The effect of motion content in action naming by Parkinson's disease patients

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abreviated title: motion content in action naming task.

ABSTRACT

Introduction: the verb-specific impairment present in patients with motion-related neurological diseases has been argued to support the hypothesis that the processing of words referring to motion depends on neural activity in regions involved in motor planning and execution. We presented a group of Parkinson's disease (PD) patients with an action naming task in order to test whether the prevalence of motion-related semantic content in different verbs influences their accuracy.

Methods: 49 PD patients and 19 healthy seniors participated in the study. All of PD participants underwent a neurological and neuropsychological assessment to rule out dementia. Subjective ratings of the motion content level of 100 verbs were obtained from 14 young voluntaries. Then, pictures corresponding to two subsets of 25 verbs with significantly different degrees of motor component were selected to be used in an action naming task. Stimuli lists were matched on visual and psycholinguistic characteristics.

Results: ANOVA analysis reveals differences between groups. PD patients obtained poor results in response to pictures with high motor content compared to those with low motor association. Nevertheless, this effect did not appear on the control group. The general linear mixed model analytic approach was applied to explore the influence of the degree of motion-related semantic content of each verb in the accuracy scores of the participants. The performance of PD patients appeared to be negatively affected by the level of motion-related semantic content associated to each verb.

Conclusions: our results provide compelling evidence of the relevance of brain areas related to planning and execution of movements in the retrieval of motion-related semantic content.

Key words: motor cortex, verb processing, parkinson´s disease, action naming.

1. Introduction

The processing of words belonging to different grammatical classes has been suggested to depend on different brain regions. For example, verbs have consistently been linked to neural activity in frontal areas. Hence, neurologically damaged patients suffering from frontal lesions have been shown to present a relative impairment of verb, compared to noun, retrieval and understanding (Berndt et al, 1997; Damasio et al., 1992; Daniele et al., 1994). Conversely, neuroimaging data obtained from healthy speakers (Martin et al.,1995; Shapiro et al., 2001, Warburton et al., 1996) have associated the processing of verbs with activity in frontal regions.

However, verbs belonging to different semantic categories (i.e concrete or abstract) have also been shown to elicit neural activity in partially different regions in the brain (Perani et al. 1999; Rodríguez-Ferreiro et al., in press). More specifically, the processing of verbs that refer to movements has been linked to neural activity in motor and premotor regions (Hauk, et alk.,2004; Kemmerer et al., 2007), what has been argued to suggest the existence of a direct link between the activation of semantic content related to motion and the brain regions involved in motor planning and execution. This hypothesis has also been supported by data obtained with patients suffering from motion-related diseases. Hence, Back et al. (2006) found that patients with progressive supranuclear palsy had poor performance in an action, compared to object, naming task. Similar results were found by Cotelli et al. (2006) in patients with corticobasal degeneration, and also by Cappa et al. (1998) assessing patients with frontotemporal dementia.

Parkinson disease (PD) is characterized by motor abnormalities resulting from a neural dysfunction related with dopaminergic pathways connecting the basal ganglia with frontal areas. Regions involved in motor control receive a strong projection from those circuits and are, thus, underactivated in PD patients (Jahansahi et al., 1995). This disturbance affects the patients' movements and, in some cases, their executive functions or language capacities too (Williams-Gray, 2007). PD patients have also been shown to present a relative impairment of verb processing, as revealed by their poor performance in action naming (Rodríguez-Ferreiro et al., 2009, Cotelli et al., 2007) as well as verb fluency tasks (Piatt et al., 1999). The results of these studies support the idea that motor cortices play a crucial role in the semantic processing of actions, however, it could also be argued that this verb-relative impairment is due to the greater dependence of the verb grammatical class on frontal regions in general.

In this study, a group of non-demented PD patients were asked to take part in an action naming task. Action pictures referring to verbs with different levels of motor content were selected in order to investigate the relevance of motor cortices in the processing of motion-related semantics. If the performance of PD patients in verb-related tasks is affected by the degree of motion-related semantic component present in each verb, the idea that the processing of the motion-related semantic content relies on neural activity in the brain structures that control motion would be supported. On the other hand, a lack of effect of the level of motion content in PD patients' performance would indicate a grammatical, rather than semantic, origin of the deficit, which could be attributed to the dependence of verbs, as a grammatical class, on frontal areas in the brain.

2. Method

2.1 Participants

A group of 49 Parkinson´s disease patients (26 females) with a mean age of 72.14 (standard deviation 9.04) and 19 healthy seniors (9 females) with a mean age of 74.84 (S.D. 7.50) took part in the study. The two groups of participants were matched on age, years of education and MMSE score (see Table 1). Prior to their participation in the experiment the PD participants had all been diagnosed with PD according to the UK Parkinson's Disease Brain Bank criteria (Gibb & Lees, 1988). The participants were all native Spanish speakers with no history of alcohol abuse, or neurological or psychiatric disorders other than PD. All the PD patients underwent a full neurological evaluation, neuroimaging and neuropsychological assessment to rule out dementia. A summary of the demographic, clinical and neuropsychological assessment of the participants is presented in Table 2.

2.2 Materials

One hundred verbs were pre-selected, and their corresponding pictures obtained from the Druks and Masterson (2000) Object and Action naming battery or the IPNP database (Szekely et al., 2004). Coloured versions of the pictures were prepared in order to improve the participants' comprehension in the naming task (Rossion & Pourtois, 2004). In order to obtain a measure of the motion content associated to the verbs, an independent sample of 14 young native speakers of Spanish were asked to rate how much movement was needed in order to perform the actions referred by each of them. A one-to-seven scale was used, where one meant "no motion" while seven meant "full motion". Subsets of 25 high (e.g. "to dig") and low (e.g. "to sleep") motor-associations action-verb pairs were then selected. The two groups were matched on the visual complexity and name agreement of the pictures, as well as the lexical frequency, age of acquisition, imageability and number of syllables and phonemes of the picture's names (see table 2). Previous studies of verb processing (Martin & Cheng, 2006) have shown that association strength and selection demands play a significant role in verb generation tasks. In our study, in which participants are asked to name pictures of actions, it seemed more relevant to control for name agreement of the pictures, which, indicates how frequent is the standard name of a given picture, and, thus, provides an indirect measure of picture-word association. These values, in addition to age of acquisition of the names of the pictures, were obtained from the Cuetos and Alija (2003) rating study. Imageability values were taken from the Valle-Arroyo (1999) imageability dictionary. Where data were missing, values were obtained from Rodríguez-Ferreiro, (2009), who gathered values using the same methods as the ones reported in these studies. Data concerning the lexical frequency of the verbs were taken from the LEXESP database (Sebastián-Gallés et al., 2000). An objective measure of the visual complexity of the pictures (Forsythe, et al., 2008) was computed by means of the JPEG compression method (Bates et al., 2003).

2.3 Procedure

Each participant was run through the experimental task individually. The pictures were presented in a separate sheet of paper each. Experimental items were pseudorandomly interspersed with the other fifty pictures of actions used as fillers. The participants were asked to produce the infinitive form of a verb that described the depicted action. Several practice stimuli were presented to the participants before the experimental session started. The experimenter kept a record of every response.

3. Results

Responses that matched the standard picture name, as well as single-word synonyms, were considered correct. Only the first response to each picture was taken into account. The mean score, correct responses out of 25 pictures per category, of PD patients in response to items with low level of motor-associations was 19 (S.D. 4.57), whereas they obtained a mean score of 14.06 (S.D. 4.89) in response to items with high motor-associations. The control group, On the other hand, obtained a mean score of 23 (S.D. 1.29) correct responses to items referring to low motor content and 22,05 (S.D. 1.92) to pictures with high motor-associations. An ANOVA analysis revealed significant differences between the scores of the two groups ($F(1,66)=34.51$ $p<.001$). Differences between the two stimuli types were also obtained ($F1,66)=26.31$ $p<.001$). Furthermore, a significant interaction between group and picture type was also obtained ($F(1,66)=62.49$ $p<.001$) showing that there are more differences between scores corresponding to low and high motor content in PD group than in controls. Planned t tests revealed significant differences between the scores obtained by PD patients in response to pictures with high and low motor content ($t(48)=-11.69$ $p<.001$). However, this effect did not appear between the scores of the control group.

In order to explore the influence of the characteristics of the items in the error production of the patients, the responses by every participant to each item were analyzed by means of the GLMM analytic approach implemented in the lme4 package in R software

A model was evaluated that included the motor-associations measure as a fixed effect and participants and items as random effects. The picture characteristics (visual complexity) as well as the psycholinguistic features of the pictures' names (log-transformed frequency, imageability and age of acquisition, as well as phoneme and syllable length) were also included in the analysis as two sets of orthogonal variables obtained through principal components analyses. The results of the analyses are summarized in table 3. The model fit statistic indicated an excellent fit (C=.86) between the predicted probabilities of correct or incorrect naming and the observed response for the model. The rated motor-associations of the different verbs appeared to influence PD patients' ability to produce correct responses ($p<.05$). One of the orthogonal factors resulting from the principal components analysis of the picture's characteristics also appeared to influence the participants' scores ($p<.01$).

4. Discussion

PD patients assessed in this study obtained significantly lower scores when asked to name actions that referred to verbs with a high degree of motor content, compared to pictures representing verbs with low motion levels. Moreover, a significant negative influence of the motion component in the PD patients' performance was revealed by a regression-like analysis in which average scores of the participants in response to each item were entered along with the respective motion content values.

According to these results, an impairment that affects the processing of verbs as a grammatical class can be ruled out in PD patients. Rather than having a grammatical origin, the verb-relative deficit present in these patients appears to have a semantic nature, with its possible cause in the degradation of dopaminergic pathways that connect brain areas involved in motor control.

It should be noted that the effect of motor associations over PD patients' capacity to name actions found in our study contrasts with the lack of influence of a related variable, manipulability (Saccuman et al., 2006), observed by Cotelli et al.

(2007). The authors relate their null effect to the absence of an impairment of simple limb movement in PD patients. A wider measure of motion content related to the whole body and not just the hand, like the motor association rating used in our study, seems to reflect PD patients' semantic deficit more accurately.

Taken together with the results of previous studies that have found deficits in action naming tasks in patients suffering from PD (Back et al., 2006; Rodríguez-Ferreiro et al., 2009; Cotelli et al., 2007) and other movement disorders (Cotelli et al., 2006), our data add to the growing evidence that patients suffering from neurological diseases affecting motion present a specific impairment of motion-related semantics, and confirm the relevance of brain structures responsible for motion planning and execution in the support of motion-related semantic content.

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Table 1. Mean values (and standard deviations) of demographic characteristics of Parkinson´s disease patients and control group

	Parkinson Mean (TD)	Control Mean (TD)
Age	71,53(9,08)	74,84 (7,50
Years of education	6,60 (3,65)	5,89 (2,70)
MMSE	27,63 (2,65)	29,15 (0,76)

Table 2. Mean Values (and standard deviations) of demographic, clinical, neuropsychological data and number of Parkinson´s disease patients with pathological scores of the Parkinson´s disease patients.

	Mean	**TD**	**nº of PD with pathological scores**
Symptom severity[1]	1,73	0,72	
Disease duration	6,34	4,69	
MMSE[2]	27,63	2,46	0
Action fluency	11,34	4,26	5
Phonemic fluency (P)	11,07	4,25	8
Semantic fluency (animals)	13,61	3,70	3
Alternate fluency	9,20	4,27	7
Phonemic fluency (F)	10,17	4,04	7
Stroop interference	1,89	7,36	15
Visual memory[3*****]	9,74	3,56	12
Cube copy[*]	1,83	1,32	15
Direct dygit[3]	4,83	0,95	13
Reverse digyt[3]	3,63	0,93	13
Attention[3**]	8,90	1,60	4
Comprehension[3***]	8,81	2,56	12
Free recall[3****]	21,19	6,25	23
Key recall[3****]	27,95	6,80	20

[1.] According to the Hoen and Yahr Scale (Hoen & Yahr, 1967)
[2.] MMSE= MiniMental State Examination (Folsteyn et al., 1975)
[3.] Tasks from Barcelona Test-Revised (Peña-Casanova, 2005)
*. Maximum score is 3; **max. score is 10; ***max. score is 12; ****max. score is 46. ***** max score is 16.

Table 3. Summary of stimuli characteristics.

	Motion Associations		
	Low n=25 mean*(S.D)*	High n=25 mean*(S.D)*	
Word characteristics			
Frequency	19.1*(22.2)*	16.1*(21.7)*	N.S.
Imageability	5.9*(0.7)*	5.8*(0.6)*	N.S.
Age of Acquisition	2.7*(0.7)*	2.8*(0.6)*	N.S.
Phonemes	5.7*(1)*	6.2*(1.4)*	N.S.
Syllables	2.2*(0.5)*	2.5*(0.6)*	N.S.
Picture characteristics			
Name Agreement	90.4*(15.5)*	88.9*(11.4)*	N.S.
Visual Complexity	35.8*(11.6)*	37.6*(12.1)*	N.S.
Motion Associations	2.2*(0.6)*	5.1*(1.3)*	***

*** if p < .001, N.S. if p>.02

Table 4. Summary of results of the mixed-effects analysis.

	Estimate	Std. Error	
Fixed Effects			
(Intercept)	1.68	0.45	***
Motion Ratings	-0.22	0.10	*
Word Pr. Comp. 1	-0.04	0.12	
Word Pr. Comp. 2	-0.23	0.14	
Word Pr. Comp. 3	-0.06	0.21	
Word Pr. Comp. 4	-0.17	0.24	
Picture Pr. Comp. 1	-0.11	0.18	
Picture Pr. Comp. 2	0.54	0.18	**
Fit Statistics			
C (concordance)	0.86		

*** if p < .001, ** if p < .01, * if p < .05

Figure 1. Results of Parkinson´s disease and control group in actions with high and low degree of motor content.