), along with 18 age-matched Healthy Controls (HC, 10 males, 8 females; 54–77 years of age, M= 64). The patients were recruited at the Movement Disorders Unit of the First Division of Neurology at the University of Campania "Luigi Vanvitelli", from a cohort of subjects with no history of previous language and speech disorder. They were all diagnosed with PD in the previous four years and did not present a relevant cognitive impairment nor major/minor depression or dysthymic disorder.

A monologic task was proposed and recorded: they were all asked to talk about positive and negative aspects of the place where they lived at the moment of data collection. All the subjects were encouraged to speak in their normal, conversational voice and at comfortable loudness. Sociolinguistic information on each speaker was also obtained through a questionnaire and all subjects gave written consent to the data collection procedure. A total duration of about 39 min of PD and healthy speech was recorded.

The collected corpus was already the object of a rhythmical analysis in a previous work [20], which highlighted a comparable articulation rate in the two groups of speakers, calculated using the VtoV parameter, i.e., the mean duration of the intervals between two consecutive vowel onsets [21]: in the PD speech the mean VtoV value was 0,188 s, in healthy speech it was 0,185 s. Moreover, mean data on speech time composition showed no statistical difference in the percentage of disfluent time on the total utterance (PD= 14%; HC= 11%). Starting from these observations, a more in-depth analysis was conducted on disfluency phenomena.

2.2. Annotation and analysis

The objects of the analysis are speech elements that are commonly referred to as "Disfluencies", though it is a highly debated umbrella term used for a wide range of phenomena. In this study, we observe speech management phenomena defined as the linguistic tools, e.g. repetitions, change of plan, segmental prolongations, pauses, that speakers can use to monitor and effectively manage the online processes of speech planning, coding, articulation, and reception [22]. According to the context of occurrence, each phenomenon is identified and annotated on three main levels [23, 24]. On the first level, the macro-structure of the event is labeled: the region to be repaired (Reparandum, RM), the repaired one (Reparans, RS), and the one where the delay occurs (Interregnum, IM). The second level is for the identification of specific items, i.e., Deletions (DEL), Insertions (INS), Substitutions (SUB), Repetitions (REP), Silent Pauses (SP), Prolongations (PRL), Filled Pauses (FP), and Lexicalized Filled Pauses (LFP) (Cohen's k= 0.82, good agreement [25]). On the third level, each item is assigned its main function: Forward-Looking (FLD), for those used to gain time for speech planning processes; Backward-Looking (BLD), for phenomena used to retrace and alter already uttered speech. An additional level of annotation is considered to specify the function(s) that could be associated with Forward-Looking Disfluencies according to their context of occurrence (Cohen's k= 0.77, substantial agreement [25]): Word Searching (WS), when they are involved in lexical retrieval [26]; Structuring (STR), for those occurring at the boundaries of syntactic or information structure, e.g., clauses and topic-comment, respectively; Focusing (FOC), when marking upcoming "semantically heavy" elements [27]; Hesitative (HES), when none of the preceding sub-functions applies and the items could just be associated with broad speech planning.

The analysis concerns the comparison of Parkinsonian (PD) and Health Control (HC) speech with reference to the following parameters:

- the frequency of disfluent items and their main contextual function;
- the specific contextual functions of Forward-Looking Disfluencies;
- the syntactic positioning of the items, i.e. within words (WTH-W), within phrases (INTRA - S), between phrases (INTER - S), between clauses (INTER - C);
- the duration of Silent Pauses, Filled Pauses and Prolongations.

The annotation was conducted using the ELAN software for multi-level linguistic annotations [28].

The statistical significance of the results is tested by building different Generalised Linear and Linear Mixed Models (lme4 [29]), with the analysis parameters as dependent variables, the health condition (PD or HC) and the subjects' biographical data (sex and age) as independent variables, and Subject as a random effect.

3. Results

3.1. General Frequencies

The analysis concerned 944 disfluency phenomena. In the observed data, more phenomena occurred in the PD productions (490) than in the HC productions (454). However, it is a slight and statistically non-significant difference (Est.= -0.07, SE= 3.32, z= -0.02, p= 0.98).

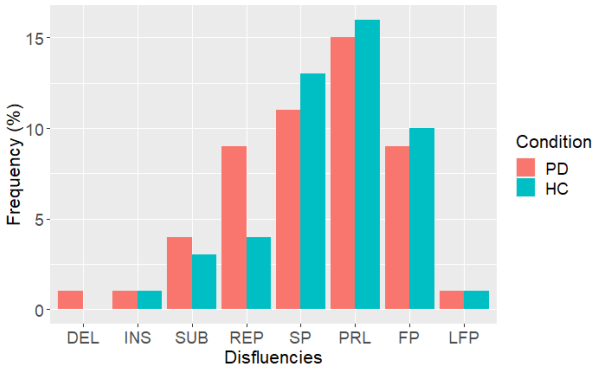

Figure 1: *Proportion of phenomena (N = 944) of different types per condition.*

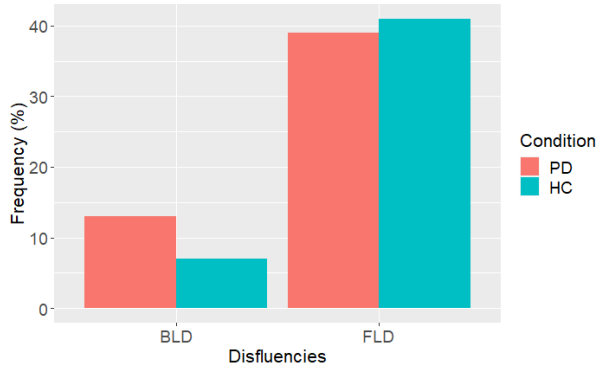

Figure 2: *Proportion of phenomena (N = 944) with Forward-Looking and Backward-Looking function per condition.*

Also, when considering the different types of phenomena (Figure 1), PD speakers only seem to produce more repetitions, but no significant difference emerges (Est.= 0.64, SE= 1.41, z= 0.45, p= 0.65). Nonetheless, when considering the main function associated with each item (Figure 2), both PD and HC speakers produce considerably more Forward-Looking Disfluencies than Backward-Looking ones, but PD speakers produce significantly more Backward-Looking Disfluencies than the control speakers (Est.= 0.62, SE= 0.24, z= 2.53, p= 0.01). No significant effect is exerted by the biographical variables.

3.2. Specific Functions

As for the contextual-specific functions ascribable to Forward-Looking phenomena, Figure 3 and 4 show a different distribution between PD and HC speakers.

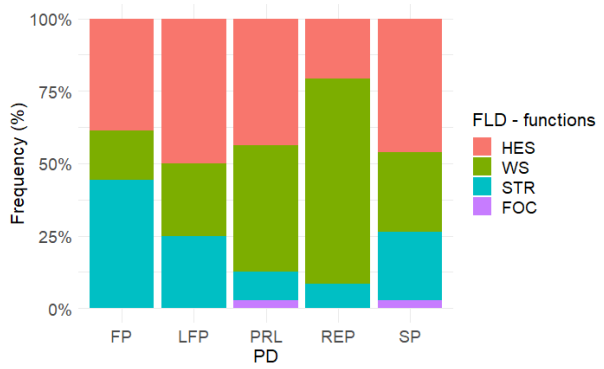

Figure 3: *Functions of Forward-Looking Disfluencies produced by PD speakers.*

More specifically, PD speakers are found to produce more phenomena associated with Word Searching function (in particular, repetitions, prolongations, and silent pauses) than HC subjects (Est.= 0.10, SE= 0.30, z= 3.32, p= 0.0008). Also, significantly more phenomena involved in lexical retrieval were produced by male speakers (counted on the total of FLDs, m= 39%, f= 17%, Est.= 0.65, SE= 0.29, z= 2.22, p= 0.02).

Moreover, as compared to HC speakers, PD speakers are also found to produce fewer phenomena associated with the Structuring function, (in particular, prolongations and repetitions, Est.= -0.85, SE= 0.41, z= -2.06, p= 0.039) and Focusing

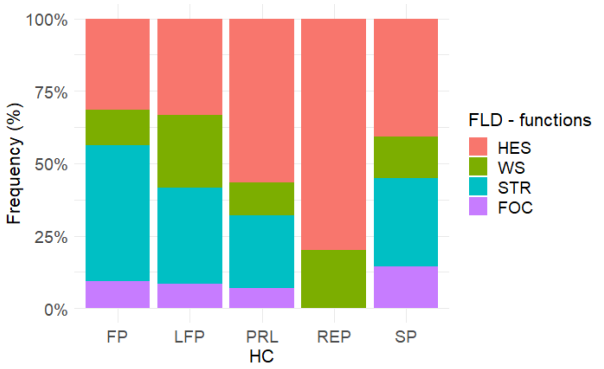

Figure 4: *Functions of Forward-Looking Disfluencies produced by HC speakers.*

function (Est.= -2.00, SE= 0.69, z= -3.04, p= 0.002).

3.3. Positioning

The distribution of phenomena with reference to syntactic structures (clauses, phrases and words) also seems quite different between the PD and the HC groups (Figure 5 and 6). In particular, in PD productions, disfluency phenomena occur significantly more frequently within words, that is interrupting the realisation of words, than in HC speech (Est.= 1.87, SE= 0.41, z= 4.57, p<.0001).

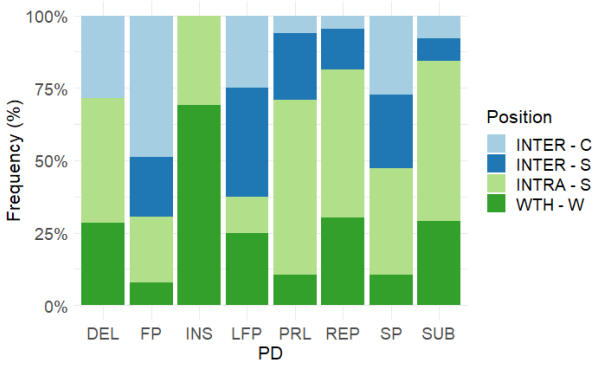

Figure 5: *Position of disfluencies produced by PD Speakers.*

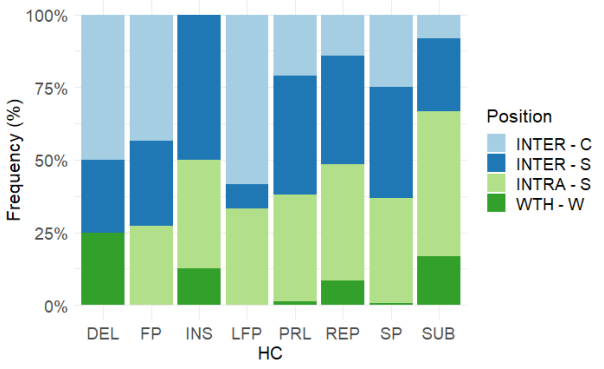

Figure 6: *Position of disfluencies produced by HC speakers.*

3.4. Duration

As reported in Table 1 and illustrated in Figure 7, Forward-Looking phenomena produced by PD speakers are on average longer than those produced by HC speakers (Est.= 102.89, SE= 46.21, df= 34.44, t= 2.23, p= 0.03). However, when considering the different types of phenomena, a significant difference only emerged for Silent Pauses (Est.= 190.35, SE= 84.02, df= 24.07, t= -2.27, p= 0.03).

Table 1: *FLDs duration values per condition: count, mean, standard deviation, standard error of the mean, and confidence interval (default 95%).*

FLD	Cond.	N	Dur (ms)	sd	se	ci
SP	HC	125	321	265	24	47
SP	PD	106	504	496	48	96
PRL	HC	147	340	197	16	32
PRL	PD	144	414	276	23	45
FP	HC	98	460	326	33	65
FP	PD	88	504	348	37	74

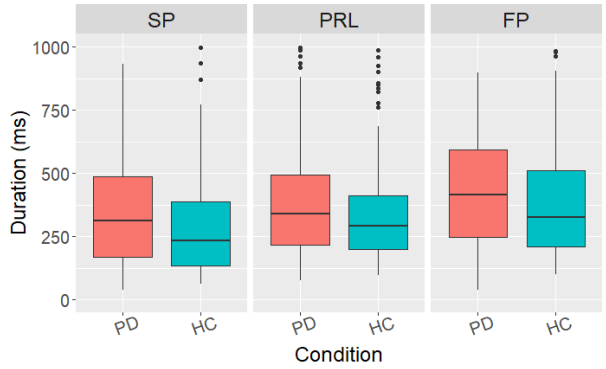

Figure 7: *Duration of Silent Pauses, Prolongations and Filled Pauses per condition.*

4. Discussion and Conclusions

This study has aimed at describing the characteristics of disfluency phenomena used by Italian patients with early-stage PD in spontaneous monologic speech. This goal has been pursued by considering the distinction between Forward-Looking and Backward-Looking Disfluencies, the former associated with a suspension of message delivery and a need for extra time for language planning, the latter used to edit something that has already been said. While the considered PD and HC speech did not differ much in the number of occurrences of different phenomena, as also previously observed in [20], and both PD and HC speakers were found to more frequently resort to phenomena suspending the speech delivery, results show that the patients need to repair something already uttered significantly more frequently than healthy subjects, with a particularly high frequency of Substitutions and Repetitions.

Moreover, significant differences were also observed in the distribution of the contextual specific functions associated with Forward-Looking Disfluencies: as compared with the healthy controls' productions, Parkinsonian speech was characterized by a higher number of phenomena involved in lexical retrieval and PD speakers used Silent Pauses, Filled Pauses and Prolongations less frequently to mark the syntactic and information structure of the utterance.

In line with these findings, data on the positioning of disfluencies show that in the speech of the HC group, disfluency phenomena mostly occur between clauses and between phrases, whereas PD speech is found to be characterized by more within-word disfluencies, both among Forward-Looking and Backward-Looking phenomena, than healthy speech, thus confirming previous findings in the literature [7, 8].

Furthermore, while PD patients tend to produce fewer Silent Pauses, Prolongations, and Filled Pauses than healthy speakers, these are on average longer, especially Silent Pauses, which corroborates previous findings [2, 3].

To summarize, the reported findings highlight the relevance of investigating the way disfluency phenomena are used by speakers to manage their speech rather than just considering the frequency of occurrence to gain insight into the features of Parkinsonian speech. At a very early stage of the disease, when the effects of dysarthria are still perceptually not evident, the use of disfluency phenomena reveals that linguistic planning and processing are somehow already altered. PD patients need (and take) time to repair their utterances and to search for the next item to utter, often interrupting the production of words and producing longer pauses than healthy speakers. It can be assumed that an explanation could be found at the intersection of cognitive impairments and motor changes in speech production, which both affect communication abilities at all stages of the disease, even in the absence of dementia [30]. However, in light of the limited size of the sample, the results of this study must be interpreted with caution and will need further and more detailed replication.

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