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Pauses as a Quantitative Measure of Linguistic Planning Challenges in Parkinson's Disease

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Abstract

Background/Objectives: Pausing is a multifaceted phenomenon relevant to motor and cognitive disorders, particularly Parkinson's Disease (PD). Thus, examining pauses as a metric for linguistic planning and motor speech difficulties in PD patients has gained significant attention. Here we examined the production of silent and filled pauses (indexing difficulties at various linguistic processing levels) during narrative tasks as to investigate the interplay between pausing behavior and informativeness/productivity measures. **Methods**: Individuals' pausing patterns during narratives were analyzed relative to their syntactic context (within and between sentences expressing motor and non-motor related content), in 29 patients in the mild-to-moderate stage of PD, and 29 age-matched healthy speakers. The interaction between communicative metrics (informativeness and productivity), motor symptoms, cognitive capabilities, and pausing behavior was explored as to characterize the mechanisms underlying pauses production and its influence on discourse content. **Results**: PD patients' pausing profile was characterized by an overall reduced number of pauses, longer silent pauses and fewer/shorter filled pauses, particularly before words that extend or specify the semantic content of sentences. Contrary to what was observed in healthy speakers, both the duration of silent pauses and the total number and duration of filled pauses could explain a significant proportion of variance in informativeness measures. Silent pauses duration significantly correlated with measures of lexical access indicating that cognitive processes influence pause production, while motor speech and cognitive challenges may also interact. **Conclusions**: Current results have significant implications for understanding discourse difficulties linked to PD and for formulating intervention strategies to improve communication efficacy.

Keywords: Parkinson's disease; narrative production; discourse analysis; pausing patterns; linguistic planning

1. Introduction

Parkinson's disease (PD) is a neurodegenerative disorder characterized by a wide range of motor and non-motor symptoms related to dysfunctions in the dopaminergic circuit. While motor symptoms are commonly acknowledged, non-motor symptoms encompassing cognitive and speech-language deficits are less studied, even though impairments in effective communication are present in more than 90% of patients [1].

Current research indicates that limited communicative abilities in individuals with PD may arise from a complex interplay involving alterations in speech, language, and cognitive functions [2]. However, the precise relationship between these elements remains unclear [1,3]. The objective and quantitative assessment of communicative skills in spontaneous speech reveals that individuals with PD demonstrate a greater occurrence of grammatical, lexical, and verb tense errors/imprecisions when compared to subjects not affected by the condition [4–7]. Further, significant reductions in productivity measures and informativeness [6,8,9] have been documented, irrespective of cognitive

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deficits and speech-motor impairments. The typical motor dysfunctions observed in PD, such as hypokinesia or akinesia, can also impact communicative effectiveness by causing an increase in the frequency of pauses in spontaneous speech (or alternatively, an accelerated speech rate) [10], which have the potential to affect the amount of information conveyed [11].

An area that has attracted considerable interest is the examination of pauses (i.e., the absence of phonetic gestures or hesitation syllables) as a quantitative measure of linguistic planning challenges in individuals with PD [3,12–14]. Indeed, due to its multi-faceted nature, pausing may be particularly informative in a combined motor and cognitive disorder such as PD [2] as pauses may reflect cognitive mechanisms underlying language production [5] (i.e., difficulties in the early stages of conceptualization and formulation), as well as problems during motor programming [15] and articulation [16–18].

Actually, the production of non-lexical vocalizations [19] (filled pauses) may occur when the speaker is struggling with language formulation, reflecting a reaction to internal cues indicating that the linguistic construction process is not proceeding as planned [12]. Likewise, difficulties in formulating a message may result in silent pauses at unexpected locations or for extended durations, negatively impacting communication [11]. Previous evidence demonstrated that speech pauses are more frequent and longer in PD either before words within an utterance (representing lexical retrieval time [3–5,14,15] particularly concerning all classes of verbs [3]) and between utterances (suggesting a decline in semantic and syntactic planning/processing [3,5,20] and narrative organization [5]). However, although both the intra- and inter-phrasal localization of pauses have been previously considered [3,20], the examination was limited to the production of silent pauses. In contrast, when both silent and filled pauses were contemplated, only the syntactic inter-phrasal level was explored [12], and insights regarding pausing as an indicator of linguistic conceptualization or formulation challenges were exclusively drawn from silent pauses [5,14,15].

Here, as a secondary analysis of narratives produced by patients diagnosed with PD and healthy comparators (HC) [8], pauses were evaluated as a quantitative measure of the linguistic construction challenges occurring during a naturalistic speech task. We indeed intended to assess the degree and nature of discourse planning difficulties (as revealed through individuals' patterns of pausing [5]) and their relation to the previously documented decrease in productivity and informativeness in narratives [8].

Although the issue is debated, since PD patients have been reported to use fewer filled pauses, with an increase in silent pausing [12,21], alternatively showing a significant reduction of the total numbers of pauses compared to healthy speakers [22], we expect differential variations in the total number/duration of filled and silent pauses. Considering the role of basal ganglia in automatic, internally cued behaviors, we anticipate fewer/shorter filled pauses in the connected speech of PD patients [12] since these represent self-reparative mechanisms supporting speech in instances of error occurrence or when cognitive demands are heightened [23,24]. Concerning pause location, we anticipate a greater occurrence of (possibly silent) pauses at the lexical/semantic level (indexing difficulties in accessing semantic representations) particularly before verbs or within utterances conveying action content [3], given the previously reported association between action naming and reduced productivity and informativeness measures in the connected speech of PD patients [8].

2. Materials and Methods

2.1. Participants and Study Procedures

The present is a further analysis of narratives produced by patients diagnosed with PD and HC (see [8]). Participants and assessment procedures for neuropsychological neuropsychiatric symptoms and for discourse analysis are detailed elsewhere [8]. Upon being informed about the study procedures (which were formally approved by the Ethics Committee of Santa Lucia Foundation through a written statement containing a waiver Prot. CE/PROG.905 20-01-21), each participant provided a signed informed consent for participating in the study and for the handling of their

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personal data. Information about data processing (including the secondary analysis herein reported) and about the potential publication of research results was included in the informed consent form.

Briefly, 29 patients with a confirmed PD diagnosis in the mild-to-moderate disease phase under stable antiparkinsonian medications, and 29 age- and gender-matched HC were enrolled in the study. Participants had normal cognitive status (scored > 24 on the Mini-Mental Status Examination [25,26] although differed from HCs for neuropsychological performance), while presented mild/moderate unipolar mood and/or anxiety disorders [27] and apathetic symptomatology [28] (see Table 1 for participants' characteristics).

Table 1. Mean sociodemographic, clinical, psychopathological, cognitive and linguistic characteristics of the studied samples.

Characteristics (Standard Deviation)	*HC (n = 29)*	*PD (n = 29)*	*t or χ2*	*d.f.*	*p*
Age (years/sd)	62,21 (9,43)	63,00 (8,46)	-0,34	56	0,74
Males n (%)	16 (55)	18 (62)	0,28	1	0,59
Educational level (years/sd)	13,17 (3,64)	11,24 (3,85)	1,96	56	**0,05§**
Duration of illness (years/sd)	-	4,02 (2,61)	-	-	-
Modified H&Y score	-	1,83 (0,54)	-	-	-
MDS-UPDRS-III score (sd)	-	14,28 (8,61)	-	-	-
Levodopa equivalents (mg/day-sd)	-	477,58 (259,41)	-	-	-
PPRS (score/sd)	-	6,72 (1,07)	-	-	-
AS tot. (score/sd)	2,31 (2,22)	4,38 (4,79)	-2,24	39,80	**0,03***
HAMA tot. (score/sd)	4,62 (3,76)	6,31 (4,86)	-1,31	56	0,19
BDI tot. (score/sd)	5,10 (4,06)	7,52 (6,12)	-1,68	56	0,09
MMSE (raw score/sd)	29,52 (0,63)	29,10 (1,08)	1,78	45,22	0,08
WCST- PE	0,31 (0,81)	1,97 (3,27)	-2,65	31,39	**0,01***
SWCT- IE-T (sec/sd)	35,86 (9,74)	41,83 (21,85)	-1,34	38,71	0,19
RF-C	32,28 (2,84)	29,07 (5,71)	2,71	41,07	**0,01***
SW-T	43,97(10,15)	37,66 (11,81)	2,18	54,76	**0,03***
Ph-F	40,48(10,23)	34,52 (9,92)	2,25	56	**0,03***
Sem-F	24,34 (4,78)	21,41 (5,99)	2,06	53,38	**0,04***
Ac-N (27 subjects)	-	53,74 (5,08)	-	-	-
Ob-N (27 subjects)	-	56,33 (4,27)	-	-	-

Table 1 - Legend: Ac-N, Action Naming; AS, Apathy Scale; BDI, Beck Depression Inventory; d.f., degree of freedom; HC, healthy controls; Modified H&Y, Hoehn and Yahr scale; HAMA, Hamilton Anxiety Rating Scale; HC, healthy controls; WCST-PE, Wisconsin Card Sorting Test perseverative errors; MMSE, Mini-Mental State Examination; Ob-N, Object Naming; PD, Parkinson Disease patients; Ph-Fon, phonological fluency; PPRS, Parkinson's Psychosis Rating Scale; RF-C, Ray Figure copy; Sem-F, semantic fluency; SW-T; total number of switches in fluency tasks; SWCT- IE-T, Stroop Word-Color Test interference effect time; MDS-UPDRS-III scale, Movement Disorder Society-Sponsored Revision of the Unified Parkinson's Disease Rating Scale Part III motor function. * indicate statistically significant differences. § indicates trend to significance.

Subjects were required to describe a single picture image ("Cookie theft", from the Boston Diagnostic Aphasia Examination [29]) and a cartoon story with six pictures ("Quarrel", from [30]), to elicit natural speech as a proxy for longer narratives [31]. Stimuli were shown using a laptop turned toward the patient, and the examinee asked to describe them as if the examiner did not know the story at all, with no further instructions, nor additional suggestions. Each story-telling was tape-recorded and subsequently transcribed verbatim by trained speech pathologists (SD and FeP) using the signal processing software Praat [32], to guarantee greater precision for the detection of silences, silent micro-pauses (>0,4 s) and hesitations. The speech sample was further manually segmented into utterances according to semantic, grammatical and phonological criteria [33]. To explore whether pausing specifically differed in PD patients during action-related language production [3], verbs were manually identified and classified as action-verbs (describing a motor action or an intentional state) and non-action verbs (auxiliary or linking verbs), and utterances containing action-verbs labeled as action-utterances (AU), while the remaining were considered non-action ones (non-AU) (see [3]). Sentences containing one action verb and one non-action verb were considered AU

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utterances because the content is centered on an action. First and second authors blinded to participants' group, independently analyzed transcripts for utterance segmentation and verb identification/classification. The inter-measurer comparisons revealed a general agreement of over 70%, with inconsistencies being addressed through discussions. The total number and duration of action and non-action utterances were computed (AU-N; AU-t; non-AU-N; non-AU-t).

2.2. Pauses Analysis

In order to identify dysfluencies assumed to reflect cognitive-linguistic, rather than speech motor processes [15], a silent pause was determined as any segment of non-speech longer than 400 msec [3]. Phonological fillers ("mmm"; "eeee"), and hesitations ("ehmm") were counted as non-silent, filled pauses. Repetitions and lexical fillers (i.e., real words) were excluded from the filled pauses total count as these are automatic productions conveying semantic content [12]. The following measures of interest were then derived: the total number and duration of pauses (N-Ptot; T-Ptot) separately computed for silent (SP-N; SP-t) and filled pauses (FP-N; FP-t) and their mean duration (SP-DURMean; FP-DURMean).

Silent and filled pauses were then categorized according to their syntactic environment. Two levels of analysis (intra- and inter-sentence) [15] were considered, since, according to exiting literature, pauses before words represent lexical retrieval time and local lexical-semantic decision making, while pauses between utterances are indicative of difficulties in semantic-syntactic planning and narrative organization at the distal discourse level [34].

At the intra-sentence level, pauses were classified according to their position immediately before a noun, a verb (stratified as action/non-action) or other parts of speech (prepositions, adjectives, etc.) (single word level of analysis [14]). Pauses position within a sentence was also classified relative to typical prosodic boundaries, or atypical locations (grammatical intra-sentence level of analysis [5]). We then considered pauses location according to syntactic boundaries (inter-sentence or between utterances level of analysis [5,15]) and defined whether they marked an independent clausal border (at the end of an independent clause and/or before a coordinated phrase) or a subordinate clausal boundary (before a finite or non-finite subordinate sentence).

The inter-measurer comparisons revealed a pause-by-pause agreement of over 70%, with inconsistencies being addressed through discussions. Then, the number and duration of pauses occurring before a noun (BN-N; BN-t), an action verb (BAV-N; BAV-t), a non-action verb (BnAV-N; BnAV-t), or other parts of speech (Baa-N; Baa-t) were separately computed for action and non-action utterances. At the same intra-sentence level, the number and duration of pauses occurring at typical (within a subordinate: WS-N; WS-t; between a subject and a predicate: BSP-N; BSP-t; in a listing: IL-N; IL-t) and atypical syntactic boundaries (between a pronoun and a verb: PV-N; PV-t, or within a word: WW-N; WW-t) [5,35] were separately calculated for AU and non-AU. Finally, at the inter-sentence level, the number and duration of pauses occurring after an independent finite clause (AI-N; AI-t) or between an independent and a subordinate clause (Bsub-N; Bsub-t) were computed. Table 2 reports a detailed description of pauses categorization.

Table 2. Detailed description of pauses categorization.

			SILENT PAUSES (SP)		**FILLED PAUSES (FP)**	
			Action utterances (AU)	non-Action utterances (non-AU)	Action utterances (AU)	non-Action utterances (non-AU)
INTRA-SENTENCE LEVEL OF ANALYSIS - WITHIN UTTERANCES	**Single word level of analyses**	Before non-action verb	SP-BnAV-AU-N	SP-BnAV-non-AU-N	FP-BnAV-AU-N	FP-BnAV-non-AU-N
			SP-BnAV-AU-t	SP-BnAV-non-AU-t	FP-BnAV-AU-t	FP-BnAV-non-AU-t
		Before action verb	SP-BAV-AU-N	SP-BAV-non-AU-N	FP-BAV-AU-N	FP-BAV-non-AU-N
			SP-BAV-AU-t	SP-BAV-non-AU-t	FP-BAV-AU-t	FP-BAV-non-AU-t
		Before noun	SP-BN-AU-N	SP-BN-non-AU-N	FP-BN-AU-N	FP-BN-non-AU-N
			SP-BN-AU-t	SP-BN-non-AU-t	FP-BN-AU-t	FP-BN-non-AU-t
			SP-Baa-AU-N	SP-Baa-non-AU-N	FP-Baa-AU-N	FP-Baa-non-AU-N

		Before other parts of speech	SP-Baa-AU-t	SP-Baa-non-AU-t	FP-Baa-AU-t	FP-Baa-non-AU-t
	Grammatical level of analyses	Within subordinate	SP-WS-AU-N	SP-WS-non-AU-N	FP-BWS-AU-N	FP-WS-non-AU-N
			SP-WS-AU-t	SP-BWS-non-AU-t	FP-WS-AU-t	FP-WS-non-AU-t
		Between subject and predicate	SP-BSP-AU-N	SP-BSP-non-AU-N	FP-BSP-AU-N	FP-BSP-non-AU-N
			SP-BSP-AU-t	SP-BSP-non-AU-t	FP-BSP-AU-t	FP-BSP-non-AU-t
		In a listing	SP-IL-AU-N	SP-IL-non-AU-N	FP-IL-AU-N	FP-IL-non-AU-N
			SP-IL-AU-t	SP-IL-non-AU-t	FP-IL-AU-t	FP-IL-non-AU-t
		Between pronoun and verb	SP-PV-AU-N	SP-PV-non-AU-N	FP-PV-AU-N	FP-PV-non-AU-N
			SP-PV-AU-t	SP-PV-non-AU-t	FP-PV-AU-t	FP-PV-non-AU-t
		Within word	SP-WW-AU-N	SP-WW-non-AU-N	FP-WW-AU-N	FP-WW-non-AU-N
			SP-WW-AU-t	SP-WW-non-AU-t	FP-WW-AU-t	FP-WW-non-AU-t
INTER-SENTENCE LEVEL OF ANALYSIS-BETWEEN UTTERANCES	Syntactic level of analyses	After independent	SP-AI-AU-N	SP-AI-non-AU-N	FP-AI-AU-N	FP-AI-non-AU-N
			SP-AI-AU-t	SP-AI-non-AU-t	FP-AI-AU-t	FP-AI-non-AU-t
		After independent and before subordinate	SP-BSub-AU-N	SP-BSub-non-AU-N	FP-BSub-AU-N	FP-BSub-non-AU-N
			SP-BSub-AU-t	SP-BSub-non-AU-t	FP-BSub-AU-t	FP-BSub-non-AU-t

Table 2 – Legend: N: number of occurrences; t: duration.

2.3. Narrative Language Outcomes

The current study exclusively considered indices that significantly differentiated patients from HCs (according to a previously performed multi-level discourse analysis [8]). A quantitative textual evaluation focusing on four main levels of discourse structure indeed demonstrated significant reductions in PD patients on measures of productivity (less well-formed words, shorter sentences) and informativeness (fewer conceptual units, less informative elements, lower number of details). However, articulation rate (number of syllables uttered divided by the total duration of the utterance, silent/filled pausing excluded) did not impact the observed reduced productivity and under-informativeness, which were rather explained by variations in linguistic abilities [8]. For the purpose of the present investigation and to control for variability in speaking rate, a new variable was computed as: modified word fluency = words divided by narrative time after subtracting the pausing time (WFmod) [3]. Additional language outcomes included: Narrative Time (NT-sec, considering talking time plus pauses), Total Words Count (TWC) and Mean Length of Utterances (MLU) as measures of productivity. The Percentage of Thematic Selection (%TH-S, the main ideas identified by speakers divided by the total number of the possible information elements), the total number of main concepts (words and verbs) accurately mentioned (CA-EssEA) and the total number of details (words and verbs) accurately stated (CA-DetEA) [36,37] were considered communicative informativeness indices (see Table 3 for language outcomes description).

Table 3. Language outcomes description.

PRODUCTIVITY	
Modified word fluency (WF_{mod})	Words divided by narrative time (NT) after subtracting the pausing time
Total word count (TWC)	The total number of phonologically well-formed words excluding phonological fillers, phonologic errors and nonwords
Mean Length of Utterances (MLU)	The total number of phonologically well-formed words divided by the number of utterances produced
INFORMATIVENESS	
Percentage of thematic selection (% TH-S)	The thematic selection included all the story's main ideas identified by the speaker. This was obtained by dividing the total number of main ideas expressed in each picture description by the total number of possible information elements. The expected number of content units was defined a priori through analysis of control group performance and

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	two basic types of information were identified: target contentive words or thematic units essential to capture the story gist, and additional appropriate content units conveying supplementary, non-essential information
Essential action and elements (CA-EssEA)	The total number of main concepts (words and verbs) accurately mentioned
Actions and elements details (CA-DetEA)	The total number of details (words and verbs) accurately stated

2.4. Statistical Analyses

After having checked distribution normality (Shapiro-Wilk test), several language variables resulted non-normally distributed with considerable within-group variance. They were therefore logarithmically transformed, re-checked for normality and depending on results, general linear models or Mann Whitney U-tests used to analyze group differences on the variables of interest.

Non-parametric bivariate correlational analyses were conducted (separately in the two samples) between productivity and informativeness measures differentiating the groups. Likewise, non-parametric correlation analyses examined the relationship between number and duration of filled/silent pauses and informativeness indices, with attention to potential variations according to pause location (intra- or inter-sentences). Additionally, in the patient group, non-parametric correlation analyses assessed the association between pausing variances and cognitive or motor symptoms. Bonferroni correction was applied to correlational analyses. All analyses were completed using IBM SPSS Statistics version 27.

3. Results

3.1. Productivity Indices and Their Relationship with Informativeness in the Studied Samples

Compared to HC, PD patients significantly produced less phonologically well-formed words (TWC, p=0,01 and p=0,02) and shorter sentences (MLU, p < 0,001) in both narrative tasks, although the number of uttered syllables in the narrative time did not affect the amount of produced words [8]. A multivariate analysis of variance with group membership (HC, PD) as independent variable and the normalized NT-sec and modified WF_{mod} as dependent variables further demonstrated a nearly significant effect of group in both tasks (Wilk's λ = 0,839; $F_{4,53}$ = 2,538; p = 0,051; partial η^2 = 0,161; power=0,679). The univariate group effect was significant for NT-sec and not for WF_{mod}. Between-subjects post-hoc pairwise comparisons revealed a decrease in NT-sec in both narratives among patients with PD, despite a speaking rate comparable to that of HC (see Table 4 for productivity measures and relative statistics).

Table 4. Pausing parameters in both groups and tasks.

	COOKIE THEFT					*QUARREL*				
	HC (29)	**PD (29)**	**F o U**	**p**	**η^2**	**HC (29)**	**PD (29)**	**F o U**	**p**	**η^2**
WF mod	2,91 (0,38)	3,12 (0,73)	1,29	0,261	0,02	2,99 (0,49)	3,10 (0,54)	0,61	0,437	0,01
NT-sec	49,80 (28,17)	32,21 (21,41)	10,14	**0,002***	0,15	53,21 (50,28)	34,79 (20,90)	5,54	**0,022***	0,09
$N\text{-}P_{tot}$	17,62 (12,51)	11,97 (9,33)	6,73	**0,012***	0,11	18,17 (24,09)	10,90 (6,74)	2,40	0,127	0,04
$T\text{-}P_{tot}$	12,91 (9,29)	11,86 (11,23)	1,94	0,169	0,03	12,69 (18,18)	13,21 (14,54)	0,10	0,756	0,002
SP-N	10,86 (5,70)	8,55 (6,91)	4,86	**0,032***	0,08	10,83 (11,16)	7,52 (4,00)	2,51	0,119	0,04
SP-t	8,21 (4,93)	10,03 (10,65)	0,30	0,586	0,005	8,22 (10,09)	11,63 (14,31)	1,76	0,19	0,03
FP-N	6,04 (7,21)	2,24 (2,93)	231,50	**0,003***	-	5,55 (11,48)	1,48 (3,10)	257,00	**0,009***	-
FP-t	4,42 (5,93)	1,45 (2,04)	219,50	**0,002***	-	4,01 (8,75)	0,95 (2,01)	256,00	**0,009***	-
$SP\text{-}DUR_{Mean}$	0,76 (0,28)	1,06 (0,62)	578,00	**0,014***	-	0,69 (0,19)	1,38 (1,01)	751,00	**< 0,001***	-
$FP\text{-}DUR_{Mean}$	0,22 (0,17)	0,11 (0,12)	255,50	**0,01***	-	0,54 (0,32)	0,36 (0,45)	271,00	**0,018***	-

Table 4 - Legend: $FP\text{-}DUR_{Mean}$ - Mean duration of filled pauses (sec); FP-N - Total number of filled pauses; FP-t - Total duration of filled pauses (sec); HC, healthy controls; $N\text{-}P_{tot}$ - Total number of pauses; NT-sec - Narrative Time (talking time plus pauses; sec); PD, Parkinson Disease patients; $SP\text{-}DUR_{Mean}$ - Mean duration of silent pauses (sec); * indicate statistically significant differences.

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A series of non-parametric correlational analyses then explored (separately in the two groups) whether the previously observed reduced informativeness (PD<HC in %TH-S, CA-EssEA and CA-DetEA) [8] was related to the reported decreased productivity in PD. Bonferroni correction was applied as a p-value adjustment by multiplying each p-value for the number of included variables. A significant correlation (surviving to correction) was observable between narrative time and the number of details reported in the HC sample only, while in the PD group, not even uncorrected correlations were observable. Likewise, Bonferroni corrected correlations between the total number of well-formed words, the percentage of main ideas expressed and the total number of correctly stated essential elements and details were discernible in the HC sample, and not in the PD group (where correlations did not survive to correction, $p_{corr}>0{,}05$). Significant (after correction) correlations were also observed between another productivity measure (MLU, expressing proficiency in syntax and grammar), and the percentage of main ideas and details correctly reported for the cartoon story by HC speakers. The significant correlations between MLU and the percentage of main ideas and essential informative elements conveyed by PD patients did not survive to correction for multiple comparisons. Table 5 reports results from the performed correlation analyses.

Table 5. Correlation analyses between productivity measures, pausing parameters and informativeness in the two groups.

						COOKIE THEFT						
	%TH-S				**CA-EssEA**				**CA-DetEA**			
	HC		**PD**		**HC**		**PD**		**HC**		**PD**	
	ρ	**p**	**ρ**	**p**	**ρ**	**p**	**ρ**	**p**	**ρ**	**p**	**ρ**	**p**
NT-sec	0,419	**0,024***	0,231	0,228	0,465	**0,011***	0,01	0,958	0,368	**0,05***	-0,020	0,919
TWC	0,561	**0,002****	0,424	**0,022***	0,515	**0,004****	0,239	0,211	0,353	0,06	0,054	0,781
MLU	0,313	0,098	0,416	**0,025***	0,043	0,826	0,446	**0,015***	-0,103	0,594	0,244	0,202
N-P$_{tot}$	0,139	0,472	0,156	0,418	0,33	0,081	-0,065	0,737	0,352	0,061	-0,093	0,630
FP-N	0,048	0,805	0,234	0,222	0,192	0,317	-0,033	0,863	0,171	0,375	-0,142	0,463
FP-t	0,091	0,638	0,293	0,122	0,172	0,371	0,04	0,838	0,152	0,43	-0,115	0,553
SP-N	0,24	0,21	0,168	0,384	0,415	**0,025***	-0,026	0,892	0,417	**0,024***	-0,062	0,749
SP-DUR$_{Mean}$	-0,379	**0,043***	-0,263	0,168	-0,137	0,478	-0,321	0,09	0,096	0,621	-0,101	0,601
FP-DUR$_{Mean}$	-0,037	0,847	0,254	0,184	0,009	0,963	-0,009	0,962	-0,044	0,822	-0,071	0,716
						QUARREL						
	%TH-S				**CA-EssEA**				**CA-DetEA**			
	HC		**PD**		**HC**		**PD**		**HC**		**PD**	
	ρ	**p**	**ρ**	**p**	**ρ**	**p**	**ρ**	**p**	**ρ**	**p**	**ρ**	**p**
NT-sec	0,442	**0,016***	0,106	0,584	0,172	0,372	-0,015	0,937	0,563	**0,001****	0,108	0,578
TWC	0,659	**0,000****	0,412	**0,026***	0,336	0,075	0,268	0,16	0,691	**0,000****	0,302	0,111
MLU	0,522	**0,004****	0,401	**0,031***	0,383	**0,04***	0,359	0,056	0,549	**0,002****	0,346	0,066
N-P$_{tot}$	-	-	-	-	0,154	0,426	-0,004	0,985	0,384	**0,04***	0,009	0,962
FP-N	-	-	-	-	0,153	0,428	0,064	0,742	0,326	0,085	0,081	0,676
FP-t	-	-	-	-	0,153	0,428	0,049	0,799	0,296	0,12	0,106	0,584
SP-N	-	-	-	-	-	-	-	-	-	-	-	-
SP-DUR$_{Mean}$	-	-	-	-	-0,077	0,693	-0,508	**0,005****	0,098	0,612	-0,162	0,400
FP-DUR$_{Mean}$	-	-	-	-	0,227	0,235	0,064	0,743	0,083	0,667	0,041	0,833

Table 5 – Legend: CA-EssEA - Essential action and elements; CA-DetEA - Actions and elements details; FP-DUR$_{Mean}$ - Mean duration of filled pauses; FP-N - Total number of filled pauses; FP-t - Total duration of filled pauses; HC, healthy controls; MLU – Mean Length of Utterance; N-P$_{tot}$ - Total number of pauses; NT-sec - Narrative Time (talking time plus pauses); PD, Parkinson Disease patients; SP-DUR$_{Mean}$ - Mean duration of silent pauses; TWC – Total word count; %TH-S – Percentage of thematic selection. **Uncorrected significance (correlation surviving after Bonferroni correction); *Uncorrected significance (correlation not surviving after Bonferroni correction).

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3.2. Pausing Parameters and Their Relationship with Informativeness Indices Differentiating the Two Groups

A significant multivariate effect of group (HC, PD) was observed on normalized pausing parameters in both narrative tasks (Wilk's $\lambda = 0{,}719$; $F_{4,53}=5{,}176$; $p<0{,}001$; partial $\eta^2=0{,}281$; power=0,954 and Wilk's $\lambda=0{,}497$; $F_{4,53}=13{,}392$; $p<0{,}001$; partial $\eta^2=0{,}503$; power=1). The univariate effect of the group was significant for the total number of pauses and the total number of silent pauses in the complex picture description only. Between subjects post-hoc pairwise comparisons on estimated marginal means revealed that PD patients produced a lower number of pauses overall, and fewer instances of silent pauses compared to HC. No other significant effect was observable. A Mann Whitney U-test on total number and duration of filled pauses and mean duration of silent and filled pauses (FP-N; FP-t; $SP\text{-}DUR_{Mean}$; $FP\text{-}DUR_{Mean}$) revealed that HC and PD individuals differed for all the considered variables in both narrative tasks. PD patients showed a reduction in both the total number and average duration of filled pauses, whereas the average duration of silent pauses was prolonged in either task. Table 4 shows the pausing parameters in both groups and tasks and relative statistics.

Non-parametric correlational analyses showed significant correlations (not surviving to Bonferroni correction) between the total number of silent pauses and the number of correctly reported essential elements and details in the HC sample only. No significant results (not even at uncorrected p-values) were detectable in the PD sample. Likewise, the significant negative correlation between the mean duration of silent pauses and the percentage of main ideas expressed in the HC sample did not survive to correction for multiple comparisons. The total number of produced pauses significantly correlated (uncorrected) with the number of properly stated details in the HC sample only. Of relevance, the mean duration of silent pauses was negatively related in the PD sample to the number of essential elements correctly conveyed, and such correlation survived to Bonferroni correction. Pauses (and specifically silent ones) contributed to explain the reduced informativeness in referential narratives (26% of the observed variance in the number of essential elements reported). See Table 5 for results from the performed correlational analyses.

3.3. Differences in Pausing Parameters According to Their Location. Association with Informativeness Indices, Neuropsychological Performance and Motor Symptoms

A Mann Whitney U-test on the duration of *within sentences* silent pauses (separately considering AU and non-AU, with occurrences N>0) revealed no significant differences (according to location) in the complex picture description, while the total duration of silent pauses produced in non-AUs (PD>HC), the duration of silent pauses produced before a non-AV within AUs (PD<HC) and the duration of silent pauses before other parts of speech within non-AUs (PD>HC) significantly differed in the cartoon story narrative. The same analysis on *between sentences* silent pauses duration demonstrated that PD patients produced significantly shorter pauses between an independent and a subordinate action clause.

Thus, although the number of non-AU silent pauses was the same in the two groups, PD patients produced longer silent pauses in general, and particularly before variant and invariant parts of speech such as prepositions, adjectives, etc. within sentences expressing non-action related content. Though the correlation between the latter and informativeness indices did not survive to Bonferroni correction ($p_{uncorr}=0{,}014$) the duration of silent pauses preceding linguistic components that elaborate on the sentence's content may elucidate 20% of the variability noted in the quantity of actions and elements that communicate the essence of the cartoon narrative. On the other hand, despite a comparable total duration of silent pauses produced within AUs, these were shorter in the PD patients' sample when occurred before a non-AV and a subordinate action clause. No pauses were observable at unexpected atypical syntactic boundaries in the patients' group.

Table 6 reports the mean duration (in secs) of intra and inter-sentences pauses produced by the two groups and results from the performed analyses.

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Table 6. Intra and inter-sentences pauses produced by the two groups and results from the performed analyses.

	COOKIE THEFT				QUARREL			
	HC (29)	**PD (29)**	**U**	**p**	**HC (29)**	**PD (29)**	**U**	**p**
SP-AU-t	6,25 (3,39)	6,31 (4,69)	402,00	0,77	7,15 (7,64)	7,90 (7,10)	490	0,28
SP-non-AU-t	1,98 (2,41)	3,78 (8,56)	402	0,763	1,08 (3,00)	3,67 (7,75)	558	**0,024***
FP-AU-N	4,86 (6,36)	1,90 (2,61)	292	**0,042***	5,07 (9,94)	1,17 (2,42)	241,5	**0,004***
FP-AU-t	3,47 (5,23)	1,24 (1,86)	285	**0,033***	3,64 (7,48)	0,72 (1,46)	244	**0,005***
FP-non-AU-N	1,21 (1,52)	0,31 (0,66)	250,5	**0,003***	-	-	-	-
FP-non-AU-t	0,97 (1,15)	0,21 (0,45)	242	**0,002***	-	-	-	-
SP Intra-sentences								
SP-BN-AU-t	1,67 (1,12)	2,02 (2,69)	360	0,345	1,91 (2,16)	2,09 (2,56)	416	0,943
SP-BN-non-AU-t	0,57 (1,01)	0,91 (2,47)	380	0,450	0,38 (0,84)	0,65 (1,11)	475	0,292
SP-BAV-AU-t	1,14 (1,19)	1,64 (1,48)	501	0,208	1,28 (1,46)	1,66 (1,45)	488,5	0,286
SP-BnAV-AU-t	0,80 (1,53)	0,45 (0,95)	334	0,128	0,97 (1,75)	0,28 (0,63)	314	**0,047***
SP-BnAV-non-AU-t	0,21 (0,53)	0,78 (1,66)	475	0,246	0,14 (0,38)	0,80 (3,07)	451,5	0,464
SP-Baa-AU-t	2,84 (2,00)	2,11 (1,83)	319	0,114	2,94 (3,71)	3,21 (6,98)	316,5	0,104
SP-Baa-non-AU-t	0,70 (1,19)	1,91 (6,08)	395	0,661	0,54 (2,17)	1,99 (4,62)	541	**0,025***
SP-WS-AU-t	1,75 (1,83)	1,58 (1,89)	377,5	0,497	1,12 (1,56)	0,93 (1,28)	372	0,436
SP-BSP-AU-t	0,33 (0,55)	0,36 (0,57)	427	0,906	0,21 (0,41)	0,35 (0,98)	365	0,237
SP-IL-AU-t	-	-	-	-	0,41 (1,15)	1,43 (3,24)	448	0,532
FP Intra-sentences								
FP-BnAV-AU-N	0,83 (1,44)	0,03 (0,19)	272,5	**0,001***	0,90 (2,23)	0,03 (0,19)	288,5	**0,003***
FP-BnAV-AU-t	0,62 (1,08)	0,02 (0,10)	272	**0,001***	0,60 (1,44)	0,03 (0,14)	289	**0,003***
FP-Baa-AU-N	1,48 (2,43)	0,41 (0,91)	302	**0,032***	2,14 (4,76)	0,24 (0,69)	287	**0,010***
FP-Baa-AU-t	1,22 (2,31)	0,31 (0,66)	305	**0,037***	1,57 (3,65)	0,09 (0,24)	278	**0,006***
FP-WS-AU-N	1,59 (2,26)	0,41 (0,78)	286	**0,018***	1,28 (2,60)	0,21 (0,77)	313,5	**0,023***
FP-WS-AU-t	1,05 (1,68)	0,28 (0,62)	292,5	**0,026***	0,97 (2,24)	0,12 (0,46)	313	**0,022***
SP Inter-sentences								
SP-AI-AU-t	2,18 (1,53)	2,22 (2,95)	354	0,301	3,18 (3,02)	5,29 (4,98)	530,5	0,087
SP-BSub-AU-t	0,47 (0,73)	0,59 (1,14)	405	0,787	0,39 (0,51)	0,19 (0,64)	298	**0,018***
SP-AI-non-AU-t	0,80 (1,33)	1,84 (3,96)	510,5	0,137	0,61 (1,46)	1,61 (3,47)	455	0,539

Table 6 – Legend: AI – after independent; AU – action utterance; Baa – before other parts of speech; BAV – before action verb; BN – before noun; BnAV – before non-action verb; BSP – between subject and predicate; Bsub – before subordinate; FP – filled pause; HC, healthy controls; IL – in a listing; non-AU – non action utterance; N – total number of pauses; PD, Parkinson Disease patients; SP – silent pause; T – total duration of pauses; WS – within subordinate; * indicate statistically significant differences.

Separate non-parametric correlation analyses between silent pauses and the total number of crucial elements and accurately recounted details in the cartoon story showed no significant correlations (not even at an uncorrected level) in the HC group, while a negative correlation (approaching significance after correction) was reported in PD patients between the duration of silent pauses produced before other parts of speech and the number of essential elements and actions correctly reported. Table 7 reports results from the performed correlation analyses.

Table 7. - Correlation analyses between intra and inter-sentence pauses and informativeness measures differentiating the two groups.

	COOKIE THEFT											
	%TH-S				CA-EssEA				CA-DetEA			
	HC		PD		HC		PD		HC		PD	
	ρ	p	ρ	p	ρ	p	ρ	p	ρ	p	ρ	p
FP-AU-N	0,14	0,467	0,28	0,141	0,216	0,261	0,006	0,975	0,154	0,424	-0,107	0,581
FP-AU-t	0,14	0,468	0,34	0,071	0,198	0,304	0,063	0,747	0,133	0,493	-0,076	0,694
FP-non-AU-N	-0,181	0,349	0,041	0,832	-0,03	0,877	-0,077	0,693	0,146	0,449	-0,03	0,877
FP-non-AU-t	-0,118	0,541	0,027	0,888	-0,037	0,847	-0,083	0,668	0,11	0,569	-0,047	0,809
FP-BnAV-AU-N	0,276	0,148	0,296	0,119	0,191	0,322	0,228	0,235	0,209	0,276	-0,025	0,899
FP-BnAV-AU-t	0,301	0,113	0,296	0,119	0,206	0,283	0,228	0,235	0,177	0,358	-0,025	0,899
FP-Baa-AU-N	0,062	0,749	0,608	**<0,001****	0,057	0,77	0,336	0,075	0,061	0,755	0,189	0,326
FP-Baa-AU-t	0,064	0,741	0,613	**<0,001****	0,018	0,925	0,348	0,065	0,074	0,702	0,184	0,339

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FP-WS-AU-N	-0,018	0,926	0,436	**0,018***	0,156	0,419	0,232	0,226	0,358	0,057	0,11	0,572
FP-WS-AU-t	-0,041	0,834	0,506	**0,005***	0,143	0,459	0,283	0,137	0,279	0,142	0,149	0,441

	QUARREL							
	CA-EssEA				**CA-DetEA**			
	HC		**PD**		**HC**		**PD**	
	ϱ	**p**	**ϱ**	**p**	**ϱ**	**p**	**ϱ**	**p**
FP-AU-N	0,242	0,206	0,234	0,221	0,27	0,157	0,11	0,568
FP-AU-t	0,21	0,275	0,234	0,221	0,218	0,257	0,134	0,49
FP-BnAV-AU-N	0,093	0,632	-0,257	0,178	0,282	0,138	0,035	0,859
FP-BnAV-AU-t	0,073	0,707	-0,257	0,178	0,281	0,14	0,035	0,859
FP-Baa-AU-N	0,27	0,156	0,162	0,401	0,15	0,438	0,007	0,97
FP-Baa-AU-t	0,26	0,174	0,152	0,431	0,137	0,480	-0,037	0,848
FP-WS-AU-N	0,1	0,607	0,134	0,49	0,449	**0,014***	-0,031	0,873
FP-WS-AU-t	0,1	0,607	0,127	0,511	0,450	**0,014***	-0,022	0,911
SP-Baa-non-AU-t	0,255	0,182	-0,450	**0,014***	-0,088	0,651	-0,061	0,754
SP-BnAV-AU-t	-0,055	0,777	-0,263	0,167	0,227	0,236	0,321	0,09
SP-Bsub-AU-t	-0,017	0,930	0,116	0,547	0,235	0,220	0,020	0,916

Table 7 - AU – action utterance; Baa – before other parts of speech; BAV – before action verb; BN – before noun; BnAV – before non-action verb; Bsub – before subordinate; CA-EssEA - Essential action and elements; CA-DetEA - Actions and elements details; FP – filled pause; HC, healthy controls; non-AU – non action utterance; N – total number of pauses; PD, Parkinson Disease patients; SP – silent pause; T – total duration of pauses; WS – within subordinate; %TH-S – Percentage of thematic selection; **Uncorrected significance (correlation surviving after Bonferroni correction); *Uncorrected significance (correlation not surviving after Bonferroni correction).

Finally, in order to explore the potential association between language pausing, cognitive abilities and motor symptom in the PD sample, non-parametric correlations were run considering SP-DUR$_{Mean}$ in the complex picture description, SP-Baa-non-AU-t in the cartoon story narrative (the pausing parameters explaining variance in informativeness measures), raw scores in neuropsychological tests indexing executive functioning, the patients' semantic-lexical competence and the severity of motor symptoms (see [8] for cognitive assessment procedures). A significant negative correlation (surviving to correction for multiple comparisons) was observable between pauses before other parts of speech and action naming performance, while the negative correlation between silent pauses mean duration and object naming capacity did not survive to correction. Likewise, the positive correlation between the former and severity of motor symptoms was only marginally significant after correction. Table 8 includes results from the correlation analyses between pausing parameters, cognitive abilities and motor symptoms.

Table 8. correlation analyses between pausing parameters differentiating the two groups, cognitive abilities and motor symptoms in PD patients.

	SWCT- IE-T		*SW-T*		*CL-T*		*WCST- PE*		*Ac-N*		*Ob-N*		*MDS-UPDRS-III*	
	ϱ	**p**	**ϱ**	**p**	**ϱ**	**p**	**ϱ**	**p**	**ϱ**	**p**	**ϱ**	**p**	**ϱ**	**p**
Cookie Theft														
FP-Baa-AU-N	0,03	0,88	0,21	0,27	0,21	0,28	-0,17	0,37	0,10	0,63	0,28	0,16	-0,13	0,52
FP-Baa-AU-t	0,02	0,93	0,22	0,25	0,22	0,26	-0,19	0,32	0,10	0,62	0,31	0,12	-0,13	0,52
FP-WS-AU-t	0,03	0,87	-0,01	0,96	-0,01	0,98	-0,10	0,62	0,05	0,79	0,03	0,87	0,24	0,21
Quarrel														
SP-DURMean	0,20	0,29	-0,22	0,25	-0,24	0,22	0,17	0,37	-0,30	0,13	-0,48	**0,01***	0,48	**0,008***
SP-Baa-non-AU-t	0,52	**0,004***	-0,52	**0,004***	-0,54	**0,003***	0,25	0,19	-0,54	**0,004****	-0,35	0,08	0,03	0,88

Table 8 – Ac-N, Action Naming; AU – action utterance; Baa – before other parts of speech; CL-T -Clustering total score; FP – filled pause; MDS-UPDRS-III scale, Movement Disorder Society-Sponsored Revision of the Unified Parkinson's Disease Rating Scale Part III motor function; N – total number of pauses; non-AU – non-action utterance; Ob-N, Object Naming; SP – silent pause; SP-DURMean - Mean duration of silent pauses; SW-T; total number of switches in fluency tasks; SWCT- IE-T, Stroop Word-Color Test interference effect time; t – total duration of pauses; WCST-PE, Wisconsin Card Sorting Test perseverative errors; WS – within subordinate;.**Uncorrected significance (correlation surviving after Bonferroni correction); *Uncorrected significance (correlation not surviving after Bonferroni correction).

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As ancillary analyses, separate non-parametric correlations between filled pausing parameters significantly differentiating the two groups (see Table 6) and informativeness indices demonstrated a significant (Bonferroni corrected) correlation in the PD group, between the number and duration of filled pauses occurring before other parts of speech in AU sentences and the proportion of thematic elements produced in the complex picture description (explained variance 37 and 38% respectively). Significant correlations between % TH-S and the number and duration of within subordinate filled pauses did not survive to correction. No significant correlations (not even uncorrected) were observable between the same filled pausing and informativeness parameters in the HC group. However, significant correlations (not surviving to correction) were discernable between the number and duration of within subordinate filled pauses in AU sentences and the number of details correctly reported in the cartoon story by HC. Results are included in Table 7.

The potential associations between filled pausing parameters contributing to explain informativeness variance in the PD group and neuropsychological performance in executive functioning and language measures and the severity of motor symptoms were also tested. No significant correlation (not even at an uncorrected level of significance) was observable. Results are reported in Table 8.

4. Discussion

Here we intended to explore whether pauses during spoken narratives could be regarded as valid measures of PD patients' difficulties in language formulation and production [3,5]. We assumed that connected speech in the disorder would be characterized by a specific pausing pattern and separately explored pauses indexing difficulties in lexical retrieval and semantic choices (i.e., those produced within sentences) or syntactic planning/discourse organization (i.e., occurring between utterances). The differential occurrence of pauses in action versus non-action sentences was also examined considering verb use impairment in PD patients [3,38–40] as well as the documented decline in the spontaneous generation of action verbs as the symptoms of the disease advance [41]. Correlational analyses assessed whether local (within utterances) or global (between) linguistic decision-making deficits accounted for reduced discourse fluency and informativeness [8]. The correlation between pausing parameters that differentiated groups and PD patients' cognitive and motor dysfunctions was evaluated to determine their influence on pausing behavior [3,9,14].

We found that while in healthy comparators measures of linguistic productivity could explain a significant proportion of observed variance in informativeness, PD patients were less informative, irrespective of their productivity. Their narrative time was shorter, despite a comparable speaking rate, they produced less words and more concise sentences, though these variables were not related to efficiency in spoken discourse. Moving forward, we found that compared to healthy speakers, PD patients produced fewer pauses (either silent and filled) while the average duration of silences was longer, and this variable could explain 26% of observed variance in the number of correctly stated essential elements and actions in narratives. Contrariwise, pauses produced by healthy comparators were not significantly related to informativeness indices. This would suggest that extended silent pauses [12] may reflect inefficiencies in language formulation, potentially linked to challenges in cognitive processes such as word retrieval, monitoring and planning [42]. At variance with previous findings [22] the reduced number of pauses was not consequent to accelerated speech rate. Extended silent pausing was however coupled with fewer filled pauses confirming that automatic responses to speech difficulties (i.e., the production of non-lexical vocalizations [19]) are impaired in PD patients [12]. Indeed, it has been demonstrated that filled pausing, providing temporal resources for rectifying errors and inconsistencies [19] is reduced in individuals with PD due to challenges in utilizing internal cues for behavioral modulation [24].

Considering pauses location (as an index of specific language formulation difficulties [5]), patients exhibited shorter silent and filled pauses in action-related utterances, especially before non-motor action verbs. In contrast, non-action utterances, prevalent in the patient group, contained longer silent pauses before elements other than verbs and nouns, while filled pauses were shorter

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before such elements in action utterances. This observation would suggest that silent pauses marked a potential impairment of the mechanism involved in constructing a syntactically well-formed sentence [4] since their duration was extended before words describing, defining or changing the information given by a noun or a verb (i.e., adjectives, determinants, adverbs, prepositions, etc.). The aggregated duration of silent pauses before these linguistic elements accounted for 20% of the variance in essential elements reported, indicating decreased informativeness with increased duration. Conversely, the number and duration of filled pauses before elements other than verbs and nouns positively correlated with the thematic elements produced, explaining over one-third of variance, suggesting that PD patients benefit from the allocation of additional time for speech planning and execution, enhancing informativeness. Thus, while silent pausing marked the disruption of cognitive mechanisms for sentence planning/construction, filled pauses represented self-reparative behaviors to profitably overcome the experienced challenges in linguistic conceptualization or formulation [43].

We might therefore suppose that PD patients' pausing profile (longer silent pauses and fewer/shorter filled pauses) denotes difficulties in conceptualization and self-repair during speech production [43] contributing to explain the observed reduced informativeness of narratives. This hypothesis is reinforced by the only previous study concurrently exploring the production of silent and filled pauses in the disorder [12] reporting a greater duration for silent pauses and fewer filled ones. Authors suggested that changes in PD patients' speech and communication may arise from both difficulties in speech production, and alterations in the capacity to automatically adapt in response to these challenges. Likewise, more frequent and longer silent pausing within utterances was interpreted as a difficulty in planning and preparing for sentences [5], which correlated with cognitive functioning [3], also potentially reflecting delays in the fluent transition between words (a form of "speech freezing" [15,44]). Actually, although produced in the context of non-AU, longer silent pauses positively correlated with action verb naming ability. However, confrontational naming tests may not reflect the complexities of continuous speech [14], and contrary to earlier studies [3], silent pauses were not more frequent before action verbs. Additionally, a marginally significant positive correlation was found between silent pause duration and motor symptom severity, indicating a potential delay in motor program transitions may influence pausing behavior [15]. Nevertheless, patients did not exhibit pauses at inappropriate linguistic boundaries, a behavior previously linked to motor speech difficulties exacerbated by syntactic processing impairments [45], while the absence of differences in speech motor function between PD patients and healthy comparators casts doubt on the theory that motor impairments solely influence pausing behavior. These observations would impede the possibility to clarify the cognitive or motor nature of the reported pausing behavior suggesting that a combination of motor impairments in speech production and cognitive/linguistic difficulties [45] may more adequately account for the observed pausing profile in PD and for the resultant decrease in productivity and informativeness. However, interventions to enhance motor system support for speech did not yield significant improvements in semantic, syntactic, or informative aspects of spoken discourse [46]. Concurrently, improvements in motor function after an aerobic training led to enhanced sentence completeness in picture description tasks, without notable changes in fluency or grammaticality [47]. This would suggest that the here observed differences in pausing behavior and the reduced informativeness in PD should be specifically targeted through rehabilitative interventions aimed at sustaining the later stages of utterance planning. For example, since extended pausing right before meaning-expanding elements suggests syntactical difficulties in PD patients' narratives (which were less detailed and informative), language interventions for expanding the repertoire of grammatical structure of sentences [48] or treatments like the Verb Network Strengthening (VNeST) [49] may be more suitable to augment informativeness in the disorder.

5. Conclusions

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In sum, to our knowledge, this is the first study quantitatively examining the production of pauses indexing difficulties at various tiers of linguistic processing (i.e., both silent and filled pauses), while also considering their syntactic contexts (within and across sentences), as well as the possible implications for discourse informativeness. By characterizing the pausing profile of PD patients during an ecologically valid measure of expressive language we were able to demonstrate that difficulties in linguistic planning, and particularly in accessing lexical items that extend or specify the semantic content of sentences, adversely affect patients' ability to efficaciously transmit relevant information. Concomitantly, in instances where self-repair mechanisms are employed (such as the production of non-lexical vocalizations and hesitations), a notable increase in the number of main ideas conveyed was evident, thereby suggesting that the allocation of additional temporal resources for the planning and formulation of speech may represent a viable strategy for enhancing PD patients' informativeness. Specific interventions aimed at improving self-repair by increasing self-monitoring (for example through parsing of inner or overt speech) [50] and the production of editing terms or phrases (to maintain the conversational turn, thereby constraining a scaffolding intervention from the interlocutor) [51] should increase the probability to produce a well-formed repair.

Although we think that the present findings bear important implications for both the comprehension of discourse challenges associated with the disorder and the development of intervention strategies for improving functional communication, it can be argued that the generalizability of results is constrained by the relatively small sample size. However, post-hoc evaluation indicated a low probability of erroneously concluding that silent pause duration significantly influenced informativeness (0.13, Power=0.87), while the power for the relationship between silent pauses before words other than nouns and verbs and informativeness was below the optimal threshold (0.36, Power=0.74), slightly diminishing confidence in the findings.

Nonetheless, consistent with previous conclusions [4], we suggested that difficulties in constructing detailed compound sentences, characterized by prolonged within utterances silent pauses, may account for the reduced conveyance of essential narrative elements. Indeed, quantitative measures of the specular mechanism (the production of longer filled pauses to overcome the experienced challenge) were related to patients' informativeness and the achieved statistical power (0.98) supports our hypothesis.

Future research will further characterize the relationship between location-specific measures of pausing and linguistic/cognitive abilities as to develop useful quantitative markers of cognitive challenges (and their progression along the disease course) in Parkinson's disease.

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Informed Consent Statement: Upon being informed about the study procedures (which were formally approved by the Ethics Committee of Santa Lucia Foundation through a written statement containing a waiver Prot. CE/PROG.905 20-01-21), each participant provided a signed informed consent for participating in the study and for the handling of their personal data. Information about data processing (including the secondary analysis herein reported) and about the potential publication of research results was included in the informed consent form.

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