

# Action naming is impaired in Parkinson disease patients

Short title: Action naming in Parkinson disease

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**Abstract**

In order to explore the possible contribution of the motor system to the representation of verbs, we studied the relative preservation of the capacity of Parkinson disease patients to name matched sets of object and action pictures. The performance of this group of participants was compared with that of a group of healthy seniors, and a group of Alzheimer disease patients. Generalized linear mixed effects analyses showed that, whereas the two control groups had similar accuracy scores in response to objects and actions, Parkinson disease patients presented a significant impairment in their capacity to name actions compared to objects. The results of this study support the idea that verb representations are grounded in neural networks to which brain areas involved in motor control contribute.

**Keywords:** verbs, semantic representations, selective impairment

Growing evidence supports the view that different semantic categories are represented as distributed neural networks that parallel the organization of the sensory-motor system (Martin & Chao, 2001). Thus, the processing of action-related words (verbs) has been associated to neural activity in cell assemblies that include areas in the regions involved in motion planning and execution (Hauk, Johnsrude, & Pulvermüller, 2004; Kemmerer, González-Castillo, Talavage, Patterson, & Wiley, 2007). Nevertheless, it is still not clear if these patterns of activity reflect a causal role of those structures in the representation of the meaning of motion-related words or they are just a spurious correlate of the processing. In order to address this issue, several studies have investigated the capacity to process actions and verbs of neurologically impaired patients with motor symptoms by means of picture naming experiments. If this kind of patients presents a deficit in their capacity to name actions compared to objects, it could be argued that the contribution of the motor system is critical for the understanding of motion-related words. Thus, Bak, O'Donovan, Xuereb, Boniface and Hodges (2001) as well as Bak and Hodges (2004) and Bak et al. (2006) reported various cases of patients with motor neuron disease showing a relative impairment of action compared to object naming. Similar results have been obtained when patients suffering from progressive supranuclear palsy (Bak et al., 2006; Cotelli et al., 2006; Daniele, Guistolisi, Silveri, Colosimo, & Gainotti, 1994) or corticobasal degeneration (Cotelli et al., 2006; Silveri & Ciccarelli, 2007) have been studied.

However, patients suffering from Parkinson disease (PD), one of the most frequent neurodegenerative disorders in the elderly, have barely been studied with this purpose yet. Some of these patients present neuropsychological impairments in the memory, attention or language domains (Green et al., 2002). Nonetheless, their disease is mainly characterized by a movement disorder with resting tremor and bradykinesia (Ramírez-Ruiz, Junqué, Martí, Valldeoriola, & Tolosa, 2006), what makes them an appropriate population to test the possible involvement of neural structures controlling motion in the lexical-semantic processing of motion-related words. Cotelli et al. (2007) studied the capacity of 32 of this kind of patients to name 60 drawings of objects and 60 drawings of actions. Their results showed a significant impairment in the action naming task, what could support the idea that the motor system is involved in the lexical-semantic processing of motion-related words. The names of the two kinds of pictures they used were matched on lexical frequency and length; however, they did not take

into account other important characteristics of the stimuli, like the name agreement or the visual complexity of the pictures, that are known to affect objects and actions to a different extent (Cuetos & Alija, 2003). It could then be argued that differences in these variables could account for the differences found between the scores in the object and action naming tasks. In fact, Cotelli et al. (2007) report a negative significant correlation between the action naming impairment of each patient and their scores in a visual memory task, what suggests that the characteristics of the drawings could have influenced the ability of those patients to name action pictures. Boulenger et al. (2008) also studied PD patients but they used a completely different procedure, based on a priming paradigm. These authors investigated the lexical decision latencies for nouns and verbs of PD patients when shown after a same-word prime presented in different letter case. Compared to control participants, which presented priming effects for the two kinds of words, PD patients showed an absence of priming effect for verbs.

The aim of this study is to explore the existence of a relative impairment in the capacity to name actions of PD patients through an object and action naming experiment. The performance of a group of PD patients will be compared with those of two control groups: a group of healthy seniors, that should present no deficit; and a group of Alzheimer disease (AD) patients that are known to have a lexical-semantic impairment that affects object and action knowledge to a similar extent (Masterson et al., 2007; Rodríguez-Ferreiro, Davies, González-Nosti, Barbón, & Cuetos, 2009). The results of this experiment will be analyzed by means of Generalized Linear Mixed-effects Models (GLMM). This procedure has several advantages over the methods used conventionally in this kind of studies, like ANOVA, because it is more robust to problems caused by repeated observations, and it allows the separation between the fluctuations in the performance due to the differences among items and participants, and the effects of the experimental manipulations in the dependent variable (Baayen, Davidson, & Bates, 2008).

## **Participants**

Three groups, consisting of a total of 84 Spanish adults, 28 PD patients without dementia, 28 patients diagnosed as probable AD, and a group of 28 healthy seniors took part in the experiment. Patients were diagnosed according to the NINCDS-ADRDA

criteria (McKhann et al., 1984; Tierney et al., 1988) in the case of AD or the UK Parkinson's Disease Brain Bank criteria (Gibb & Lees, 1988) in the case of PD. All the patients underwent a full neurological evaluation, as well as blood tests, neuroimaging and neuropsychological assessment including the MiniMental State Evaluation (MMSE). They all were native Spanish speakers and none of them had a history of alcohol abuse, or neurological or psychiatric disorders other than PD or AD. A summary of the demographic and clinical characteristics of the participants is presented in Table 1. The three groups of participants were matched on age and years of education, however, significant differences ( $F(2,83)=147.299$ ,  $t<.001$ ) appeared between their MMSE scores. Tukey's HSD analyses revealed that PD patients had significantly better MMSE scores than AD patients ( $p<.001$ ) but similar to those of healthy seniors ( $p=.385$ ).

## **Materials**

Fifty pictures of objects and fifty pictures of actions matched in the main psycholinguistic variables were selected to be used in the experiment. Object pictures were taken from the coloured version (Rossion & Pourtois, 2004) of the Snodgrass and Vanderwart (1980) set. Action pictures were gathered from the Druks and Masterson (2000) Object and Action naming battery or the IPNP database (Szekely et al., 2004) and coloured by ourselves. A summary of item characteristics including the name agreement and visual complexity of the pictures as well as the frequency, age of acquisition, imageability and number of phonemes of the picture's names, is reported in Table 2. Experimental items were presented pseudorandomly interspersed with fifty pictures of objects and actions that were used as fillers. Data concerning the lexical frequency of picture names were taken from the Spanish LEXESP corpus (Sebastián-Gallés, Carreiras, Cuetos, & Martí, 2000). Values for the rated imageability of picture names were taken from the Valle-Arroyo (1999) database. Where imageability data were missing, we gathered values from a 50 participant sample using the same methods as those reported by Valle-Arroyo (1999). Name agreement values for some of the action pictures and age of acquisition of their names were obtained from the Cuetos and Alija (2003) study. Missing age of acquisition and name agreement values were gathered by us in two normative studies following the same methods used by Cuetos and Alija (2003). Two new groups of 50 students participated in those surveys. The

JPEG compression method described in Bates et al. (2003) was used to get an objective measure of how complex each picture was (Forsythe, Mulhern, & Sawey, 2008). Kolmogorov-Smirnov analyses showed no significant differences between the name agreement percentages of the object and action pictures or the lexical frequency, imageability, age of acquisition and phoneme length values of their names. However, visual complexity of action pictures turned out to be significantly higher than that of object pictures.

## **Procedure**

The participants were tested individually. The object and action pictures were presented as two separate tasks. The order of the tasks was counterbalanced across participants. Each picture was presented in a separate sheet of paper. The participants were asked to describe the depicted objects or actions using a single word that should be a noun or the infinitive form of a verb respectively. Prior to the experimental tasks several practice stimuli were presented to the participants. The experimenter kept a record of every response.

## **Results**

A summary of the results is presented in Table 3. Only the first response recorded in each trial was entered in the analysis. We counted as correct those responses that matched the standard picture name or were single-word synonyms of the target name (e.g. “andar” and “caminar” in the picture “to walk”). The production of correct responses by each group of participants in response to each picture type was analyzed using the GLMM analytic approach by means of the lme4 package (Bates, 2005) in R (R development core team, 2005).

We first conducted a global analysis evaluating a model that included the three participant groups (Parkinson, Alzheimer and healthy seniors) and the two picture types (actions and objects) as fixed effects. Participants and items were introduced in the model as random effects. Psycholinguistic characteristics of the stimuli were also taken into account in the analyses. However, given the strong correlations existing between most of these variables, we decided to convert them into two separate sets of orthogonal predictors through principal components analyses in order to avoid possible problems due to collinearity. On the one hand, psycholinguistic characteristics of the picture

names (logfrequency, imageability, age of acquisition and phoneme length) were transformed into four independent factors. On the other hand two uncorrelated variables were obtained from the picture-related characteristics (name agreement and visual complexity). These factors could be interpreted as abstract measures of the difficulty of the items in terms of word- and picture-related qualities; however, they do not directly represent any of the initial predictors. The results of the analyses are presented in Table 4.

The performance of the whole group of participants was affected by the difficulty of the different items, in terms of word- ( $p < .001$ ) and picture-related ( $p < .05$ ) features. Overall, control participants produced significantly more correct responses than PD patients ( $p < .001$ ). Even though PD patients performed numerically better than AD patients, no significant differences appeared between these two groups of participants ( $p > .1$ ). In general, significantly more correct responses were produced in response to objects than to actions ( $p < .001$ ). Moreover, the effect of the interactions between picture type and participant group also reached the significance threshold ( $p < .001$ ). The model concordance measure, which indicates how reliable a model is, took a high value ( $C = 0.88$ ) showing an excellent fit between the predictions of the model and the observed data.

In order to more easily interpret the interaction effects, separate analyses were carried out for each participant group (see Table 4). Again, the three groups of participants appeared to be affected by the characteristics of the pictures ( $p_s < .01$ ) and the picture names ( $p_s < .05$ ). Interestingly, our results show that, whereas healthy seniors and AD patients produced similar results in the object and action naming tasks ( $p > .1$ ), PD patients presented a significant ( $p < .001$ ) impairment in action naming compared to object naming. The concordance measures of these models also took high values ( $C_s > 0.87$ ), indicating a very good predictive capacity.

## **Discussion**

According to our predictions, the group of healthy seniors produced the higher amount of correct responses. On the other hand, the AD group showed a very impoverished capacity to name object and action pictures, probably due to the generalized degradation of semantic knowledge that this kind of patients usually present

(Hodges, Salmon, & Butters, 1992). Importantly, neither the control group nor the AD group presented significant differences between their scores in the object and action naming tasks. The PD patients, however, showed a significant impairment of their capacity to name actions compared to objects. These differences appear even when the effects of the characteristics of the pictures and the pictures names are taken into account in the analyses.

Taken together with the results of previous studies that have explored the ability to name actions of other kinds of patients suffering from motor impairments, the data presented here support the idea that the processing of verbs relies on distributed neural networks to which structures associated to motor planning and execution contribute. Similar conclusions had been drawn in studies in which PD patients were also investigated but using an absolutely different method, based on a priming paradigm. However, it should be noted that, due to the use of a single task, we cannot disentangle which is the precise functional component, lexical or semantic, whose degradation results in the selective verb impairment presented in PD patients. Noun-verb dissociations may result from a selective deficit of a certain semantic category, but also from a disturbance affecting a specific group of lexical representations. Further studies using a variety of production and comprehension tasks should be conducted in order to investigate the specific significance of the motor system's role in the representation of verb knowledge.



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## References

- Auer, S., & Reisberg, B. (1997). The Global Deterioration Scale/Functional Assessment Staging. *International Psychogeriatric Association*, 9(Suppl 1).
- Baayen, R. H., Davidson, D. J., & Bates, D. M. (2008). Mixed-effects modeling with crossed random effects for subjects and items. *Journal of Memory and Language*, 59, 390-412.
- Bak, T. H., & Hodges, J. R. (2004). The effects of motor neurone disease on language: Further evidence. *Brain and Language*, 89, 354-361.
- Bak, T. H., O'Donovan, D. G., Xuereb, J. H., Boniface, S., & Hodges, J. R. (2001). Selective impairment of verb processing associated with pathological changes in Brodmann areas 44 and 45 in the motor neurone disease-dementia-aphasia syndrome. *Brain*, 124, 103-120.
- Bak, T. H., Yancopoulou, D., Nestor, P. J., Xuereb, J. H., Spillantini, M. G., Pulvermüller, F., et al. (2006). Clinical, imaging and pathological correlates of a hereditary deficit in verb and action processing. *Brain*, 129, 321-332.
- Bates, D'Amico, S., Jacobsen, T., Székely, A., Andonova, E., Devescovi, A., et al. (2003). Timed picture naming in seven languages. *Psychonomic Bulletin and Review*, 10(2), 344-380.
- Bates, D. M. (2005). Fitting linear mixed models in R. *R News*, 5(27-30).
- Boulenger, V., Mechtouff, L., Thobois, S., Broussolle, E., Jeannerd, M., & Nazir, T. (2008). Word processing in Parkinson's disease is impaired for action verbs but not for concrete nouns. *Neuropsychologia*, 46, 743-756.
- Cotelli, M., Borroni, B., Manenti, R., Zanetti, M., Arévalo, A., Cappa, S. F., et al. (2007). Action and object naming in Parkinson's disease without dementia. *European Journal of Neurology*, 14, 632-637.
- Cotelli, M., Borroni, B., Manteni, R., Alberici, A., Calabria, M., Agosti, C., et al. (2006). Action and Object Naming in Frontotemporal Dementia, Progressive Supranuclear Palsy, and Corticobasal Degeneration. *Neuropsychology*, 20(5), 558-565.
- Cuetos, F., & Alija, M. (2003). Normative data and naming times for action pictures. *Behavior Research Methods, Instruments, & Computers*, 35(1), 168-177.
- Daniele, A., Guistolisi, L., Silveri, M. C., Colosimo, C., & Gainotti, G. (1994). Evidence for a possible neuroanatomical basis for lexical processing of nouns and verbs. *Neuropsychologia*, 32, 1325-1341.
- Druks, J., & Masterson, J. (2000). *An object and action naming battery*. London: Psychology Press.
- Forsythe, A., Mulhern, G., & Sawey, M. (2008). Confounds in pictorial sets: The role of complexity and familiarity in basic-level picture processing. *Behavior Research Methods*, 40(1), 116-129.
- Gibb, W. R., & Lees, A. J. (1988). The relevance of the Lewy body to the pathogenesis of idiopathic Parkinson's disease. *Journal of Neurology Neurosurgery and Psychiatry*, 51, 745-752.
- Green, J., McDonald, W. M., Vitek, J. L., Evatt, M., Freeman, A., Haber, M., et al. (2002). Cognitive impairments in advanced PD without dementia. *Neurology*, 59, 1320-1324.
- Hauk, O., Johnsrude, I., & Pulvermüller, F. (2004). Somatotopic representations of action words in human motor and premotor cortex. *Neuron*, 41, 301-307.

- Hodges, J. R., Salmon, D. P., & Butters, N. (1992). Semantic memory impairment in Alzheimer's disease: Failure of access or degraded knowledge? *Neuropsychologia*, *30*(4), 301-314.
- Hoen, M., & Yahr, M. D. (1967). Parkinsonism: onset, progression and mortality. *Neurology*, *17*, 427-442.
- Kemmerer, D., González-Castillo, J., Talavage, T., Patterson, S., & Wiley, C. (2007). Neuroanatomical distribution of five semantic components of verbs: Evidence from fMRI. *Brain and Language*, doi:10.1016/j.bandl.2007.09.003.
- Martin, A., & Chao, L. L. (2001). Semantic memory and the brain: structure and processes. *Current Opinion in Neurobiology*, *11*(2), 194-201.
- Masterson, J., Druks, J., Kopelman, M., Clare, L., Garley, C., & Hayes, M. (2007). Selective naming (and comprehension) deficits in Alzheimer's disease? *Cortex*, *43*(921-934).
- McKhann, G., Drachman, D., Folstein, M., Katzman, R., Price, D., & Stadlan, E. M. (1984). Clinical diagnosis of Alzheimer's disease: report of the NINCDS-ADRDA work group under the auspices of the Department of Health and Human Services Task Force on Alzheimer's disease. *Neurology*, *34*, 939-944.
- R development core team. (2005). R: A language and environment for statistical computing (Version 2.5.1). Vienna: R foundation for statistical computing.
- Ramírez-Ruiz, B., Junqué, C., Martí, M. J., Valldeoriola, F., & Tolosa, E. (2006). Neuropsychological deficits in Parkinson's disease patients with visual hallucinations. *Movement Disorders*, *21*, 1483-1487.
- Rodríguez-Ferreiro, J., Davies, R. A. I., González-Nosti, M., Barbón, A., & Cuetos, F. (2009). Name agreement, frequency and age of acquisition, but not grammatical class, affect object and action naming in Spanish speaking participants with Alzheimer's disease. *Journal of Neurolinguistics*, *22*(1), 37-54.
- Rossion, B., & Pourtois, G. (2004). Revisiting Snodgrass and Vanderwart's object pictorial set: The role of surface detail in basic-level object recognition. *Perception*, *33*, 217-236.
- Sebastián-Gallés, N., Carreiras, M., Cuetos, F., & Martí, M. A. (2000). *LEXESP. Léxico informatizado del español*. Barcelona: Publicacions UB.
- Silveri, M. C., & Ciccarelli, N. (2007). The deficit for the word-class "verb" in corticobasal degeneration: Linguistic expression of the movement disorder? *Neuropsychologia*, *45*, 2570-2579.
- Snodgrass, J. G., & Vanderwart, M. (1980). A standardized set of 260 pictures: Norms for name agreement, image agreement, familiarity and visual complexity. *Journal of Experimental Psychology: Human Learning and Memory*, *6*, 174-215.
- Szekely, A., Jacobsen, T., D'Amico, S., Devescovi, A., Andonova, E., Herron, D., et al. (2004). A new on-line resource for psycholinguistic studies. *Journal of Memory and Language*, *51*(2), 247-250.
- Tierney, M. C., Fisher, R. H., Lewis, A. J., Zoritto, M. L., Snow, W. G., & Reid, D. W. (1988). The NINCDS-ADRDA work group criteria for the clinical diagnosis of probable Alzheimer's disease: A clinico-pathologic study of 57 cases. *Neurology*, *38*, 359-364.
- Valle-Arroyo, F. (1999). *Normas de Imaginabilidad*. Oviedo: Universidad de Oviedo. Servicio de Publicaciones.