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Special issue: Research report

Word selection processing in Parkinson's disease: When nouns are more difficult than verbs

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ARTICLE INFO

Article history:

Received 21 August 2016

Reviewed 17 January 2017

Revised 21 March 2017

Accepted 28 May 2017

Published online xxx

Keywords:

Parkinson's disease

Word selection processing

Morphology

Verbs

Dysexecutive syndrome

ABSTRACT

Patients with Parkinson's disease (PD) are impaired in verb production. Interpretations range from grammatical deficits to semantic-conceptual decay of action representation. The verb production deficit in PD can also be considered a dysexecutive disorder, specifically, a deficit of selection processing during word production, due to corticostriatal damage. Producing verbs is "more difficult" than producing nouns, because verb-forms must be selected from a large set of word-forms which share the verb-root, and the set of possible verb-forms is larger than the set of possible noun-forms when a noun has to be produced. However, if we devise a condition in which a noun must be selected from a set of alternatives larger than the set of alternative forms from which a verb must be selected, we expect an opposite pattern, with nouns becoming more difficult than verbs. We used morphological tasks varying in the number of alternative responses during word production. Fourteen PD patients and 14 healthy Controls participated in the study. Participants performed a noun-from-verb ('observation' from 'to observe') and a noun-from adjective derivation task ('kindness' from 'kind'), and a verb-from-noun ('to observe' from 'observation') and an adjective-from-noun generation task ('kind' from 'kindness'). Input-stimuli were presented singularly on a screen and participants produced the response as fast as possible. Response latencies were longer in derivation tasks (several alternative responses) than in generation tasks (one possible response), irrespective of the grammatical class of the target word, with no difference between groups. PD patients were significantly less accurate than Controls only in the noun-from-verb derivation task, that is, in the task with the highest number of alternative responses (PD: 60%; Controls: 81%). Results suggest that the verb production disorder in PD patients may reflect disturbed selection processes among competitors: the higher the number of alternative responses the more severe the impairment.

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1. Introduction

A dissociable deficit for different classes of words, such as nouns and verbs, is supported by enduring evidence in the neuropsychological literature, suggesting that these two classes of words can be supported by segregated neural substrates (Caramazza & Hillis, 1991; Daniele, Giustolisi, Silveri, Colosimo, & Gainotti, 1994).

Noun-verb dissociation has been occasionally reported in comprehension (Miceli, Silveri, Nocentini, & Caramazza, 1988) and in lexical decision tasks (Boulenger et al., 2008), but most evidence comes from production tasks. Impaired production of nouns is consistently associated with lesions of the left temporal lobe (Damasio, Tranel, Grabowski, Adolphs, & Damasio, 2004; Daniele et al., 1994; Silveri & Di Betta, 1997), whereas a verb deficit may become apparent following a wider range of lesions in the frontoparietal regions (Cappa et al., 1998; Hillis, Oh, & Ken, 2004; Silveri, Perri, & Cappa, 2003; Silveri, Salvigni, Cappa, Della Vedova, & Puopolo, 2003; Thompson-Schill, D'Esposito, Aguirre, & Farah, 1997) and connected subcortical structures, first of all the basal ganglia (Bertella et al., 2002; Bocanegra et al., 2015; Colman et al., 2009; Cotelli et al., 2007; Fernandino et al., 2013a,b; Péran et al., 2003; Piatt, Fields, Paolo, & Tröster, 1999; Rodríguez-Ferreiro, Menéndez, Ribacoba, & Cuetos, 2009; Signorini & Volpato, 2006; Silveri et al., 2012).

The deficit in verb production has received different interpretations over time: as a grammatical class disorder (Caramazza & Hillis, 1991; Péran et al., 2003; Zingeser & Berndt, 1990), a morphological deficit (Shapiro, Shelton, & Caramazza, 2000), or a degraded conceptual representation of the actions the verbs denote (Boulenger et al., 2008; Rodríguez-Ferreiro et al., 2009), the last interpretation consistent with the hypothesis that information about verbs might be grounded in the neural motor system (Cardona et al., 2014). However, this latter interpretation should be limited to verbs that express actions (action verbs) and principally physical actions as opposed to mental or abstract actions.

Some studies also suggested that the verb deficit can be an expression of the dysexecutive disorder produced by damage to the anterior regions of the brain (Silveri et al., 2003) or the corticostriatal circuits (Cotelli et al., 2007), connecting the prefrontal cortex and basal ganglia.

Evidence from activation studies corroborates this view, as higher activation of the left prefrontal cortex (inferior frontal gyrus – IFG) has been demonstrated during verb compared to noun processing (Perani et al., 1999; Shapiro, Moo, & Caramazza, 2006).

Thompson-Schill et al. (1997) found, by means of a functional MRI study, that the IFG is active when selection of information among many competing alternatives was requested in a verb-from-noun generation task based on semantic association (e.g., 'wheel' → 'turn'), and that activation was dependent on selection demand. Impaired generation of verbs from nouns has been confirmed in patients with lesions in this area (Thompson-Schill et al., 1998; Tippett, Gendall, Farah, & Thompson-Schill, 2004), but only for stimuli with high selection demand (that is, with many appropriate associated responses without any clearly dominant response).

Crescentini, Shallice, and Macaluso (2010) obtained activation of the mid part of the inferior prefrontal cortex in a production task in a high selection condition, irrespective of grammatical class. Other studies confirmed that verb generation is sensitive to selection demands and that selection demands activate substrates of the IFG (Snyder, Banich, & Munakata, 2011) and basal ganglia (Persson et al., 2004).

Thompson-Schill and Botvinick (2006) suggested that the role of the left IFG in language tasks is to resolve competition among incompatible representations. In this perspective, any variable that can influence activation of competitors can modulate IFG activation as well. The authors proposed Usher and McClelland's (2001) network to model their view of processes involved in verb-generation task and concluded that a response is produced when only one representation crosses an activation threshold. Reaction times are assumed to reflect the time a node needs to cross the threshold.

In this framework, the probability distribution over response candidates (nodes) would be influenced by several variables, including number of word competitors: It could be assumed that the higher is the number of competitors, the stronger is the inhibition among nodes and the response selection is bound to be slowed down. If this is the case, then verb processing is expected to be more demanding than noun processing, because, in most languages, the set of inflected and derived words for verbs is larger than for nouns or adjectives. For instance, in a language with rich morphology such as Italian, there are about 50 inflected verb forms (with different suffixes to differentiate forms by tense, mood, person, and number), 2–4 noun forms, and 2–4 adjective forms (with different suffixes for gender and number). For this reason, distributional properties of noun, adjective, and verb forms have been considered as one of the main features that may generate differences between grammatical classes in word recognition tasks (e.g., Deutsch, Frost, & Forster, 1998, for Hebrew; Kostić & Katz, 1987, for Serbo-Croatian; Traficante, 2012; Traficante & Burani, 2003, and Traficante, Marelli, Luzzatti, & Burani, 2014, for Italian).

Siri et al. (2008) provided evidence that activation of the left IFG is modulated by selection demands during morphological processes rather than by verb-specific processing. In an event-picture naming task (e.g., a girl reading a book), they found higher activation of the IFG when the production of an action noun (e.g., the derived noun 'lettura' [reading]) is required rather than when the production of an inflected verb (e.g., 'legge' [she reads]) or an infinitive verb (e.g., 'leggere' [to read]) is required. The authors interpreted this result claiming that when pictures depicting actions are presented, the production of a verb (both inflected and infinitive form) is the most automatic response, whereas the production of an action noun involves the selection of a less favorite response. They suggested that left IFG activations are affected by the complexity of the morphological processes and/or by the selection demands of the task, rather than being associated with verb-specific processing.

These results are consistent with the findings by Marangolo, Piras, Galati, and Burani (2006). These authors used a noun-from-verb and noun-from-adjective derivation task, that is, they required the production of a derived noun from the corresponding verb or adjective bases (e.g.,

'osservazione' [observation] from 'osservare' [to observe]; 'gentilezza' [kindness] from 'gentile' [kind]), and a verb-from-noun generation task, that is, the production of a verb from a noun (e.g., 'osservare' [to observe] from 'osservazione' [observation]), with input words presented orally. The derivation task is expected to trigger selection processes among sets of competitors, whereas the generation task might require only retrieving the base word from which the noun has been derived, so that no selection process would be involved. An extensive activation of the left frontoparietal regions was found in unimpaired adults during derivational processing, but not in the generation task.

Marangolo et al.'s (2006) study shows that a morphological task may allow word production difficulty to vary and obtain a condition in which, contrary to the majority of observations, noun derivation (that requires selection among many alternatives) is more difficult than verb generation (that requires production of the verb base form only). Specifically, the production of a noun from a verb- or an adjective-base (e.g., 'observation' from 'observe', 'kindness' from 'kind') requires the selection of a word among a set of competing suffixed-words. In contrast, the generation of the verb-base form from a derived noun involves only the retrieval of the base word, without any selection process (e.g., only 'correre' [to run] can be generated as a base form from the noun 'corsa' [run]).

PD patients seem a particularly suitable population to study the verb production deficit. The characterizing pathological feature is the damage to the corticostriatal circuits connecting the striatum to the dorsal frontal cortex, including the IFG. This functional pathway represents the neural basis of executive control, and consistently, as reported above, the basal ganglia and IFG are active during selection processes (Crescentini et al., 2010; Persson et al., 2004). The striatum, however, also receives connections from the motor cortex and is part of the functional systems assigned to movement control. Thus, in relation to the localization of the pathology, a verb production deficit in PD is prone to be interpreted either as loss of executive control (Cotelli et al., 2007), or as a disorder of action-verb semantic representation (Ibáñez et al., 2013). This is consistent with the embodiment hypothesis, according to which motor information is part of word meaning, and thus is degraded in the presence of damage to the neural substrates of motor function. Indeed, PD patients proved to be more impaired, compared to normal controls, in processing action verbs than abstract verbs, both in sentence (Fernandino et al., 2013a) and in single word comprehension tasks (Fernandino et al., 2013b), suggesting that their disorder has to do with one of specific classes of verbs that differ in the nature of semantic representation, and not with verbs as such.

In the present study we assumed, based on the above mentioned evidence, that a principal factor of PD patients' difficulties in verb production originates from verbs being "more difficult" than other grammatical classes, because verb forms must be selected from a large set of word forms that share the verb root, and the set of possible verb forms is larger than the set of possible noun forms when a noun must be produced. However, if we devise a condition in which a noun must be selected from a set of alternatives larger than the set of alternative forms from which a verb must be selected, we

should expect an opposite pattern of results, with noun production becoming more difficult than verb production. To assess this hypothesis, PD patients were asked to derive a noun from a verb and from an adjective (derivation tasks)¹ or a verb and an adjective from a derived noun (generation tasks) (Marangolo et al., 2003).

In the derivation task, the input was a verb (in the infinitive form, e.g., 'osservare' [to observe]) or an adjective (in the citation form, e.g., 'gentile' [kind]) and the respondent was asked to produce a corresponding derived noun (e.g., 'osservazione' [observation] from 'osservare'; 'gentilezza' [kindness] from 'gentile'); in the generation task, the input was a derived noun and the response was the verb base (in the infinitive form, e.g., 'fallire' [to fail] from 'fallimento' [failure]) or the corresponding adjective base (in the citation form, e.g., 'bello' [beautiful] from 'bellezza' [beauty]). The main difference between the two tasks is the number of different lexical entries among which the response must be selected. For instance, in the case of the verb 'camminare' [to walk], 6 different nouns can be considered as a response in the derivation task: 'cammino' [walk], 'camminata' [walk], 'camminamento' [route], 'camminante' [walking], 'camminatrice' [walker, female], 'camminatore' [walker, male]. In the case of the noun-from-adjective derivation task, alternatives are in general fewer than in the case of the noun-from-verb derivation task. For instance, for the adjective 'fresco' [fresh], there are two possible derived nouns: 'freschezza' [freshness] and 'frescura' [coolness]. From these entries, the participant must choose his/her response, selecting only one noun, and inhibiting the alternatives. In other words, the derivation task is supposed to involve response selection and inhibition of alternative entries. We assume that this process is similar to the process involved in the production of an individual inflected verb form, which must be selected among different options (in Italian, about 50). In contrast, when, in the generation task, a verb- or an adjective-base must be produced in response to a derived noun, selection and inhibition processes are not required: for example, from 'fallimento' [failure] only the verb 'fallire' [to fail] can be considered, and from 'felicità' [happiness], only the adjective 'felice' [happy] is available. Thus, the generation task is supposed to be similar to the simple retrieval of a noun from the lexicon.

The aim of the present study was to investigate the influence of selection demands on word production, contrasting derivation from many alternatives (noun from verb) with derivation from few alternatives (noun from adjective) and with the simple retrieval of one lexical entry (generation of verb and adjective base forms from a derived noun).

We expected PD patients to be more impaired than controls in production tasks that require selection among many alternatives (thus more impaired in the derivation than in the generation task), and that the severity of the selection impairment would depend on the number of alternatives (with a more serious impairment in deriving a noun from a verb than a noun from an adjective).

¹ The reversed condition, i.e., the derivation of a verb (and an adjective) from a noun could not be assessed because of the low number and the peculiar characteristics of the Italian verbs and adjectives which are derived from nouns.

2. Method

2.1. Participants

Fourteen non-demented PD patients, eight males and six females, were selected from those referred to the Aging Medicine Center of the Policlinico Gemelli Hospital – Catholic University of Rome. Selection was performed according to the following inclusion criteria: a) Diagnosis of idiopathic Parkinson's disease according to the clinical criteria of the United Kingdom Parkinson's Disease Society Brain Bank (Hughes, Daniel, Kilford, & Lees, 1992); b) Mild to moderate stage of the disease (Hoehn & Yahr scale: Hoehn & Yahr, 1967); c) Education \geq 8 years; d) Italian as native language; e) MMSE normal for age and education (Grigoletto, Zappalà, Anderson, & Lebowitz, 1999); f) Stable drug therapy with L-Dopa (alone or in association with dopamine agonistics, catechol-O-methyltransferase inhibitors, monoamine oxidase inhibitors and anticholinergic drugs); g) No current or previous history of other neurological or psychiatric disorders (excluding presence of mild-moderate depression; 30 item-Geriatric Depression Scale \leq 12; Yesavage et al., 1983) or major internal diseases.

Fourteen matched healthy subjects (six males and eight female) formed the control group (PD patients' mean age \pm SD = 74.29 \pm 6.04, Controls' mean age \pm SD = 72.57 \pm 6.28, $t = .74$; $p = n.s.$; PD patients' mean education \pm SD = 14.21 \pm 2.86, Controls' mean education \pm SD = 15.14 \pm 4.11, $t = .69$; $p = n.s.$) (Welch's t -test). Demographic and clinical data of PD patients are reported in Table 1.

Patients underwent an extensive neuropsychological examination; frontal functions were also explored in detail (Table 2).

All participants gave informed consent to the experiment, which was approved by the Institutional Ethics Committee of the Catholic University- Policlinico Gemelli Foundation.

2.2. Stimuli

Stimuli consisted of four lists of words (see Marangolo et al., 2003): 144 verbs (e.g., 'osservare' [to observe]), 84 adjectives (e.g., 'gentile' [kind]), 144 singular nouns derived from the 144 verbs (e.g., 'osservazione' [observation]), and 84 singular nouns derived from the 84 adjectives (e.g., 'gentilezza' [kindness]). Verbs and adjectives were input stimuli in the derivation task (VN: noun from verb; AN: noun from adjective) and targets in the generation task (NV: verb from noun; NA: adjective from noun), whereas nouns were targets in the derivation task (VN, AN) and input stimuli in the generation task (NV, NA). In the derivation task, the derived noun that was produced by over 90% of the participants was confirmed as the expected target response, and anything else was considered as an error. In the generation task, there was only one correct response, that is, the correspondent verb- or adjective-base form.

The four sets of experimental items differed for frequency of usage (Istituto di Linguistica Computazionale, CNR, 1989; see also Marangolo et al., 2003): nouns derived from verbs (the critical targets, for which a worse performance was expected) were more frequent ($M = 50.74$, out of 1.5 million occurrences;

Table 1 – Main anagraphic and clinical data of PD patients (LED = Levodopa equivalent doses; MMSE = Mini-Mental State Examination; GDS = Geriatric Depression Scale; UPDRS = Unified Parkinson's Diseases Rating Scale; ADL = Activities of Daily Living; IADL = Instrumental Activities of Daily Living).

Patient	Sex	Age	Education (Yrs)	Handed-ness	Affected side	Disease duration (months)	Drugs ^a	LED	MMSE	GDS	UPDRS	ADL	IADL
1	M	85	18	R	L	8		350	27	6	39	6	4
2	M	77	13	R	L	32		399	28	5	33	5	4
3	M	74	14	R	R	26	DA, COMPT-I	300	39	12	14	6	8
4	M	68	13	R	L	84		455	30	2	27	4	3
5	M	70	8	R	R	50	MAOIs, DA	302	25	3	18	5	4
6	F	81	18	R	L	120	MAOIs, DA	800	30	9	42	4	2
7	M	80	18	R	L	84	DA	485	29	2	34	2	4
8	F	57	13	R	R	60	MAOIs, DA	318	28	1	26	5	4
9	F	64	13	R	L	74	MAOIs, DA	930	29	4	9	4	6
10	F	66	14	R	R	180	DA, AC	740	26	8	48	3	2
11	F	81	13	L	L	144	DA, COMPT-I, AC	375	28	2	32	4	5
12	M	76	13	R	L	36		500	29	5	42	2	0
13	F	73	18	R	R	20		650	30	7	12	5	5
14	M	63	13	R	L	122	MAOIs, DA	450	29	5	23	3	4

^a In addition to stable therapy with L-Dopa; DA = Dopamine Agonists; COMPT-I = Catechol-O-Methyltransferase Inhibitors; AC = Anticholinergic drugs; MAOIs = Monoamine Oxidase Inhibitors.

Table 2 – Neuropsychological examination (pathological scores in bold; cut-off in italics).

Patient	Rey Immediate recall	Rey Delayed recall	Naming	Verbal span forward	Raven Colored Matrices	Word fluency	Rey Figure	WCST	Stroop-Time	Stroop-Errors	Trail Making Test-B
	<i>≥28.53</i>	<i>≥4.69</i>	<i>25.9 ± 1.70</i>	<i>7 ± 2</i>	<i>≥18.96</i>	<i>≥17.35</i>	<i>≥33.24</i>	<i><50</i>	<i><36.92</i>	<i><4</i>	<i><282</i>
1	39.6	6.20	27	5	22.8	15.3	27.75	27.27	28.31	2	446.68
2	47.2	11.90	28	5	26.8	29.5	37.5	0	27.34	2.5	2.80
3	28.60	6.80	28	6	23.4	27.5	27	14.29	19	0	75.12
4	37	10	28	6	28.4	16.9	34	0	13.63	0	37.97
5	35.9	5.90	26	5	26	41.9	19	100	39.95	0	153
6	30.3	9.80	28	6	26.4	42.5	11	33.3	18.14	1	123.16
7	30.6	9.2	27	5	27.8	20.3	35.25	25	25.66	1	159.44
8	44.2	10.9	28	6	27.8	36.5	33.5	0	15.26	0	17.13
9	38	8.90	27	5	36.9	30.9	36	20	22.71	.5	59.12
10	25.3	4.70	26	6	26.4	23.9	21.25	60	21	0	83
11	49.4	10.6	28	5	24.5	43.5	15.5	100	94	5	63
12	28.5	3.90	26	6	21.8	10.5	16.5	62.5	57.28	7.5	173.48
13	54.3	8.80	28	7	30.4	36.5	24	0	21.87	0	48.35
14	27.3	5.60	28	6	27.4	22.9	13	58	44.37	6	125.86

SD = 106.05) than the corresponding verb base forms ($M = 28.85$; $SD = 68.99$; $t = 2.08$, $p < .04$). Nouns derived from verbs were also more frequent than the nouns derived from adjectives ($M = 26.14$; $SD = 43.90$; $t = 2.03$, $p < .05$). However, these differences went against the hypothesis of worse performance for nouns derived from verbs. Nouns derived from verbs did not differ in frequency from adjectives ($M = 76.32$; $SD = 104.06$; $t = -1.77$, $p = .08$).

The four lists of stimuli differed from each other, as expected, also for the main variable that is crucial to be assessed to prove our hypothesis, that is, they differed for the number of alternatives among which the respondent had to select his/her response to the stimulus. This variable was estimated as the number of word-types listed in the corpus of written Italian by Bertinetto et al. (2005) (CoLFIS, <http://www.ge.ils.cnr.it/strumenti.php>), that share the root with the input word and are likely to be involved in processing the response. This number was found to be much higher for verbs (range: 1–8; $M = 3.1$; $SD = 1.6$) than for adjectives (range: 1–4; $M = 1.39$; $SD = .6$), and it was 1 for all nouns. Another variable that could affect processing in the derivation task is the presence, in the set of alternatives, of words more frequent than the target. For instance, from the verb ‘abitare’ [to reside], the noun produced by all participants (that is, the target) was ‘abitazione’ [residence], but the most frequent derived noun from this verb listed in the CoLFIS is ‘abitante’ [resident]. In the subsequent statistical analyses, this variable was coded as 1, to mark the presence of at least one alternative more frequent than the target, and as 0 to mark the absence of such alternative(s).

Finally, nouns derived from verbs did not differ in length ($M = 8.34$; $SD = 2.56$) from verbs ($M = 8.12$; $SD = 1.50$) or from nouns derived from adjectives ($M = 8.36$; $SD = 1.37$), whereas adjectives were shorter ($M = 6.26$; $SD = 1.30$) than words in the other three sets ($F_{3,455} = 20.64$, $p < .01$).

2.3. Apparatus and procedures

SuperLab pro Software (Cedrus, Phoenix, Arizona) was used for stimuli presentation. The software enable registering of the RTs, that is, the time elapsing between the appearance of the word on the screen and the participant's onset of response. SuperLab software creates an Excel spreadsheet from which RTs were taken. Stimuli were presented one at time, in system font, bold, black color, and size 60, on the center of a computer screen. Participants were seated in a quiet room 40 cm away from the video display.

Two blocks of input-words for the derivational morphology task (the 144 verb bases and the 84 adjective bases) and two blocks of input-words for the generation task (the 144 nouns derived from a verb base and the 84 nouns derived from an adjective base) were presented, in a random order both between blocks and within each block. Before presenting each block, participants were instructed to say aloud as quickly and accurately as possible the expected target. For instance, for the NV generation task, the instructions were the following:

“In this task, when a noun appears on the screen, you have to turn the noun into a verb in the infinitive form. For example, if the noun ‘sentimento’ [feeling] appears, you have to say aloud the verb ‘sentire’ [to feel] as quickly as

possible, because the microphone will record your latency. There is a brief training set of items to get used to the task. If it is clear to you how to perform the task, when the word ‘pausa’ [pause] appears, you can press any key to continue.”

For the VN derivation task the instructions were the following:

“In this task, when a verb appears on the screen, you have to turn the verb into a noun. For example, if the verb ‘partire’ [to depart] appears, you have to say aloud the noun ‘partenza’ [departure] as quickly as possible, because the microphone will record your latency. There is a brief training set of items to get used to the task. If it is clear to you how to perform the task, when the word ‘pausa’ [pause] appears, you can press any key to continue.”

The whole testing session (administration of the four blocks of words) lasted about 50 min. The presentation of each block started with the appearance of the word ‘via’ [start] on the screen and ended with the word ‘fine’ [end]. Stimuli were presented in the following sequence: blank page (duration 250 msec); fixation point ‘+’ (duration 750 msec); stimulus word (duration 5000 msec).

The verbal responses were recorded by means of a microphone. The output of the microphone produced a signal that marked the onset of the verbal response. Accuracy was scored manually. During the task, participants did not receive any feedback.

To exclude potential interference of visual perceptual disorders with the analysis of visually presented stimuli (written words), a screening reading test (a list of seven words different from the stimuli of the experiment) was previously administered with the same procedure as in the experiment. All participants (both patients and healthy subjects) performed at ceiling.

2.4. Statistical analyses

To assess differences among the four conditions of the morphology task, mixed ANOVAs were carried out, *by subjects* and *by items*, on both accuracy (as proportion of correct responses) and time (log-transformed RTs). In the *by subject* ANOVAs, group (2 levels: PD patients vs Controls) was the between factor, whereas condition (4 levels: VN, NV, AN, NA) was the repeated measure. In the *by item* ANOVAs, condition was the between factor, and group was the repeated measure.

Input frequency, target frequency, number of alternatives, and number of alternatives more frequent than the target were considered as fixed effects in mixed-effects regression analyses (Baayen, Davidson, & Bates, 2008), to better understand their role in determining the effects tested by the factorial ANOVAs. Group (PD patients vs Controls) was introduced in the regression analyses as well and interactions between all the predictors were tested.

Word frequency was obtained from the corpus of written Italian by Bertinetto et al. (2005) (CoLFIS, <http://www.ge.ilc.cnr.it/strumenti.php>), and was log-transformed to reduce skewness in the distributions (see Kuperman, Bertram, & Baayen, 2010).

In mixed-effects models, not only participants and items were tested as random effects (as these models require), but also the other three variables that can randomly vary within conditions of stimuli, and that might influence performance. The first, dichotomous (0, 1) random variable added to the models was phonetic transparency of derivation, as participants could produce either a transparent derivation such as ‘divertimento’ [entertainment] from ‘divertire’ [to entertain], or an opaque derivation such as ‘distruzione’ [destruction] from ‘distruggere’ [to destroy]. The second, dichotomous (0, 1) variable was the presence or absence of homography between the derivative noun and a verbal inflected form: sometimes the derivative noun was homographic to the 1st or 3rd singular person of the verb (e.g., ‘odio’ [hate, I hate]; ‘firma’ [signature, he/she signs]), whereas in other cases it was not. The third, continuous, variable was input length in graphemes.

The first step of the analysis, carried out with R Software (R Core Team, 2012), was a full factorial model which was progressively simplified by removing the variables that did not reach significance level. No parameter was removed from the model if part of a higher-order interaction. Random effects of participants, items, phonetic transparency, homography, and input length were also tested, to evaluate whether their inclusion significantly increased the model goodness of fit. The statistical significance of the fixed effects was evaluated using a Markov chain Monte Carlo (MCMC) sampling (Baayen et al., 2008). Once the models were fitted, atypical outliers were identified and removed (employing 2.5 SD of the residual errors as criterion). The models were refitted to ensure that the results were not driven by a few overly influential outliers.

A second regression analysis, using the procedure adopted for RTs, was carried out with response accuracy as dependent variable. In this case, mixed-effects logistic models were employed (Jaeger, 2008). It is worth noting that these models do not allow testing of other random effects but participants and items, so the random effects of transparency, homography, and length of the input were not assessed for accuracy.

3. Results

Technical failures and out-of-time responses, that is, responses given after the time limit of 5000 msec (PD patients: 7.2%; Controls: 7.3%) were excluded from the analyses. Raw RTs and accuracy are shown in Fig. 1a–b.

3.1. Latency

For the analysis of RTs, only trials in which the word was correctly produced were taken into consideration (accuracy for PD patients: 80.8%; for Controls: 91.1%). In factorial ANOVAs, only the condition effect was significant both *by subjects* and *by items* ($F_{1,3,78} = 22.14, p < .001$; $F_{2,3,448} = 141, p < .001$), whereas the group effect was significant only *by items* ($F_{1,26} = .35, n.s.$; $F_{2,1,448} = 59, p < .001$) as PD patients were slower than Controls (PD patients: $M = 1612.75, SD = 204.9$; Controls: $M = 1543.25, SD = 148.1$). The interaction effect did not reach significance in either analysis.

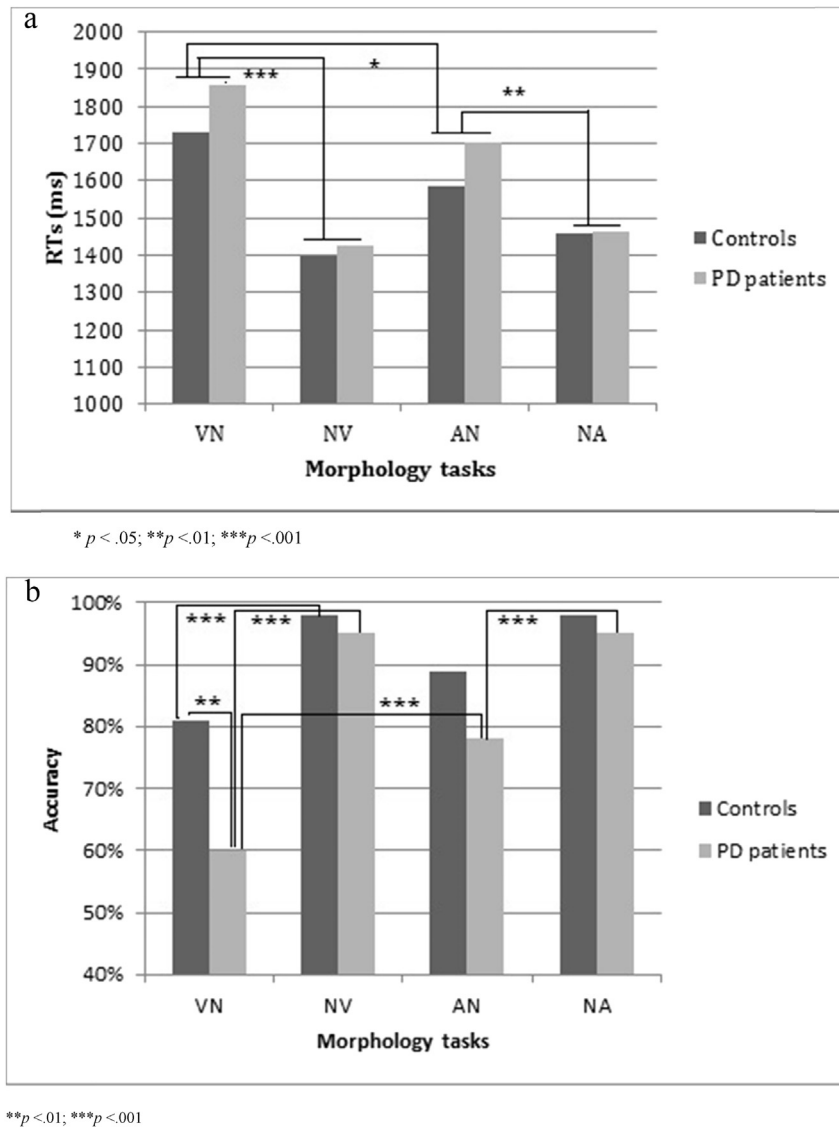


Fig. 1 – a. Response times (in ms) of PD patients and Controls in the various conditions (VN: noun from verb; NV: verb from noun; AN: noun from adjective; NA: adjective from noun). Fig. 1 b. Accuracy (% of correct responses) of PD patients and controls in the different experimental conditions (VN: noun from verb; NV: verb from noun; AN: noun from adjective; NA: adjective from noun).

The effect of condition shows that the derivation tasks, that involve selection among alternatives, were more difficult than the generation tasks, which only required retrieving the word-base: all participants were slower when requested to produce a noun derived from a verb (VN; e.g., ‘osservazione’ [observation] from ‘osservare’ [to observe]; $M = 1774.13$ msec; $SD = 636.9$) than when requested to generate the verb base-form from a derived noun (NV; e.g., ‘fallire’ [to fail] from ‘fallimento’ [failure]; $M = 1412.09$; $SD = 454.3$) (HSD Tukey’s test on $VN > NV$: $p < .001$). In a similar way, latencies to produce a noun derived from an adjective (AN; e.g., ‘gentilezza’ [kindness] from ‘gentile’ [kind]; $M = 1644.73$; $SD = 490.3$) were longer than to produce an adjective base-form from the corresponding derived noun (NA; e.g., ‘bello’ [beautiful] from ‘bellezza’ [beauty]; $M = 1460.23$; $SD = 487.8$) (HSD Tukey’s test on $AN > NA$: $p = .005$).

The difference between the two conditions of the generation task (that is, NV vs NA, in which the input word is a derived noun and the required production is a verb- or an adjective-base form, respectively, was not significant (HSD Tukey’s test: $p = .842$), whereas the difference between the two conditions of the derivation task (that is, VN vs AN, in which the input word is a verb- or an adjective-base form, and the expected production is a derived noun) was significant, as the derivation of noun from verb was slower than noun from adjective (HSD Tukey’s test on $VN > AN$: $p = .02$). It is worth noting that the alternatives in deriving a noun from verb are more numerous than in deriving a noun from adjective.

The mixed-effects model that best fitted the whole data set confirmed the inhibitory effect (which resulted in longer latencies) of input frequency ($b = .009$, $t = 5.73$, $p < .001$), number

of alternatives ($b = .0165$, $t = 7.91$, $p < .001$), and number of alternatives more frequent than the target ($b = .0167$, $t = 2.68$, $p = .007$). These results show that the stronger the competition among lexical entries, due to the high number of alternatives and the presence of high-frequency competitors (including the input word itself), the slower is target selection. In contrast, target frequency produced a facilitatory effect (shorter latencies as a function of the higher frequency) as a main factor ($b = -.0132$, $t = -7.28$, $p < .001$), but also in interaction with group ($b = -.004$, $t = -2.34$, $p = .019$), with the facilitatory effect being more evident for PD patients than for Controls (Fig. 2). This result suggests that when the selection of the target is the outcome of controlled selection processes, as in the case of low-frequency items, PD patients have trouble, but when a high-frequency target overtakes the alternatives thanks to strong activation, PD patients show performance similar to Controls. Phonetic transparency of the derivation, homography between noun and verb forms, and input length, all considered as random variables, had negligible effects on latency.

In summary, latency was longer in derivation than in generation tasks in both groups; in derivation tasks, producing nouns from adjectives (fewer alternatives) was faster than producing nouns from verbs (more alternatives). Frequency of the input, number of alternatives, and number of alternatives more frequent than the target had inhibitory effects on response (longer RTs). High frequency targets facilitated response production (faster responses), mainly in PD patients.

3.2. Accuracy

In the factorial ANOVAs all the effects reached significance level: group ($F_{1,26} = 14.724$, $p < .001$; $F_{2,450} = 301.96$, $p < .001$), condition ($F_{1,78} = 52.406$, $p < .001$; $F_{2,450} = 114.15$, $p < .001$), and interaction group by condition ($F_{1,78} = 5.778$, $p = .001$; $F_{2,450} = 73.57$, $p < .001$): in the VN condition (e.g., ‘osservazione’ [observation] from ‘osservare’ [to observe]) PD patients had a lower level of accuracy than Controls (60.4% vs 80.8%; HSD Tukey’s test: $p = .005$), with a high percentage of pseudoword production from the combination of the verb root with the suffix *-mento*, as a default choice (e.g., ‘osservamento’* [observament*]). The difference between PD and Controls was not reliable in any other condition.

Consistent with the data on latencies, for both Controls and PD patients the derivation of nouns from verbs (VN) was associated with lower accuracy than the generation of verbs from nouns (NV: e.g., ‘fallire’ [to fail] from ‘fallimento’ [failure]) (for both groups HSD Tukey’s test: $p < .001$). However, only PD patients were less accurate when requested to derive nouns from adjectives (AN: e.g., ‘gentilezza’ [kindness] from ‘gentile’ [kind]; 78.3%) than adjectives from nouns (NA: e.g., ‘bello’ [beautiful] from ‘bellezza’ [beauty]; 95.5%) (HSD Tukey’s test: $p < .001$), whereas in controls the difference between the two conditions was not significant (AN: 89.2%; NA: 98.1%; HSD Tukey’s test: $p = .18$). This result suggests that the selection process is particularly difficult in PD patients, as few alternatives to choose from are enough to generate difficulties in response selection.

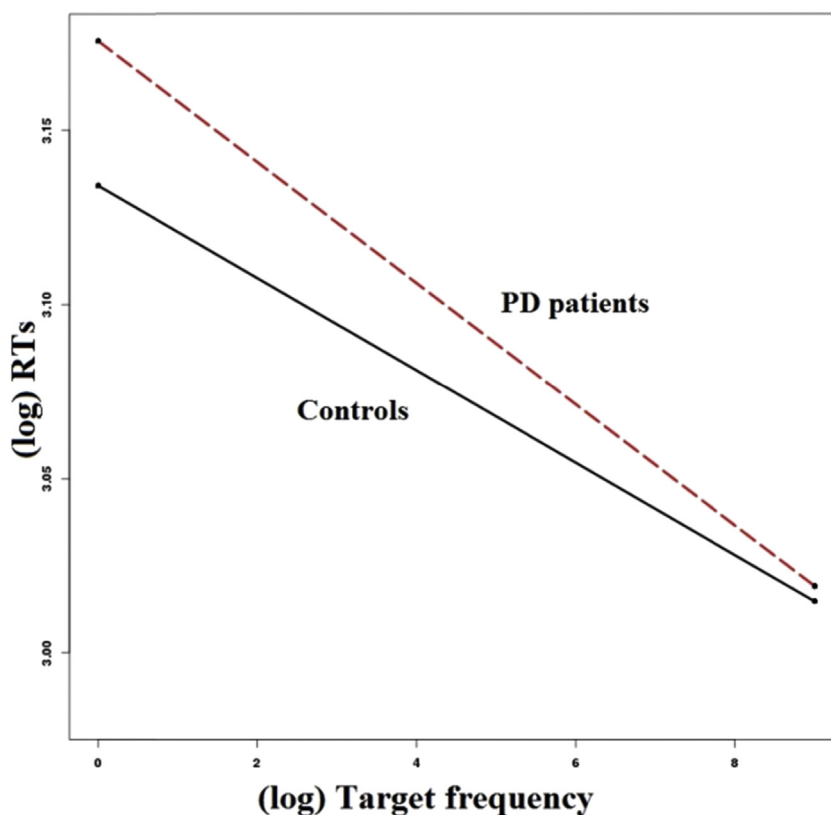


Fig. 2 – Target frequency effect on RTs for PD patients and Controls. The figure refers to the whole data set.

This sensitivity of PD patients to the presence of different alternatives from which the response has to be selected is confirmed by the result that only PD patients were less accurate in deriving nouns from verbs than from adjectives (HSD Tukey's test on VN < AN: $p < .001$), as deriving nouns from verbs requires selection among a higher number of alternatives than deriving nouns from adjectives. When the stimulus word was a noun and the production of a verb (NV) or an adjective (NA) was requested (generation tasks), no difference was significant in either group.

The role of the number of alternatives was confirmed also by mixed-effects logistic models, as this variable reached significance level both as a main factor ($b = -.3978$, $z = -5.85$, $p < .001$) and in an interaction with group ($b = -.1036$, $z = -2.33$, $p = .02$): for PD patients, the difficulty due to the number of alternatives was stronger than for Controls (Fig. 3). Logistic analysis confirmed for accuracy of the main effects found for latency: not only the inhibitory effect of input frequency ($b = -.3106$, $z = -5.649$, $p < .001$), and of the number of alternatives more frequent than the target ($b = -.4033$, $z = -2.474$, $p = .013$), but also the facilitatory effect of target frequency ($b = .4989$, $z = 8.99$, $p < .001$) were confirmed.

In summary, all participants were less accurate in deriving a noun from a verb than generating a verb from a noun. However, for PD patients the derivation task was particularly difficult: in deriving a noun from a verb their accuracy was lower than that of Controls. Moreover, in the derivation tasks, PD patients were less accurate in deriving a noun from a verb (VN: e.g., 'osservazione' [observation] from 'osservare' [to observe]) than deriving a noun from an adjective (AN: e.g., 'gentilezza' [kindness] from 'gentile' [kind]). We assume that

this difference was due to the number of alternatives being higher in the VN condition than in the AN condition. In other words, as expected, PD patients were more sensitive than Controls to the number of alternatives, as their accuracy dramatically decreased when the task required selection among several alternatives. Frequency of the input and the number of alternatives more frequent than the target had inhibitory effects on response (lower accuracy) of both groups. On the contrary, frequency of the target had a facilitatory effect (higher accuracy for more frequent targets) for all participants.

4. Discussion

The use of a morphological paradigm that compares derivation and generation tasks, showed the following: i) contrary to the majority of observations that report difficulties in the production of verbs, noun production can be more difficult than verb production, mostly for PD patients, but also for unimpaired people, due to the complexity of the morphological processes and resources demands associated with the selection processes in derivation tasks; ii) regarding nouns, all participants, but principally PD, showed worse performance when requested to produce a noun, which implied selecting among a larger set of alternatives (as in deriving a noun from a verb) than when requested to produce a noun that had to be selected among fewer alternatives (as in the production of a noun from an adjective-base form); iii) regression analyses confirmed the inhibitory effect of input frequency, number of alternatives, and number of alternatives more frequent than

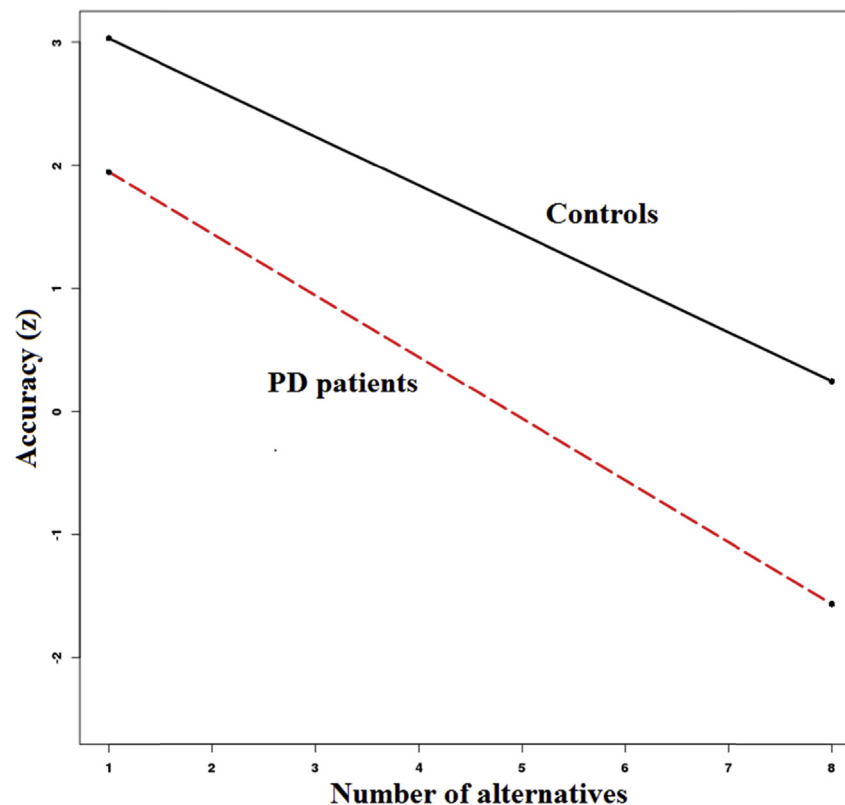


Fig. 3 – Effect of number of alternatives on accuracy for PD patients and Controls. The figure refers to the whole data set.

the target in both groups, and the facilitatory effect of target frequency. It is worth noting that PD patients' latencies were more sensitive to target frequency than those of controls. PD patients' accuracy was also more affected by the number of alternatives than controls' accuracy.

This pattern of results is consistent with [Thompson-Schill and Botvinick's \(2006\)](#) proposal on the mechanisms involved in standard verb-generation tasks, that were described as a network aimed to resolve competition among several alternatives ([Usher & McClelland, 2001](#)).

Our main hypothesis was fully confirmed. In tasks requiring selection processes, latency and accuracy are influenced by the number of alternatives in word selection, irrespective of grammatical class.

Not only number, but also frequency of competitors, and the number of competitors more frequent than the target proved to influence response latency and accuracy. These findings suggest that not only selection but also controlled retrieval could be impaired in PD, as proposed by [Crescentini, Mondolo, Biasutti, and Shallice \(2008\)](#). These authors found in a population of PD patients poor performance on verb production, mostly in the condition in which there was a weak association between stimulus and response, that is, in a condition of high selection demands. As already mentioned, in an fMRI study conducted on healthy subjects, [Crescentini et al. \(2010\)](#) found in a noun-verb production task, activation of the mid part of the inferior prefrontal cortex in a high selection condition, irrespective of noun or verb production (grammatical class); in addition, they also found activation of the anterior part of the inferior prefrontal cortex when a weakly stimulus-related target had to be produced. In this condition, and only when the target was a verb, additional activation was observed in the basal ganglia. The authors concluded, in agreement with [Badre, Poldrack, Paré-Blagoev, Insler, and Wagner \(2005\)](#) that the prefrontal cortex supports not only selection but also controlled retrieval, that is, retrieval in the presence of task-irrelevant interference (in their case interference of nouns that are strongly associated in semantic memory) allowed activation “by default,” in the place of verbs; in this last condition, the prefrontal cortex would be supported by the basal ganglia.

Our results are consistent with the latter conclusion. In the present study, we have shown that a population with corticostriatal damage, such as PD patients, showed increasing difficulties as a function of the number of alternatives involved in response selection, and in the presence of task-irrelevant interference, that is, in the presence of alternatives with a higher word-frequency than the target.

A further finding was that target frequency significantly influenced PD patients' responses, compared to Controls, suggesting, in agreement with previous observations, that PD patients perform better when they are in the condition to easily retrieve the most active alternative. In contrast, they are more prone to fail in the presence of low frequency targets, because, in this condition, their responses may result from controlled selection retrieval.

Many studies confirm that PD patients are unimpaired in tasks requiring automatic access to verbal (syntactic or semantic) information. [Copland \(2003\)](#) obtained normal semantic priming effects in lexical decision with short prime-

target intervals (automatic condition), but not with long prime-target intervals; [Longworth, Keenan, Barker, Marslen-Wilson, and Tyler \(2005\)](#) did not find any impairment in populations with striatal damage (PD and Huntington disease patients) when engaged in tasks requiring automatic regular past tense comprehension and production (with a highly predictable “-ed” suffixation procedure); however, patients showed an inability to suppress activation of representations that become incompatible with speech signals and are semantically appropriate alternatives when trying to inflect novel verbs. The authors considered these results as evidence that the fronto-striatal network is not essential in applying grammatical rules, that is, in combining sequences of morphemes to produce inflected verbs. Instead, their analysis of errors showed that moderate Parkinson's disease is associated with a general difficulty in inhibiting prepotent responses: when asked to inflect a novel verb, they tended to produce lexical intrusion errors, correctly inflected. Similarly, in an event-related brain potential experiment in PD patients who performed syntactic comprehension tasks, early automatic left anterior negativity could still be documented while late P600 potentials related to integration processes were reduced when compared with that of age-matched Controls ([Friederici, Kotz, Werheid, Hein, & von Cramon, 2003](#)).

In general, all these studies demonstrate that the basal ganglia-corticostriatal connections subserve both selection and controlled retrieval during word production and that both processes can be impaired in PD patients; in contrast, automatic processes could be preserved in this population (but see [Colman et al., 2009](#)).

Our findings are definitely consistent with these conclusions; a higher number of correct and faster responses is produced when automatic retrieval is triggered by high frequency targets; however, when the production of automatic responses cannot be facilitated due to low frequency targets, errors and slower responses emerge, due to reduced top-down control during selection processes among alternatives (controlled retrieval), since any factor that increases demands for the inhibition of alternative information has detrimental effects on both accuracy and latency.

Ultimately, our results support the hypothesis that impaired verb production, frequently documented in the literature, could be related to higher processing demands for verbs compared to nouns. In fact, in an experimental condition in which processing demand is higher for nouns than for verbs, nouns get worse.

We do not deny that verbs might be degraded in subjects with disorders of the motor systems ([Bak & Chandran, 2012](#); [Fernandino et al., 2013a](#); [Ibáñez et al., 2013](#)). Neither do we intend to underestimate the involvement of a morphosyntactic deficit in the performance of PD patients ([Péran et al., 2003](#)).

Our results suggest that when interpreting the dissociation between noun and verb processing in PD (but also in other pathological conditions and in unimpaired subjects) the “weight of item difficulty,” that generally penalizes verbs, should be considered. In our experiment, which created conditions that made nouns “more difficult” than verbs, subjects obtained an inverse pattern than that generally described. In other words, the manipulation of variables that interact with task demands, both during word selection and retrieval, such

as the number and strength of competitors in word production and the frequency of the target, may downsize the relevance of linguistic (Caramazza & Hillis, 1991; Péran et al., 2003; Shapiro et al., 2000; Zingeser & Berndt, 1990) or semantic representational factors (Boulenger et al., 2008; Cardona et al., 2014; Rodríguez-Ferreiro et al., 2009).

The interpretation we offer is plausible principally in PD, whose main damage is in the corticostriatal circuits, with less direct involvement of the motor cortex than, for example, in patients with motoneuron disease (although an executive disorder has been hypothesized also in this pathology; Papeo, et al., 2015). In PD patients, in fact, damage to neural substrates, tasked with those processes included in the general term of executive control (the corticostriatal pathway and IFG), makes subjects particularly sensitive to task demands, thus, to any condition that increases the difficulty of the task.

Overall, our results are in line with previous studies that point out the relevance of selection process in word production in PD patients, with the aim to provide an interpretation of the apparent dissociation between grammatical classes in terms of dysexecutive disorders (Crescentini et al., 2010; Siri et al., 2008). Our data are also consistent with the hypothesis that selection processes, at least for verbal material, are subtended by neural substrates in the left prefrontal cortex that interact with the basal ganglia. The selection process is only one of the components that contribute to the complex capacity of word production and we do not underestimate that action verb representation, and thus also production, could be undermined by pathologies that involve the motor systems, as assumed in an “embodied” view where motor experience is at the base of action representation (Barsalou, 1999). Pathology in PD in fact involves cortical areas where motor responses are planned and programmed.

This research did not receive any grant from funding agencies in the public, commercial, or not-for-profit sectors.

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