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Narrative discourse production in Parkinson's disease: Decoupling the role of cognitive-linguistic and motor speech changes

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A R T I C L E I N F O

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A B S T R A C T

Introduction: the interplay between neuropsychological and communicative abilities in Parkinson's disease (PD) has been relatively overlooked, and it is not entirely understood which difficulties are consequent to impaired motor control, and which have a linguistic/cognitive basis. Here, we examined narrative discourse in PD using a multi-level analysis procedure considering sentence-level (productivity, lexical-grammatical processing) and discourse-level processes (narrative organization, informativeness), and partialling out patients' motor speech impairments. The interaction between cognitive (i.e. linguistic and executive) and communication abilities was also investigated.
Methods: Twenty-nine PD subjects in the mild stage of the disease were compared to 29 matched healthy comparators (HC) on quantitative measures of narrative discourse derived from two picture description tasks. Multivariate (considering articulation rate and educational attainment as covariates) and univariate (with group membership as independent variable) analyses of variance were conducted on separate linguistic domains. The contribution of executive/linguistic abilities to PD's narrative performance was explored by multiple regression analyses on narrative measures significantly differentiating patients from HC.
Results: significant reductions in patients were observed on measures of productivity (less well-formed words, shorter sentences) and informativeness (fewer conceptual units, less informative elements, lower number of details) and these alterations were explained by variations in linguistic abilities (action and object naming) rather than executive abilities. Articulation rate and educational attainment did not impact the observed reduced productivity and under-informativeness.
Conclusion: referential narrative discourse is altered in PD, regardless of motor impairments in speech production. The observed reductions in productivity/informativeness aspects of narratives were related to naming abilities and in particular to verbs processing, consistently with the neurocognitive model of motor language coupling. Since narratives are amenable to recurrent and automated analysis for the identification of linguistic patterns potentially anticipating the development of PD and the onset of cognitive deterioration, discourse abilities should be quantitatively and repeatedly profiled in the disorder.

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1. Introduction

Patients with Parkinson's disease (PD) suffer from a wide range of motor and non-motor symptoms. Impairments in effective communication are present in more than 90% of patients [1] and may have both motor and cognitive influences [2]. Slowness and rigidity of the vocal apparatus lead to motor speech changes including variations in articulation rate. Alterations of verbal fluency, with hesitations and pauses, and a variable number of syllables or phonemes produced in the unit of time, are frequent as well [3]. The common observed characteristics of language production in the disorder also comprise lexical retrieval difficulties, especially for action words, reduced information content, impaired grammaticality, and impoverished syntactic complexity (see ref. [2,3] for a review). Evidence additionally suggests that language use (and specifically the ability to use linguistic devices to join sentences together [4] and to communicate the substance of a message [5]) is impaired in PD, independently from motor speech changes [4] and cognitive decline [5]. The ensuing deterioration of language performance seems to be related to increased atrophy in linguistic brain regions as the disease progresses, being not exclusively a consequence of worsening motor symptoms [5].

Likewise, the hallmark features of the disorder, i.e. executive dysfunctions in inhibition and set shifting processes [6,7] may influence PD's communicative abilities, as these skills contribute to successful word retrieval [8] and to information sequencing and discourse structuring [9].

However, contrasting evidence exists [10–13] and it is not entirely understood which communicative difficulties are consequent to impaired motor control, and which have a linguistic or cognitive basis, as the interplay between neuropsychological and communicative disabilities in PD has been relatively overlooked [3,5,14,15].

Given the current evidence suggesting an interaction between speech, language and cognitive changes in PD, a comprehensive evaluation of potential communication challenges faced by patients is warranted [1]. Due to limitations of standard speech assessments evaluating communication deficits in the disorder [2], the use of objective and quantitative measures of spontaneous speech and narrative discourse has been advocated to provide a more detailed and sensitive evaluation of communicative abilities in PD [16]. Specifically, discourse analysis is a method to characterize language performance in a range of neurological diseases [17]. When applied to narrative discourse samples, which are assumed to reflect typical speech, it allows researchers to observe complex cognitive/linguistic behaviors during a communicative act, evaluating the speaker's ability in language use and information structuring [4, 18,19].

Since quantitative measures are derived, correlational research can be undertaken to investigate the potential contribution of cognitive processes -as inferred from neuropsychological assessment metrics- to language processing within the context of natural speech, so as to identify the underlying mechanisms of communicative difficulties in PD.

Indeed, current models of narrative production assume the interplay between a linguistic and an executive resource component [9] with the former involved in structuring the sentence level of information, and the latter contributing to organize the discourse level of narratives [17]. Considering the prevalence of executive deficits in PD, and the cognitive input necessary for the planning, initiation, and maintenance of narrative discourse, changes in communication abilities and specifically, in efficiently conveying information, are expected in the disorder. Since the production of speech is a complex task integrating motor and cognitive processing in real-time, here we aimed at: a) analyzing the referential narrative discourse in subjects diagnosed with PD using a multi-level discourse analysis [17, 20] thus considering sentence-level (productivity, lexical and grammatical processing) and discourse-level processing skills (narrative organization and informativeness) partialling out the motor speech changes observed in the disorder; b) investigating the interplay between cognitive (i.e. linguistic and executive) variations and discourse abilities in PD, also c) exploring -through a linear regression analysis-, which cognitive metric could better predict the discourse measure(s) potentially differentiating PD patients from neurologically healthy controls.

In accordance with recent psycholinguistic theories stating that supervisory cognitive capacities are integral to language processing and production [21,22] we expected to observe a significant contribution of higher level (i.e. cognitive and linguistic) processes to patients' narratives. Specifically, a significant relationship between discursive metrics (derived from the multi-level discourse analysis) and executive abilities (as indexed by measures of response inhibition and set-switching capacities) was anticipated.

An improved understanding of the language production abilities of PD patients and the possible correlation with linguistic/executive abilities has the potentiality to enhance future interventions. Indeed, fluctuations in communicative efficiency are observable long before frank neuropsychological deficits are apparent [23] and new therapeutic approaches incorporating cognitive aspects of discourse abilities may improve outcomes on functional communication [2]. As cognitive-language function has far-reaching effects on individual and family quality of life, improvements in communication abilities will help in achieving and maintaining optimal psychosocial adjustment and integration [1]. Additionally, given that narrative discourse abilities evolve as PD progresses, metrics derived from discourse multi-level analysis and speech temporal acoustic parameters could be used as a proxy of disease and cognitive status [2,13,24,25].

2. Materials and methods

2.1. Participants

Thirty-five consecutive subjects diagnosed with PD, according to international criteria [26,27]] in the mild-to-moderate disease phase (modified Hoehn and Yahr scale $\leq$3) [28], were selected for inclusion. Subjects were enrolled at the Movement Disorder Outpatient Service of IRCCS Santa Lucia Foundation between January 2020 and January 2021 and regularly followed up; clinical diagnosis of PD was confirmed along a period of 36-months from symptom onset. Age- and gender-matched healthy comparators (HC) were recruited through spread of mouth and local advertisement in the same geographical area. Common inclusion criteria for both groups were: (1) age between 45 and 80 years; and (2) vision and hearing sufficient for compliance with testing procedures. PD patients were included if their spontaneous speech was normal or only mildly impaired (score ≤2 in the Movement Disorder Society-Sponsored Revision of the Unified Parkinson's Disease Rating Scale -MDS-UPDRS- scale [29], Part III, section 3.1).

Exclusion criteria for all subjects were: (1) diagnosis of Major Neurocognitive Disorder according to DSM-5 criteria [30], and a Mini Mental State Examination (MMSE) score <24 [31,32]; (2) known or suspected history of alcoholism, drug dependence or abuse, other neurological disorders, head trauma, personality disorders and present/past major mental illness (apart from mild/moderate unipolar mood and/or anxiety disorders) [33]; (3) major not stabilized medical illnesses; (4) vascular lesions, brain tumors, significant cortical and subcortical atrophy evidenced by a structural magnetic resonance screening (see Ref. [34] for a more exhaustive description of exclusion criteria). By applying exclusion criteria, the PD sample was reduced to a total of 29 patients (3 had evidence of cerebro-vascular disease, 2 were diagnosed with major depression, 1 had a severe visual impairment).

All patients were under stable dopaminergic drugs for at least 2 months before enrollment and examined in ON-state. Dopamine replacement therapy was calculated as daily levodopa equivalents (LED) for each patient based on theoretical equivalence to levodopa [35].

Sociodemographic characteristics, clinical features, neuropsychological/neuropsychiatric assessment scores for both groups and dopamine replacement therapy dosages for the PD group are summarized in Table 1.

2.2. Ethics statement

The study was approved (by a written statement containing a waiver Prot. CE/PROG.905 20-01-21) and under-taken in accordance with the guidelines of the Santa Lucia Foundation Ethics Committee. All participants gave their written informed consent for research after they had received a complete explanation of the study procedures. Information about the potential publication of research results was included in the form, and a signed consent to the processing of personal data obtained from all participants.

2.3. Cognitive assessment

After having been screened for global cognitive impairment [31], all study subjects underwent a comprehensive neuropsychological evaluation [36] performed by trained neuropsychologists (FeP e FaP). As to explore the executive resources component of narrative abilities, classical tests of executive functioning were administered including the Modified Wisconsin Card Sorting Test short form (WCST) and the short version of the Stroop Word-Color Test (SWCT); response inhibition difficulties were inferred from the number of perseverative errors in the Modified WCST (WCST-PE) and from the time interference effect in the Stroop test (SWCT-IE-T). Visuo-constructive abilities were evaluated through the Rey-Osterrieth Complex Figure test (RF-C, copy and delayed recall). The

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 $\chi 2$	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 (raw score/sd)	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 (raw score/sd)	32,28 (2,84)	29,07 (5,71)	2,71	41,07	**0,01**
SW-T (total number/sd)	43,97(10,15)	37,66 (11,81)	2,18	54,76	**0,03**
Ph-F (raw score/sd)	40,48(10,23)	34,52 (9,92)	2,25	56	**0,03**
Sem-F (raw score/sd)	24,34 (4,78)	21,41 (5,99)	2,06	53,38	**0,04**
Ac-N (27 subjects, raw score/sd)	–	53,74 (5,08)	–	–	–
Ob-N (27 subjects, raw score/sd)	–	56,33 (4,27)	–	–	–

Legend: Ac-N, Action Naming; AS, Apathy Scale; BDI, Beck Depression Inventory; d.f., degree of freedom; HAMA, Hamilton Anxiety Rating Scale; HC, Healthy Comparators; MDS-UPDRS-III scale, Movement Disorder Society-Sponsored Revision of the Unified Parkinson's Disease Rating Scale Part III motor function; MMSE, Mini-Mental State Examination; Modified H&Y, Hoehn and Yahr scale; Ob-N, Object Naming; PD, Parkinson Disease patients; Ph-F, 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; WCST-PE, Wisconsin Card Sorting Test perseverative errors. Bold values indicate statistically significant differences. [§] indicates trend to significance.

linguistic component underlying narrative production was assessed evaluating the subjects' semantic-lexical competence using an object and action naming sub-test (Ac-N, Ob-N). The Controlled Word Fluency Test from the Mental Deterioration Battery (Ph-F) [36] and the Semantic Fluency test (Sem-F) were used to assess the phonological and semantic processes central to speech production and the executive processes implied in word search and switching between subcategories (SW) [8].

2.4. Neurological and neuropsychiatric assessment

Demographic and neurological features were collected at enrolment by trained neurologists (CP and AB) with expertise in movement disorders. Disease stage was measured by the modified Hoehn and Yahr scale (H&Y) [28], and the severity of motor symptoms by the MDS-UPDRS scale, Part III [29]. All subjects underwent a detailed neuropsychiatric evaluation. Apathy was diagnosed according to the adapted Marin's criteria [37]. Severity of anxiety symptoms was quantified by the Hamilton Anxiety Rating Scale (HAMA). Severity of depressive symptoms was investigated by the Beck Depression Inventory (BDI). Apathy severity was quantified through the Apathy Scale (AS). The Parkinson's Psychosis Rating Scale (PPRS) was used to assess the severity of psychotic symptoms in the PD group. Clinical interviews and mental disorder diagnoses were made by a senior psychiatrist (GS).

2.5. Assessment of narrative abilities

2.5.1. Speech transcription, segmentation, temporal acoustic parameters

Narrative production was elicited using a single picture image ("Cookie theft", from the Boston Diagnostic Aphasia Examination) and a cartoon story with six pictures ("Quarrel", from Ref. [38]) previously used to analyze textual competence and discourse information content.

Stimulus complexity varied between the two tasks: in the case of the single picture ("Cookie theft") many specific items had to be described, while for the filmstrip narrative ("Quarrel"), the creation of a story was dependent upon the speaker's understanding of the sequential elements of story grammar. In order to avoid any contextual biases in patients' production due to referent sharing (such as the use of demonstrative pronouns instead of precise nouns), 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. No further instruction nor additional suggestions were given. Each story-telling was tape-recorded and subsequently transcribed by trained speech pathologists (SD and FeP) using the signal

Table 2
Linguistic variables considered in the quantitative discourse analysis.

PRODUCTIVITY	
Total words count (TWC)	The total number of phonologically well-formed words excluding phonological fillers, phonologic errors and non-words
Word Fluency (WF)	All phonologically well-formed words divided for narratives time (s)
Mean Length of Utterances (MLU)	The total number of phonologically well-formed words divided by the number of utterances produced
LEXICAL-GRAMMATICAL PROCESSING	
Percentage of paragrammatic errors % (PAR)	The percentage of words classified as paragrammatic errors (number of paragrammatism divided for total word count)
Number of omissions of morphosyntactic information MOR-OM	Number of omissions of morphosyntactic information. An omission was counted whenever the argumental structure of a given word -e.g. the agent, the theme or the goal of an action- was not complete
Percentage of phonological errors % PH-E	Percentage of phonological/phonetic errors (such as false starts, words incorrectly spelled by adding, substituting or deleting a given phoneme or a phonetic cluster and neologisms)
Proportion of complex sentences % CX-S	Number of sentences containing an independent clause and one or more dependent clauses on the total number of complete sentences produced
NARRATIVE ORGANIZATION	
Percentage of local coherence errors LCOH-E	The percentage of utterances that were not accurately connected because they presented local coherence errors (missing or incorrect use of pronouns or referents, abrupt interruptions of utterances hindering the information flow, etc.)
Percentage of global coherence errors GCOH-E	The percentage of utterances violating global coherence rules was calculated considering the number of utterances either deviating from the story gist, or not providing any new information. These included: tangential utterances (supplying information irrelevant respective to the task), conceptually incongruent utterances (describing elements not depicted in the stimulus), propositional repetitions (containing ideas already expressed) and filler utterances (sentences not purposeful, neither containing formal meaning and usually expressed as pauses).
INFORMATIVENESS	
Lexical informativeness LI	Lexical informativeness was calculated considering words not only phonologically well-formed, but also appropriate from a grammatical and pragmatic point of view (thus excluding words classified as paraphasias, fillers, paragrammatisms or included in tangential utterances)
Percentage of thematic selection % TH-S	The thematic selection included all the main ideas of the story identified by the speaker. 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 [17] and 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.
Percentage of details % DET	Measure of informativeness derived by dividing the number of optional information elements produced (i.e. details) by the total number of essential content units expressed.

processing software Praat [39], which guarantees greater precision in detecting silences, silent micro-pauses (>0,4 s) and hesitations compared to transcription by ear.

Based on Praat software segmentation, the Articulation Rate (AR) was manually calculated as the number of syllables uttered, divided by the total duration of the utterance (which was further used to derive word fluency rates), excluding silent pauses (>0,4 s) and non-silent pauses (phonological fillers, hesitations and repetitions).

2.5.2. Discourse analysis

The speech sample was further manually segmented into utterances according to semantic, grammatical and phonological criteria [17]. Utterances boundaries were determined by pinpointing empty or filled pauses (silence >1 s or non-lexical emissions or fillers), considering conceptual and grammatical completeness and chunking utterances in the presence of false starts (beginning an utterance and subsequently aborting it prior to completion).

The segmented speech was subjected to a quantitative textual analysis focusing on four mains levels of discourse structure:

Table 3
Research questions, statistical analyses and main results.

Research questions	
Q1 Do PD patients differ from HC on sentence-level (productivity, lexical-grammatical processing) and discourse-level (narrative organization and informativeness) processing skills?	
Testing: univariate analyses of variance (group as independent variable) on quantitative discourse parameters (adjusted for articulation rate and educational attainment).	**Results:** *-Complex picture:* PD < HC for total number of phonologically well-formed ($p_{corr} = 0{,}01$) and informative words ($p_{corr} = 0{,}004$) produced, for mean sentence length ($p_{corr} < 0{,}001$), and for the number of main ideas ($p_{corr} = 0{,}002$) and details conveyed ($p_{corr} = 0{,}028$). *-Sequence:* PD < HC for total number of phonologically well-formed words ($p_{corr} = 0{,}021$) produced, word fluency ($p_{corr} = 0{,}038$), mean sentence length ($p_{corr} < 0{,}001$), and for the number of main ideas conveyed ($p_{corr} = 0{,}002$). PD > HC for errors in accessing the adequate morphological and morphosyntactic information relative to the selected words ($p_{corr} = 0{,}042$).
Q1.1 Do discrepancies in the inherent speed of articulatory movements and in educational attainment in the studied populations affect sentence-level and discourse-level processing skills?	
Testing: multivariate analyses of variance with articulation rate and years of formal education as covariates. Main effect of covariates explored.	**Results:** *-Complex picture:* articulation rate affected word fluency ($F_{1,52} = 18{,}154$; $p < 0{,}001$); educational attainment affected the total number of phonologically well-formed words produced ($F_{1,52} = 5{,}210$; $p = 0{,}027$), the mean sentence length ($F_{1,52} = 7{,}599$; $p = 0{,}008$) and the number of main ideas conveyed ($F_{1,52} = 5{,}539$; $p = 0{,}022$). *-Sequence:* educational attainment affected the mean sentence length ($F_{1,52} = 4{,}480$; $p = 0{,}039$).
Q1.2 Do the inherent speed of articulatory movements and years of formal education <u>differentially</u> affect sentence-level and discourse-level processing skills in the studied populations?	
Testing: multivariate analyses of variance with articulation rate and years of formal education as covariates. Interaction group*covariate explored.	**Results**: *-Complex picture:* significant interaction group*articulation rate on word fluency ($F_{1,52} = 4{,}026$; $p = 0{,}050$): increased rate of speaking determined a higher number of well-formed words produced in HC ($F_{2,26} = 4{,}194$; $p = 0{,}026$) and NOT in PD ($F_{2,26} = 2{,}980$; $p = 0{,}068$). significant interaction group*educational attainment on mean sentence length ($F_{1,52} = 4{,}133$; $p = 0.047$): HCs (and NOT PDs) ($p_{uncorr} = 0{,}034$) who attended university studies produced longer sentences. *-Sequence:* the articulation rate affected word fluency in the HC group only ($F_{2,29} = 8{,}376$, $p = 0{,}002$).
Q2 Do variations in cognitive and linguistic abilities explain in the PD sample the observed differences in measures indexing sentence-level (productivity) and discourse-level (informativeness) processing skills?	
Testing: multiple regression analyses (predictors selected based on bivariate significant correlations) between interference effect in the Stroop test, objects naming performance (as independent variables) and the percentage of main ideas conveyed, and between the interference effect, total number of words produced in the semantic fluency task, total number of switches in both fluency tasks, action naming performance (as independent variables) and word fluency.	**Results**: *-Complex picture*: a significant model emerged ($F_{1,25} = 10{,}442$; $p = 0{,}003$) in which variations in object naming ($\beta = 0{,}543$; $t = 3{,}231$; $p = 0{,}003$) explained 26% of variance observed in the percentage of main ideas identified. No other significant predictor contributed to explain variations in the number of content units conveyed (β Stroop interference $= -0{,}11$; $p > 0{,}05$). *-Sequence*: a significant model emerged ($F_{4,26} = 5{,}952$; $p = 0{,}002$) in which variations in action naming ($\beta = 0{,}519$; $t = 2{,}928$; $p = 0{,}008$) explained 43% of variance observed in word fluency. No other significant predictor contributed to explain fluency performance (βs from $-0{,}18$ to $0{,}09$; $p > 0{,}05$). Likewise, action naming performance explained 24% of observed variance ($F_{1,26} = 9{,}061$; $p = 0{,}006$) in the number of content units conveyed ($\beta = 0{,}516$; $t = 3{,}01$; $p = 0{,}006$). No other significant predictor contributed to explain variations in the percentage of main ideas identified (βs from 0,08 to 0,15 $p > 0{,}05$).

productivity, lexical and grammatical processing, narrative organization and informativeness. Within each level, different variables were derived according to the analysis procedure thoroughly described in Ref. [17]. The scoring and segmentation processes were performed independently by two raters (SD and FeP) and then compared. An acceptable level of inter-rater reliability ($k \geq 0.80$) was achieved for all the linguistic scores in the present study.

As for verbal *productivity*, the following variables were coded: Total Word Count (TWC), Word Fluency (WF) and Mean Length of Utterance (MLU). The abovementioned indices are measures of verbal fluency and reflect the ability to select well-formed real words in response to a visual complex stimulus, regardless of contextual appropriateness.

Lexical and grammatical processing was measured considering: the percentage of paragrammatic errors (% PAR), and the percentage of phonological errors (% PH-E). Syntactic processing was analyzed in terms of sentence completeness and complexity and two measures derived: the number of omissions of morphosyntactic information (MOR-OM) and the proportion of complex sentences (% CX-S).

Regarding *narrative organization*, we considered the structural and semantic coherence among parts of the produced discourse, identifying at the sentence level, the total number of local coherence errors (LCOH-E) and at the inter-sentential level the global coherence errors (GCOH-E).

Finally, *informativeness* was evaluated at the single word and at the concept level through the lexical informativeness index (LI), and at the concept level through the percentage of thematic selection (% TH-S). Then a qualitative measure of informativeness was derived by the percentage of details (% DET), as an index of subjects' ability to convey critical information in a focused fashion.

See Table 2 for a detailed description of the linguistic variables investigated.

2.5.3. Statistical analysis

Comparisons of sociodemographic variables (gender, age, educational attainment, global cognitive functioning) were performed using unpaired *t*-test for continuous measures and chi square for categorical variables. Unpaired t-tests were also performed to compare HC's and PD's neuropsychological performance and neuropsychiatric assessment scores. Significance (two-tailed, unequal variances assumed) was set at $p \leq 0.05$.

A series of multivariate analyses of variance were conducted on each level of discourse structure in the two production tasks separately. Group membership (HC-PD) was the independent variable while educational attainment (in years) and the AR were considered as covariates (given the marginally significant t statistic for the difference between HC and PD in educational attainment, and considering the potential interference of AR on discourse parameters). The main effect of group, of covariates and the potential interaction group*covariates (group*educational attainment; group*AR) were tested. In case of a significant interaction effect, covariates were transformed into categorical variables (≤8 y = LOW; ≤1 3y = MEDIUM; >13 y = HIGH for educational attainment; ≤4.85 syllables/s = SLOW; ≤5.28 syllables/s = MEDIUM; >5.28 syllables/s = FAST speakers according to terciles based on HC and PD distribution of AR) and their effect separately explored in the two groups.

Univariate analysis of variance (considering the group as independent variable and the different discourse parameters as dependent variables) and between subjects post-hoc pairwise comparisons were used to evaluate differences among estimated marginal means (adjusted for covariates) of discourse parameters within each level of discourse structure. A Bonferroni correction for multiple comparisons was adopted, and significance set at $p \leq 0.05$.

Bivariate correlational analyses were performed for the PD group in order to determine any potential relationship between discourse parameters significantly differing between the two groups, and: a) executive (planning: RF-C; inhibiting: WCST-PE and SWCT-IE-T; switching: SW-T from both the Ph-F and Sem-F tasks), b) language scores (semantic-lexical competence: Ac-N and Ob-N; verbal fluency: Ph-F and Sem-F total score) indexing the cognitive resources implied in narratives. Multiple regression analyses (stepwise, F to enter ≥ 3,84; F to exit ≤ 2,71) were used to explore the relationship between pre-selected predictors (on the basis of correlation significance) and narrative performance. In order to control for potential multicollinearity, only variables with a variance inflation factor (VIF) < 5 were included in the regression model [40].

Bivariate correlational analyses between neuropsychiatric evaluation scores and discourse parameters also investigated any potential relation between the presence of depressive, anxious, apathetic and psychotic symptomatology and changes in narrative abilities such as depression-associated reduced verbal fluency and referential failures. Table 3 in the results section summarizes the research questions tested, and the statistical analyses conducted.

3. Results

3.1. Sociodemographic and cognitive features

As expected from the matching procedure, the two groups did not significantly differ for age, gender and global cognitive functioning. A marginally significant difference between the two groups was appreciable for educational attainment. Patients with PD significantly differed from matched HCs for neuropsychological performance (except for the time interference effect in the Stroop test), and for apathetic symptomatology (see Table 1).

3.2. Cookie theft

In a first multivariate analysis of variance a significant main effect of education (Wilk's $\lambda = 0{,}771$; $F_{3,50} = 4{,}958$; $p = 0{,}004$; partial $\eta^2 = 0{,}229$), and AR (Wilk's $\lambda = 0{,}733$; $F_{3,50} = 6{,}070$; $p = 0{,}001$; partial $\eta^2 = 0{,}267$) and a significant interaction group*education

(Wilk's $\lambda = 0{,}848$; $F_{3,50} = 2{,}994$; $p = 0{,}039$; partial $\eta^2 = 0{,}152$) were observed on *productivity* indices. A significant effect of group ($F_{1,52} = 6{,}105$; $p = 0{,}017$) and AR, and a significant interaction group*AR were detected on WF implying that speaking fluency differentially affected word production in the two groups (see Table 3). Specifically, the number of uttered syllables in the narrative time did not affect the number of well-formed words produced by PD patients, while in HCs an increased rate of speaking had an effect on fluency, with slow speakers significantly producing less well-formed words compared to fast speakers ($p = 0{,}024$). The level of educational attainment affected the total number of produced words and the length of uttered sentences with a significant interaction group*education on the latter. Specifically, educational attainment had a significant effect on MLU in HC subjects only, as subjects who completed the lowest level of education (up to middle school) produced significantly shorter sentences ($p = 0{,}038$) compared to individuals who attended university studies (see Table 3 for detailed results).

Univariate analysis of variance for the group effect on estimated marginal means, and pairwise post-hoc tests demonstrated that after having accounted for potential differences between the two groups in AR and educational attainment, PD's production was characterized by less words ($p = 0{,}01$) and shorter sentences ($p < 0{,}001$) compared to normal controls. Table 4 (section a) reports results from univariate analyses of variance on narrative indices.

As for multivariate analyses performed on indices of *lexical and grammatical processing* and *narrative organization*, no significant main effects nor interactions were found ($p > 0{,}05$). Univariate analyses of variance on the group effect and pairwise post-hoc tests further demonstrated no significant effect of diagnosis on estimated marginal means of the considered variables ($p > 0{,}05$). A trend toward significance ($p = 0{,}056$) was observable on a measure of narrative organization (i.e. GCOH-E), while pairwise comparisons demonstrated that PD patients produced a higher number of coherence errors at the inter-sentential level.

Likewise, no main effects nor significant interactions were observed on *informativeness* indices ($p > 0{,}05$). When the between subjects' effects were tested, a significant effect of education on %TH-S ($F_{1,52} = 5{,}539$; $p = 0{,}022$) was observed for both groups. Univariate analyses of variance on estimated marginal means showed a significant difference in all the considered indices. Pairwise comparisons showed that PD subjects significantly produced a lower number of phonologically well-formed and appropriate words (LI, $p = 0{,}004$), less informative elements (%TH-S, $p = 0{,}002$) and a lower number of details (%DET, $p = 0{,}028$).

3.2.1. *Predictors of narrative abilities in "Cookie theft"*

When potential correlations between productivity and informativeness indices significantly differing between groups (TWC; MLU, LI; %TH-S) and executive/linguistic abilities underpinning narrative abilities were explored in the patients' group, a significant correlation was observed between the number of produced words (TWC) and the total switching score from verbal fluency tests ($r = 0{,}374$ $p = 0{,}046$). None of the linguistic domain variables (semantic-lexical competence and verbal fluency) significantly correlated with the number of produced words ($p > 0{,}05$). Significant correlations were also found between mean length of utterance (MLU) and object naming scores ($r = 0{,}385$; $p = 0{,}048$).

As for *informativeness* indices, no significant correlations with executive/linguistic abilities were observed for the number of phonologically well-formed and appropriate words produced (LI, $p > 0{,}05$), nor for the number of produced details (%DET, $p > 0{,}05$). The number of uttered informative elements (%TH-S) negatively correlated with the time interference effect in the Stroop test ($r = -0{,}376$; $p = 0{,}045$) and positively with the object ($r = 0{,}543$; $p = 0{,}003$) and action naming ($r = 0{,}467$; $p = 0{,}014$) performance.

Table 4
Univariate analysis results on quantitative measures of referential narrative discourse in the two tasks. a) complex image description task (Cookie Theft), b) sequence picture description task (Quarrel).

	a) Cookie Theft					b) Quarrel				
	HC (n = 29) Mean (sd)	**PD (n = 29)** Mean (sd)	**F**	**p**	**η^2**	**HC (n = 29)** Mean (sd)	**PD (n = 29)** Mean (sd)	**F**	**p**	**η^2**
Productivity										
TWC	105,79 (57,66)	61,07 (37,82)	7,107	**0,010**	0,120	112,76 (84,08)	64,97 (33,51)	5,666	**0,021**	0,098
WF	2,16 (0,40)	2,11 (0,72)	0,609	0,439	0,012	2,28 (0,53)	2,03 (0,59)	4,533	**0,038**	0,080
MLU	10,93 (4,07)	7,04 (2,15)	16,237	**<0,001**	0,238	10,50 (4,69)	6,23 (2,04)	15,231	**<0,001**	0,227
Lexical-grammatical processing										
% PAR	0,31 (0,57)	0,87 (1,70)	2,458	0,123	0,045	0,19 (0,37)	0,59 (1,24)	4,364	**0,042**	0,077
MOR-OM	1,14 (1,60)	1,28 (1,25)	0,013	0,908	0,000	0,86 (1,48)	2,31 (2,92)	3,473	0,068	0,063
% PH-E	5,67 (4,75)	5,04 (5,62)	0,104	0,748	0,002	6,97 (12,88)	2,86 (3,15)	1,245	0,270	0,023
% CX-S	21,28 (11,14)	26,28 (16,13)	2,919	0,093	0,053	17,48 (12,05)	19,40 (16,02)	0,678	0,414	0,013
Narrative organization										
LCOH-E	0,48 (0,95)	0,76 (1,12)	0,477	0,493	0,009	0,24 (0,79)	1,10 (2,82)	1,133	0,292	0,021
GCOH-E	1,38 (1,37)	2,86 (3,78)	3,818	**0,056**§	0,068	1,72 (3,40)	1,69 (1,78)	0,337	0,564	0,006
Informativeness										
LI	81,39 (11,82)	65,52 (25,29)	9,057	**0,004**	0,148	85,37 (13,00)	79,34 (14,95)	3,704	0,060	0,067
% TH-S	60,92 (20,28)	37,16 (24,72)	10,460	**0,002**	0,167	67,90 (19,62)	48,81 (20,38)	11,207	**0,002**	0,177
% DET	29,44 (9,52)	20,51 (14,54)	5,144	**0,028**	0,090	85,27 (31,71)	65,46 (40,90)	3,695	0,060	0,066

Legend: % CX-S, proportion of complex sentences; % DET, percentage of details; % PAR, Percentage of paragrammatic errors; % PH-E, percentage of phonological errors; % TH-S, percentage of thematic selection; GCOH-E, global coherence errors; HC, Healthy Comparators; LCOH-E, total number of local coherence errors; LI, Lexical informativeness; MLU, Mean Length of Utterance; MOR-OM, number of omissions of morphosyntactic information; PD, Parkinson Disease patients; sd, standard deviation; TWC, Total Word Count; WF, Word Fluency. Bold values indicate statistically significant differences. § indicate trend to significance.

The abovementioned executive/linguistic measures (time interference effect in the Stroop test and objects naming) were entered as independent variables in a further stepwise multiple regression analysis (conducted on 27 subjects due to missing values in the naming tasks) in which the percentage of thematic selection was the dependent variable. Action naming scores were not entered in the model due to a VIF > 5. A significant model emerged which included objects naming, while the time interference effect in the Stroop test was excluded. Variations in objects naming explained 26,6% of the variance observed in the percentage of informative elements produced by subjects with PD (see Table 3 for detailed results).

No significant correlation ($p > 0.05$ two tailed) was observed between discourse parameters differentiating patients from healthy comparators and neuropsychiatric measures of depressive, anxious, apathetic and psychotic symptomatology.

3.3. *Quarrel*

In a first multivariate analysis of variance no significant effects of the considered variables were observed on *productivity* indices ($p > 0,05$). The level of educational attainment significantly affected the length of uttered sentences only, while a significant interaction group*AR was detected on WF ($F_{1,52} = 10,214$; $p < 0,001$). In the whole sample, post-hoc tests demonstrated a significant difference in the length of uttered sentences between subjects who completed the lower level of education (up to middle school) as compared to individuals with the highest level of educational attainment ($p = 0,041$). When the significant interaction group*AR on WF was explored, the articulation rate affected word fluency in the healthy subject group only since slow speakers significantly produced less well-formed words compared to fast speakers ($p = 0,001$).

Univariate analysis of variance on the group effect and pairwise post-hoc tests demonstrated that after having accounted for potential differences between the two groups in AR and educational attainment, PD patients' production was characterized by less words ($p = 0,021$), lower word fluency ($p = 0,038$) and shorter uttered sentences ($p < 0,001$) compared to normal controls. Table 4 (section b) reports results from univariate analyses of variance on narrative indices.

As for multivariate analyses performed on indices of *lexical and grammatical processing*, no significant main effects nor interactions were found ($p > 0,05$). Univariate analyses of variance on the group effect and pairwise post-hoc tests on estimated marginal means demonstrated a significant effect of diagnosis on percentage of paragrammatisms (% PAR, $F_{1,52} = 4,364$; $p = 0,042$). Pairwise comparisons showed that PD patients produced a significantly higher number of paragrammatisms than HC.

Multivariate analysis performed on *narrative organization* indices showed a significant main effect of education (Wilk's $\lambda = 0,868$; $F_{2,51} = 3,893$; $p = 0,027$; partial $\eta^2 = 0,132$) and a significant interaction group*education (Wilk's $\lambda = 0,851$; $F_{2,51} = 4,459$; $p = 0,016$; partial $\eta^2 = 0,149$). Specifically, the latter was detected on the total number of local coherence errors (LCOH-E, $F_{1,52} = 4,835$; $p = 0,032$) and on total global coherence errors (GCOH-E, $F_{1,52} = 6,367$; $p = 0,015$). Nevertheless, when the potential effect of covariates was accounted for in univariate analyses of variance on the group effect, and pairwise post-hoc comparisons, no significant effect of diagnosis on narrative coherence indices emerged.

Likewise, no main effects nor significant interactions were observed on *informativeness* indices ($p > 0,05$). Univariate analyses of variance on estimated marginal means showed a significant effect of group on the percentage of informative elements conveyed (%TH-S, $F_{1,52} = 11,207$; $p = 0,002$), and pairwise comparisons demonstrated that PD patients produced fewer conceptual units than HC, when the effect of covariates was removed. Fig. 1 depicts the observed difference in productivity and informativeness measures.

3.3.1. *Predictors of narrative abilities in "Quarrel"*

When potential correlations between productivity and informativeness indices significantly differing between groups (TWC; WF; MLU, %TH-S) and executive/linguistic abilities underpinning narrative abilities were explored in the patients' group, significant correlations were observed between WF and interference/time score from the Stroop test ($r = -0,411$; $p = 0,027$) and between the

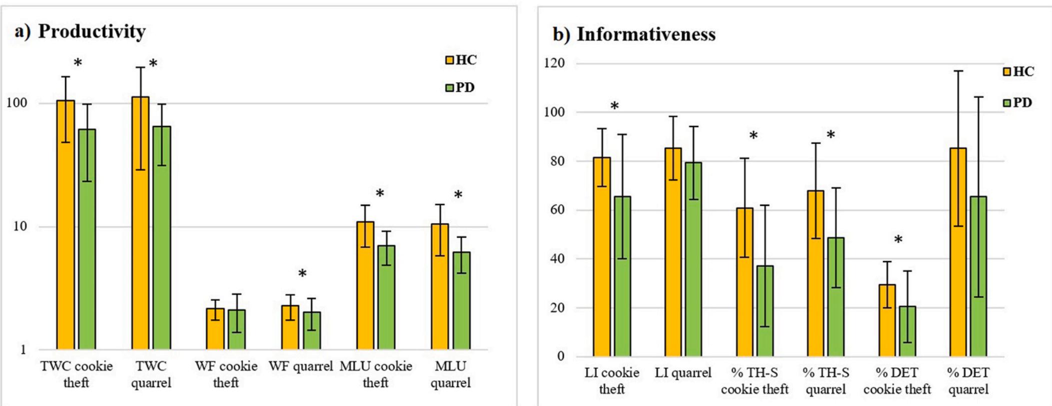

Fig. 1. Productivity (panel a) and Informativeness (panel b) performance on referential narrative discourse tasks in the studied samples. A base-10 logarithmic scale was used for displaying productivity measures (analyses ran on raw data). Legend: % DET, percentage of detail; % TH-S, percentage of thematic selection; LI, Lexical informativeness; MLU, Mean Length of Utterance; TWC, Total Word Count; WF, Word Fluency.

total number of switches in phonological and semantic fluency tasks ($r = 0{,}522$; $p = 0{,}004$). None of the executive domain variables significantly correlated with the number of produced words (TWC) or mean length of utterance (MLU, $p > 0{,}05$).

Positive correlations were found between all the neuropsychological variables in the linguistic domain and WF. In particular, a correlation with phonological verbal fluency ($r = 0{,}563$; $p = 0{,}001$), semantic verbal fluency ($r = 0{,}443$; $p = 0{,}016$), actions ($r = 0{,}678$; $p < 0{,}001$) and objects naming ($r = 0{,}673$; $p < 0{,}001$) emerged. The abovementioned executive/linguistic measures were entered as independent variables in a further stepwise multiple regression analysis in which WF was the dependent variable. Considering a VIF < 5 only the interference/time score from the Stroop test, the total number of switches in phonological and semantic fluency tasks, the action naming and the semantic verbal fluency scores were entered as independent variables. A significant model emerged which included action naming, while the interference/time score from the Stroop test, the total number of switches in phonological and semantic fluency tasks and the semantic fluency scores were not significant predictors of fluency in the patients' sample. Results showed that variations in performance in action naming explained 43% of the observed variance in WF ($R^2 = 0{,}432$).

As for *informativeness* indices, the number of uttered informative elements (%TH-S) positively correlated with object naming ($r = 0{,}499$; $p = 0{,}008$), action naming ($r = 0{,}516$; $p = 0{,}006$) and phonological verbal fluency ($r = 0{,}379$; $p = 0{,}043$). However, a further stepwise multiple regression including %TH-S as the dependent variable and object, action naming, and phonological verbal fluency scores demonstrated that action naming performance was the only significant predictor of the number of uttered informative elements and able to explain 24% of the observed variance. The remaining variables were excluded from the model. See Table 3 for detailed results.

Like for the single picture description, no significant correlation ($p > 0.05$ two tailed) was observed between discourse parameters differentiating patients from healthy comparators and neuropsychiatric measures of depressive, anxious, apathetic and psychotic symptomatology.

4. Discussion

Here we take an embracive look at referential narrative discourse in PD patients using a multi-level procedure, and partialling out the effect of potential articulatory impairments on quantitative linguistic parameters, thus using an innovative perspective. The correlation between productivity and informativeness indices significantly differentiating patients from healthy comparators and executive functioning and linguistic performance was also considered, and their contribution to discourse production investigated. PD patients significantly produced less well-formed words, shorter sentences and fewer conceptual units, with a reduced number of informative elements and less details. These alterations were dependent on variations in linguistic abilities (action and object naming), rather than on executive deficits. Motor impairments in speech production did not impact the observed decline in narrative fluency and in the number of informative elements conveyed, as the amount of well-formed uttered words was not affected by articulation rate in PD.

Different studies agree that disruptions of fluency in PD can be attributed to difficulties in the early stages of language production (e.g.: conceptualization), as well as to problems during motor programming and articulation [3,14,15]. Our findings, demonstrating that PD patients produced less well-formed words and shorter sentences regardless of articulation rate, indicates that productivity is affected in PD by difficulties in linguistic processing, and specifically in the ability to access and retrieve target words from their mental lexicon. The observation that patients' productivity did not vary according to educational attainment (which was not the case in HC) further strengthen our data also suggesting that once the linguistic system is impaired, there may be no resources for compensation, and no evidence of cognitive reserve [41]. PD patients also produced fewer conceptual units, a lower number of phonologically well-formed and appropriate words, less informative elements and a lower number of details, confirming previous evidence [3,10,15] of under informative narratives in the disease.

Although the observed difference in productivity and informativeness measures was not related to discrepancies in the inherent speed of articulatory movements in the studied populations (which was accounted for), the possibility that PD patients adjusted their production based on perceived articulatory effort, -trying to maximize articulatory ease and minimize the listener's perceptual strain [42]- cannot be completely ruled out. Actually, variations in objects naming scores explained a significant portion of variance in the percentage of informative elements produced in the complex image description task, while action naming performance was the only significant predictor, among those tested, of the number of uttered informative elements in the sequence picture description. At variance with previous findings [14,15,43] and contrary to our expectations, executive abilities did not contribute to explain the observed reduction in productivity and informativeness measures. Despite a significant correlation between productivity and informativeness measures and set-switching and inhibitory control capacities, the observed divergences in language use tended to fluctuate with cognitive variations, and were predicted by lexical linguistic abilities only [10,14].

Based on a multi-levels model of discourse production [44], previous studies [10] demonstrated that reduced discourse informativeness in PD reflects disruptions to both conceptual (i.e. discourse planning to elaborate the message/event/story to be conveyed) and lexical/linguistic processes (i.e. the activation/selection of lexical units that relay information concepts). A reduced production of words per minute, a lower percentage of well-formed sentences [45] and reduced efficiency in conveying essential information [10] correlate with general cognitive functioning [10,45], but also with impaired action verb retrieval [10] and word-finding difficulties (as inferred from an increased number of pauses within utterances, particularly before verbs) [45].

Congruently, both a decrease in productivity measures and in lexical/conceptual informativeness was explained in our sample by variations in lexical access, since measures indexing the efficiency of word-finding processes, and the ability to name objects and actions accounted for a significant portion of observed variance.

While the correlation between productivity/informativeness indices of discourse production and the linguistic ability to name actions and objects was poorly researched [10], several pieces of evidence suggested that PD patients may have difficulties in accessing action concepts within the event structure [10,25]. Action naming is indeed impaired in PD in comparison with controls, with more severe deficits compared to those observed in object naming [46–48]. Consistently with the embodied view of cognition [46,47,49] and the neurocognitive model of motor-language coupling in a pathology typically dominated by movement disorders [47,50], such action naming deficit in PD has been linked to a degradation of the conceptual motor representations embedded in verbs [10,48,49]. The here observed motor-language coupling in PD discourse could be consequent to the basal ganglia participation in both action-naming [50,51] and referential narrative discourse [52], as they contribute to the supervisory/control linguistic processes required for lexical retrieval and global coherence maintenance [52]. However, when we tested the impact of executive-linguistic abilities to PD patients' productivity and informativeness measures, performance in control executive tasks did not contribute to explain observed variance.

Alternatively, aberrant activation patterns within frontal and sensorimotor cortices, related in PD to difficulties in ordering action sequence components into a coherent story frame [53] and in producing/appraising verb-related information [46] also in naturalistic texts [25,54], may explain the observed contribution of action naming to conceptual informativeness in narratives.

Overall our results suggest that lexical and conceptual informativeness measures may be sensitive parameters of cognitive–linguistic changes in PD when administered as part of a larger assessment battery. Since picture description tasks are undemanding, non-stressful, and non-fatiguing, while the evaluation of narrative abilities (and particularly the here adopted measure of conceptual informativeness) is relatively time-consuming, discourse analysis might complement the combination of validated clinical and neuropsychological tests to tap the integrity of neural (and particularly, motor) networks, especially when direct neuroimaging evidence is not available. Indeed, the potentiality for embodied language abilities to signal motor-network degeneration has been demonstrated in the disease early stages [55] irrespective of the patients' overall cognitive status [56], and even in pre-clinical stages [57], and impairments in such functions constitute a prodromal sign anticipating eventual development of PD [57] and a sensitive marker for cognitive decline [54] (but see Ref. [25] for a different view). As picture description is amenable to recurrent and automated analysis of certain linguistic features [24], symptom monitoring outside the traditional clinic setting could be more frequent, while a data-driven health care approach based on massive information gathering will better answer to patients' and clinicians' needs [13,45]. Although we used two picture description tasks considering the many benefits deriving from such instruments (above all, the controlled nature of the speech content which reduces the ambiguity about the subject matters), more naturalistic tasks such as story retelling [25], or spontaneous discourse [58] may better capture language impairments in prodromal phases of synucleinopathies [58]. However, when compared to unplanned speech, tasks such as story repetition and picture description (particularly the film-strip narrative employed in this study) are better suited for capturing the contribution of higher-order cognitive processes to narrative discourse [58]. This is because coherent semantic content must be generated in order to communicate conceptual information, whereas for narratives prompted by visuals, a cognitive representation of the story must be constructed without the micro and macro-linguistic signals included in a previously read tale [59]. Additionally, referential tasks offer a means of assessing patients' potential for successful exchange of information, as they incorporate aspects of realistic communication by requiring participants to make available specific knowledge that cannot be acquired from alternative sources (since the reference is usually not shared). The uniqueness of the referential communication paradigm here adopted may however, have affected the obtained outcomes as for example, the information content was evaluated considering pre-defined thematic units [59] thus impeding further analyses on the spontaneous organization of unplanned speech.

It has also been suggested that the conversational problems reported by PD patients may stem from difficulties in formulating ideas and in retrieving words, with an overall reduction in information content and efficiency that contribute to impairments in everyday language use [60]. As we demonstrated that a decrease in narratives productivity and informativeness was accounted for by reduced efficiency in word retrieval and action verbs naming, interventions targeting word-finding difficulties, and aimed at improving message accuracy during naturalistic exchanges should alleviate the conversational problems observed in the disorder. Further studies on the nature of communication difficulties in PD and the development of intervention programs addressing embodied language functions will contribute to better address nonmotor communication concerns raised by individuals with PD and their families.

Before concluding, we must acknowledge the potential limitations of the present study as the representativeness of the investigated sample might be limited. Indeed, we selected patients in a mild stage of the disease with a prevalent unilateral presentation and well-controlled motor symptoms, which may partially explain the null correlation between narrative measures and motor symptoms, possibly driven by dopaminergic supplementation. Yet, in our sample of medicated patients no significant correlation was observable between the quantitative discourse measures differentiating patients from healthy comparators and daily levodopa equivalents. Additionally, the fact that significant differences between patients and controls were still observable in productivity/informativeness measures even after having been adjusted for variances in motor aspects of speech production (which are surely improved by dopaminergic replacement therapy), would disprove the hypothesis of a potential dopamine effect on discourse performance. However, future longitudinal studies comparing narrative discourse abilities in patients before and after the introduction of anti-parkinsonian therapy or contrasting performance in patients on/off dopamine [61] will clarify the issue. A further limitation of the present investigation is that data on cognitive daily function (as measured for example through questionnaires [62]) were not acquired, thus impeding the investigation of the potential relationship between functional measures of cognition in everyday life and the observed reduction in narrative abilities. However, linguistic features extracted from connected speech tasks and particularly, the narrative one here employed (picture description) demonstrated high accuracy and specificity in discriminating patients with cognitive decline (including subjects with functional deterioration) from healthy controls in populations with neurodegenerative disorders [63]. The fact that individuals with PD perform more poorly in this kind of constrained tasks than in open ended ones like conversation [64], while the length of utterances and sentence complexity are related to cognition [64], would suggest that the here investigated discourse measures can be considered a proxy of functional deterioration [54].

As a concluding remark we must acknowledge that since we intended to estimate the prevalence of narrative discourse changes in PD patients, the possibility to draw final and complete conclusions on the issue might be impeded by the cross-sectional nature of the study design and the relatively limited sample size. However, when we purposely evaluated whether the performed regression analyses were sufficiently powered (post-hoc calculation to compute the achieved power for a two-tailed multiple linear regression, $\alpha = 0.05$) we found that word finding performance (and particularly action naming) was strongly associated (Cohen's $d = 0.72$ and $d = 1.52$, power $= 0.85$ and 0.99) with patients' ability to efficiently communicate pertinent information. Furthermore, the fact that we demonstrated the contribution of variations in lexical access to discourse processing in the mild phase of the disorder is an added value of the present investigation since it complements previous evidence of an early impairment in language skills in PD [55]. Indeed, the gradual cortical dopamine depletion likely contributing to frontal lobe impairment at later stages of the disorder may blur the participation of linguistic abilities to discourse processing, since other deficits in frontal functions can account for reduced narrative performance in PD [14].

5. Conclusions

In conclusion, the results of this study demonstrate that referential narrative discourse is impaired in PD subjects regardless of motor impairments in speech production. The observed reductions in productivity/informativeness aspects of narratives were related to verbs processing, which is particularly compromised since the early phases of PD, being also a specific marker of disease progression, and predictive of future dementia [47]. Such finding suggests that a simple task as picture description, where conceptual representations of the action motor components have to be accessed, might help in identifying the specific linguistic profile of PD since the mild stage of the disease. As picture description is amenable to recurrent and automated analysis for the identification of distinct linguistic patterns [24] potentially anticipating the development of PD [57] and the onset of cognitive deterioration [49], frequent and objective assessment of narrative discourse abilities should be regularly performed as a useful complement to cognitive screening in the neuropsychological assessment of PD.

Author contribution statement

Sara D'Ascanio; Federica Piras, PhD: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Wrote the paper.

Fabrizio Piras, PhD: Conceived and designed the experiments.

Nerisa Banaj, PhDORCID; Francesca Assogna, PhD; Andrea Bassi, MD: Contributed reagents, materials, analysis tools or data.

Clelia Pellicano, MD, PhD: Performed the experiments; Contributed reagents, materials, analysis tools or data.

Gianfranco Spalletta, MD, PhD: Conceived and designed the experiments; Analyzed and interpreted the data.

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Data availability statement

Data will be made available on request.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper

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