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Unspeakable motion: Selective action-verb impairments in Parkinson's disease patients without mild cognitive impairment

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ABSTRACT

Parkinson's disease (PD) patients show marked impairments in processing action verbs, and to a lesser extent, concrete (specially, manipulable) nouns. However, it is still unclear to what extent deficits in each of these categories are influenced by more general cognitive dysfunctions, and whether they are modulated by the words' implied motility. To examine these issues, we evaluated 49 non-demented PD patients and 49 healthy volunteers in an oral production task. The patients were divided into two groups depending on the presence or absence of mild cognitive impairment (PD-MCI and PD-nMCI, respectively). Participants named pictures of actions varying in motion content (low and high) and of objects varying in manipulability (low and high). The PD-MCI group showed deficits across all four categories. However, PD-nMCI patients exhibited a selective difficulty for high-motion action verbs. This finding corroborates and refines previous results suggesting that disturbances of action-related lexico-semantic information in PD constitute a *sui generis* alteration manifested early in the course of the disease's physiopathology. Moreover, it suggests that the grounding of action verbs on motor circuits could depend on fine-grained intracategorical semantic distinctions.

1. Introduction

Abundant research couched in the embodied cognition framework indicates that high-order domains, including lexical semantics, are grounded in lower-level sensorimotor mechanisms (Barsalou, 2008; Gallese & Lakoff, 2005). For instance, in healthy subjects, motor and premotor brain areas are differentially recruited during processing of action verbs – i.e., verbs denoting bodily actions (Aziz-Zadeh, Wilson, Rizzolatti, & Iacoboni, 2006; Boulenger, Hauk, & Pulvermüller, 2009; Hauk, Johnsrude, & Pulvermüller, 2004; Romero Lauro, Mattavelli, Papagno, & Tettamanti, 2013; Tettamanti et al., 2005). In the same vein, processing of manipulable nouns – i.e., nouns involving manual motor affordances– engages viso-motor circuits (Chao, Haxby, & Martin, 1999; Chao & Martin, 2000; Gerlach, Law, & Paulson, 2002; Grafton, Fadiga, Arbib, & Rizzolatti, 1997; Kellenbach, Brett, & Patterson, 2003; Króliczak & Frey, 2009; Martin, Wiggs, Ungerleider, & Haxby, 1996; Noppeney, Price, Penny, & Friston, 2006). Interestingly, while both action verbs and manipulable nouns involve distinct motor network activity, the latter do so to a lesser extent (Grabowski, Damasio, & Damasio, 1998; Grafton

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et al., 1997), as explicitly captured by a recent model of dynamic crossmodal language embodiment mechanisms (García & Ibáñez, 2016b).

In line with such findings, damage to motor networks has been proposed to differentially compromise processing of action-related language (Abrevaya et al., 2017; Bak, 2013; García, Abrevaya et al., 2016; García, Carrillo et al., 2016; García & Ibáñez, 2014). A crucial model to test this hypothesis is afforded by Parkinson's disease (PD), a neurodegenerative condition in which motor skills are progressively compromised by continuous loss of dopaminergic striatal innervation (Kalia & Lang, 2015). Several studies on non-demented PD patients have reported difficulties in both action verbs and nouns, with more pronounced deficits in the former (Cotelli et al., 2007; Crescentini, Mondolo, Biasutti, & Shallice, 2008). However, abundant research has shown that lexico-semantic deficits in PD can manifest as a selective impairment of action verbs with relative preservation of nouns (Boulenger et al., 2008; Peran et al., 2003; Rodrigues, Ferreira, Coelho, Rosa, & Castro-Caldas, 2015; Rodriguez-Ferreiro, Menendez, Ribacoba, & Cuetos, 2009; Signorini & Volpato, 2006).

Against this background, recent evidence (Bocanegra et al., 2015) suggests that impairments in either category may differentially depend on the integrity of non-linguistic mechanisms: in PD, only action verbs and action concepts would be altered irrespective of general cognitive impairment and executive dysfunction. Moreover, action-verb deficits in PD have been reported to worsen in proportion to their implied motility (Herrera & Cuetos, 2012; Herrera, Rodríguez-Ferreiro, & Cuetos, 2012). However, no study has assessed whether this pattern is related to the patients' overall cognitive profile.

To address these issues, we recruited PD patients with and without mild cognitive impairment (PD-MCI and PD-nMCI, respectively), alongside matched controls, and asked them to name pictures of actions varying in motion content (low and high) and objects varying in manipulability (low and high). Following Bocanegra et al. (2015), we predicted that, even if both action verbs and nouns are grounded in motor networks, only the former should be compromised when damage to those networks has not yet triggered domain-general cognitive disturbances. More specifically, we expected PD-MCI patients to be impaired across all categories, while perhaps showing greater difficulties for action-verb than noun processing. Conversely, PD-nMCI patients were expected to evince a selective deficit in at least one category of action verbs. Confirmation of these hypotheses would further highlight the neurofunctional specificity of the grounding of action verbs in motor (and, particularly, basal ganglia) networks.

2. Materials and methods

2.1. Participants

Forty-nine PD patients and 49 healthy volunteers participated in this study. All of them were Spanish native speakers from Colombia. PD patients were diagnosed by expert neurologists (B. O., M.L., P.D., and L.F.) according to the criteria of the United Kingdom PD Society Brain Bank (Hughes, Daniel, Kilford, & Lees, 1992). Disease stage was established with the Hoehn & Yahr scale (H&Y) (Hoehn & Yahr, 1967), and motor disability was evaluated with section III of the Unified Parkinson's Disease Rating Scale (UPDRS-III) (Fahn & Elton, 1987). All the patients were taking antiparkinsonian medication and were evaluated during the "on" phase. The Levodopa equivalent daily dose was computed according to standard conversion factors of individual anti-parkinsonian drugs (Tomlinson et al., 2010). Patients with Parkinson-plus symptomatology, other neurological disorders, or major psychiatric conditions were excluded. The patients' cognitive screening was performed with the Montreal Cognitive Assessment (MoCA) (Nasreddine et al., 2005), an instrument with reliable psychometric properties which has been recommended to identify MCI in PD (Dalrymple-Alford et al., 2010; Gill, Freshman, Blender, & Ravina, 2008; Hoops et al., 2009; Kandiah et al., 2014; Nazem et al., 2009) and which has been validated in the Colombian population (Gil, Ruiz de Sánchez, Gil, Romero, & Pretelt Burgos, 2015). Finally, the patients' functional skills were rated with the Barthel Index (Mahoney & Barthel, 1965) and the Lawton & Brody Index (Lawton & Brody, 1969).

After a clinical interview and the functional and cognitive screening, patients were classified as PD-MCI ($N = 15$) and PD-nMCI ($N = 34$). These subgroups were similar in age, education level, and clinical features such as years since diagnosis, UPDRS-III score, H&Y rating, and Levodopa equivalent doses (for details about the demographical and clinical variables, see Table 1). MCI diagnosis was made according to the Movement Disorder Society (MSD) Task Force Level I criteria (Litvan et al., 2012). Patients were classified as PD-MCI if they had preserved functional independence and a MoCA score below 23 – the cutoff score suggested for the Colombian population (Gil et al., 2015). Inclusion criteria for the PD-nMCI group were spared functional independence and a MoCA score of 23 or above. None of the patients gave signs of dementia.

The patients' cognitive performance was compared to that of 49 sociodemograhically matched healthy controls with no history of neurological or psychiatric disease. All controls had a score of 23 or above on the MoCA and they had functional independence. These participants were separated into two groups, each matched for age, gender, and years of education with its corresponding PD subgroup (PD-MCI controls: $N = 15$; PD-nMCI controls: $N = 34$). See Table 1 for full demographic and clinical data, including statistical comparisons between the patients' subgroups and their respective controls.

The study was approved by the Ethics Research Committee of Antioquia University and performed according to the Declaration of Helsinki. All participants provided written informed consent.

2.2. Picture-naming task

2.2.1. Stimuli

We pre-selected 100 pictures of objects and 100 pictures of actions. Object pictures were taken from the Center for Research in Language International Picture-Naming Project corpus (Bates et al., 2003) – these have been tested across various languages, including Spanish. Action pictures were selected from Druks and Masterson (2000). All images were monochromatic drawings on a white background.

To classify the object pictures in terms of manipulability (low vs. high), and the action pictures in terms of motion content (low vs. high), we carried out two norming action-semantics rating studies with 34 university students. Prior to each study, participants viewed four illustrative trials with pre-rated items implying low, intermediate, and high degrees of manipulability and motion content. These practice trials provided a common point of reference that helped minimize inter-subjective variability in the ratings. For the object pictures, participants were asked to rate the extent to which each depicted item could be grasped and employed in a manual action. For the action pictures, they were requested to rate how much movement of the limbs and torso was needed to perform the action represented by each item. In both cases, ratings were made on a scale from 1 to 100, with those extremes values indicating minimal and maximal manipulability/motility, respectively. Items rated below 30 points were considered as featuring low manipulability/motility, whereas items rated above 60 points were classified as involving high