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Title: A third-person perspective on co-speech action gestures in Parkinson's disease.

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Corresponding Author: Ms. Stacey Humphries, MRes

Corresponding Author's Institution: University of Manchester

First Author: Stacey Humphries, MRes

Order of Authors: Stacey Humphries, MRes; Judith Holler, PhD; Trevor J Crawford, PhD; Elena Herrera, PhD; Ellen Poliakoff, PhD

Abstract: A combination of impaired motor and cognitive function in Parkinson's disease (PD) can impact on language and communication, with patients exhibiting a particular difficulty processing action verbs. Co-speech gestures embody a link between action and language and contribute significantly to communication in healthy people. Here, we investigated how co-speech gestures depicting actions are affected in PD, in particular with respect to the visual perspective—or the viewpoint - they depict. Gestures are closely related to mental imagery and motor simulations, but people with PD may be impaired in the way they simulate actions from a first-person perspective and may compensate for this by relying more on third-person visual features. We analysed the action-depicting gestures produced by mild-moderate PD patients and age-matched controls on an action description task and examined the relationship between gesture-viewpoint, action-naming, and performance on an action observation task (weight judgement). Healthy controls produced the majority of their action-gestures from a first person perspective, whereas PD patients produced a greater proportion of gestures produced from a third person perspective. We propose that this reflects a compensatory reliance on third-person visual features in the simulation of actions in PD. Performance was also impaired in action-naming and weight judgement, although this was unrelated to gesture viewpoint. Our findings provide a more comprehensive understanding of how action-language impairments in PD impact on action communication, on the cognitive underpinnings of this impairment, as well as elucidating the role of action simulation in gesture production.



The University of Manchester

Max Planck Institute
for Psycholinguistics

*Professor S. Della Sala
& Professor J. Grafman
Editors, Cortex*

6th August, 2015

Dear Professors Della Sala and Grafman,

I am pleased to submit the manuscript "*A third-person perspective on co-speech action gestures in Parkinson's disease*", co-authored by Judith Holler, Trevor Crawford, Elena Herrera and Ellen Poliakoff, to *Cortex*.

A growing body of research in recent years has investigated language impairments in Parkinson's disease, with a particular focus on action-verb processing impairments. However, little attention has been paid to how co-speech gestures (the spontaneous movements of the hands and arms which accompany speech) are affected. The submitted manuscript is the first comprehensive analysis of gestures which specifically depict actions in Parkinson's and provides unique insights into the cognitive processes underlying action representation in this patient group. We observed that when people use their gestures to depict actions, healthy controls produce these overwhelmingly from a first-person perspective (acting out the action) whereas this is significantly reduced in Parkinson's disease. Patients instead tend to depict actions in gesture from a third-person perspective (where their hand may represent an entire person moving through space, for example). We discuss this finding in the context of motor imagery literature in Parkinson's, which suggests that patients may compensate for their impaired ability to simulate actions from kinaesthetic information by relying more on third-person visual features.

These findings shed new light on how Parkinson's disease affects cognitive representations of action as well as overt actions and, critically, how this impacts on communication in real life interaction. The work has implications for understanding more about the nature of communicative changes in Parkinson's, as well as elucidating the role of action representation and motor imagery in gesture production. The paper should be of relevance to those with an interest in action-simulation, language in Parkinson's disease, as well as the current debate around the relationship between language and the motor system more generally.

Thank you for considering this manuscript for publication. We look forward to hearing from you.

Yours sincerely,

Stacey Humphries

Correspondence address:
University of Manchester
103E, Zochonis building
Brunswick Street
Manchester
M13 9PL

Email: Stacey.humphries@postgrad.manchester.ac.uk

Tel: +447446817567

A third-person perspective on co-speech action gestures in Parkinson's disease.

Stacey Humphries^a, Judith Holler^b, Trevor J. Crawford^c, Elena Herrera^d, and Ellen Poliakoff^a

^aSchool of Psychological Sciences,
University of Manchester
Oxford Road
Manchester
M13 9PL
United Kingdom

^bMax Planck Institute for Psycholinguistics
P.O. Box 310
6500 AH Nijmegen
The Netherlands

^cDepartment of Psychology, Centre for Aging Research,
University of Lancaster
Fylde Avenue
Lancaster
LA1 4YF
United Kingdom

^dUniversity of Oviedo
Plaza Feijoo
33003 Oviedo
Spain

Email:

Stacey.Humphries@manchester.ac.uk (*corresponding author*)

Judith.Holler@mpi.nl

T.Crawford@lancaster.ac.uk

elenaherreragomez@gmail.com

Ellen.Poliakoff@manchester.ac.uk

A third-person perspective on co-speech action gestures in Parkinson’s disease.

Abstract

A combination of impaired motor and cognitive function in Parkinson’s disease (PD) can impact on language and communication, with patients exhibiting a particular difficulty processing action verbs. Co-speech gestures embody a link between action and language and contribute significantly to communication in healthy people. Here, we investigated how co-speech gestures depicting actions are affected in PD, in particular with respect to the visual perspective—or the viewpoint – they depict. Gestures are closely related to mental imagery and motor simulations, but people with PD may be impaired in the way they simulate actions from a first-person perspective and may compensate for this by relying more on third-person visual features. We analysed the action-depicting gestures produced by mild-moderate PD patients and age-matched controls on an action description task and examined the relationship between gesture-viewpoint, action-naming, and performance on an action observation task (weight judgement). Healthy controls produced the majority of their action-gestures from a first person perspective, whereas PD patients produced a greater proportion of gestures produced from a third person perspective. We propose that this reflects a compensatory reliance on third-person visual features in the simulation of actions in PD. Performance was also impaired in action-naming and weight judgement, although this was unrelated to gesture viewpoint. Our findings provide a more comprehensive understanding of how action-language impairments in PD impact on action communication, on the cognitive underpinnings of this impairment, as well as elucidating the role of action simulation in gesture production.

Keywords

Parkinson’s disease, gesture, motor imagery, language, action simulation.

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4 **1. Introduction**
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9 Historically, Parkinson’s disease (PD) has primarily been considered a movement disorder,
10 characterised by cardinal motor symptoms such as tremor, rigidity, postural instability, and
11 particularly slowness of movement. It is now well-recognised that PD leads to cognitive deficits in
12 areas such as attention, memory, executive function and visuospatial abilities (Verbaan et al., 2007).
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14 This combination of motor and cognitive impairment can have a profound effect on language and
15 communication, contributing significantly to reductions in quality of life for people with PD (Miller,
16 Noble, Jones, & Burn, 2006). In addition to motor-based speech deficits which result in dysarthria
17 and slowness of speech, PD patients show a reduction in performance on cognitive language tasks
18 such as verbal fluency (Raskin, Sliwinski, & Borod, 1992), providing word definitions, interpreting
19 metaphors, constructing sentences and naming objects (Lewis, Lapointe, Murdoch, & Chenery,
20 1998).
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38 Over and above a more general difficulty with language, PD patients are particularly impaired on
39 tasks where language has an action component. When asked to generate lists of verbs, patients
40 perform significantly worse than on fluency tasks involving other semantic or phonological
41 categories (Signorini & Volpato, 2006). While this deficit could reflect an impairment in executive
42 function, because verbs are more cognitively complex than other parts of speech (Signorini &
43 Volpato, 2006), accumulating evidence suggest it is attributable to the involvement of the motor
44 system in representing verbs (see Cardona et al., 2013, for a review). First, Fernandino et al. (2013)
45 found that PD patients were only impaired relative to controls when processing action verbs (e.g. to
46 grasp, to squeeze), but not abstract verbs (e.g. to depend, to improve). This cannot be explained by
47 executive dysfunction since abstract words are more cognitively complex than concrete words
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1 (Hoffman, Rogers, & Lambon Ralph, 2011) . Second, it has been shown that PD patients make more
2 errors when naming actions with a high motor content (e.g. digging) compared to a low motor
3 content (e.g. sleeping) (Herrera, Rodríguez-Ferreiro, & Cuetos, 2012). Furthermore, impairments in
4 action-verb production and action semantics have been found to occur in the early stages of the
5 disease, in the absence of mild cognitive impairment, and are unrelated to executive function
6 deficits (Bocanegra et al., 2015).
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16 Despite the fact that impairments relating to action and language are well-documented in PD, one
17 area which has received little attention in this clinical population is that of co-speech gestures, which
18 embody a clear link between these two cognitive domains. That is, they are a form of action which is
19 tightly linked to language (Willems & Hagoort, 2007). Co-speech gestures are the spontaneous
20 movements of the hands and arms (and occasionally other body parts) which speakers frequently
21 produce while talking (Kendon, 2004; McNeill, 1992). In healthy people, co-speech gestures are
22 closely related to speech (temporally, semantically and pragmatically), and contribute a great deal to
23 communication (Holler & Beattie, 2003; Hostetter, 2011). Several different types of co-speech
24 gestures, with various functions, have been identified. *Iconic gestures* represent concrete semantic
25 information, often depicting the size, shape, relative position or motion of an object, whereas
26 *metaphoric gestures* represent abstract information (e.g. gesturing in higher gesture space to
27 indicate high intelligence, McNeill, 1992). *Deictic gestures* are pointing gestures, where the speaker
28 typically uses an extended finger or their hand to indicate a referent (Kendon, 2004; McNeill, 1992).
29 Other gestures do not convey any semantic, propositional information themselves but play more of
30 an interactive or pragmatic role. *Interactive gestures* refer to “some aspect of the process of
31 conversing with another person” (Bavelas, Chovil, Lawrie, & Wade, 1992, p.473) such as checking
32 understanding or regulating turn-taking, and *beats* are bi-phasic flicks of the hand which are used to
33 add emphasis and beat the rhythm of speech (McNeill, 1992).
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Some PD patients exhibit ideomotor apraxia when asked to pantomime movements (e.g. “use a hammer”), commonly making spatial errors such as using a body part to represent an object (Leiguarda et al., 1997). However, pantomimic gestures are different to the co-speech gestures we describe in this article, in that they are produced on demand in the absence of speech, whereas co-speech gestures are produced naturally and idiosyncratically as part of the speech-production process (Bernardis & Gentilucci, 2006; Kendon, 2004; McNeill, 1992, 2008). Only a small number of studies have investigated how co-speech gestures specifically are affected in PD and their approach has been limited. An early study by Pitcairn, Clemie, Grey and Pentland (1990) found that gesture production was significantly reduced in PD (N=4), but they analysed gestures without considering the concurrent speech and did not consider all types of gesture. These shortcomings were addressed by Cleary, Poliakoff, Galpin, Dick and Holler (2011) who found no difference between PD patients and controls in gesture rate per 100 words of speech (which takes into account the slower rate of speech in PD) and no difference in terms of the percentage of gestures of each type produced (iconic, metaphoric, deictic, pragmatic and interactive). Participants were video-recorded whilst they described simple actions (pressing a button and turning a door handle) that they had actually performed during an earlier experiment. Whilst gesture rate was unimpaired, the gestures of the PD patients were significantly less precise than controls (e.g. using their whole hand with a downward movement to indicate pressing a button, rather than extending and moving down a single finger), despite the fact they were capable of performing the actions earlier, and that their gesture precision was unrelated to motor symptom severity. This suggests that the cognitive representation of the action underlying the gesture may be less detailed, less accessible, or otherwise affected in PD.

This interpretation is consistent with the Gesture as Simulated Action framework (Hostetter & Alibali, 2008) which proposes that gestures arise from motor simulations which underlie cognitive representations and imagery. When a gesture represents an action we can assume this is based on an underlying cognitive representation of that action, which should activate motor imagery of either

1 an explicit (where participants are specifically asked to imagine a movement) or implicit (where
2 imagery is not directly instructed) nature. Both types of motor imagery have been shown to be
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4 slowed in Parkinson's, such as when people are asked to imagine a sequential finger movement
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6 (explicit) or judge the laterality of rotated images of hands (implicit) (Dominey, Decety, Broussolle,
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8 Chazot, & Jeannerod, 1995). If the production of action gestures does indeed rely on action
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10 representations involving simulations of motor movements, it is reasonable to expect PD patients to
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12 have difficulty producing these kinds of gestures.
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19 One aspect of gesture which provides a window into how the gesturally-depicted action is
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21 cognitively represented is the viewpoint (or visual perspective) that the speaker takes when
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23 producing the gesture. McNeill (1992) describes character viewpoint (C-VPT) gestures, where the
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25 speaker takes on the role of the person enacting the action, from a first-person perspective, placing
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27 their own body in the event. In C-VPT gestures the speaker would use their own hands to represent
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29 the hands of the character they are describing, by "acting out" the action. For example, someone
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31 describing the actions of a skier by clenching the hands into fists while moving them synchronously
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33 up and down at the sides of the body to depict someone using skiing poles would be classed as a C-
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35 VPT gesture. Conversely, observer viewpoint (O-VPT) gestures occur from a third-person
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37 perspective. In this case, the speaker's body remains external to the event; rather than the hands
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39 representing the character's hands, the speaker's hand represents the character (and his/her
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41 actions) as a whole. Someone using the index finger to trace the slalom skiing path a skier followed
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43 down a hillside would be classed as an O-VPT gesture.
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52 There is some evidence that people with Parkinson's favour a third-person strategy during motor
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54 imagery. When mentally rotating hands, patients use the same brain areas normally activated in
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56 healthy people (the posterior parietal-dorsal premotor circuitry), whilst also showing additional
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58 activation in the occipito-parietal cortex and left extrastriate body area (Helmich, de Lange, Bloem, &
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1 Toni, 2007). This suggests that PD patients may compensate for their impaired motor system by
2 using a third-person viewpoint or visual imagery strategy (Helmich, et al., 2007). If the ability to
3
4 imagine and represent movement from a first-person perspective is impaired in PD, this may affect
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6 how first- and third-person viewpoints are used in gesture.
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11 The present study therefore aimed to further investigate the nature of the mental representations
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13 underlying iconic action gestures in PD patients. Speakers' gestures were analysed as they described
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15 viewed actions, whilst the following research questions were considered. (1) Does Parkinson's affect
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17 the rate at which gestures are produced, and is this different for different kinds of gestures? Cleary
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19 et al.'s (2011) study suggests no difference in the rate of gesture production whilst describing a
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21 limited range of actions. We sought to replicate and extend this finding by looking at a wider range
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23 of everyday actions. We also made the task communicative by asking participants to describe the
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25 information to an addressee other than the experimenter, who they were told was unfamiliar with
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27 the material. (2) Does Parkinson's affect the viewpoint employed in gesture when talking about
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29 actions? Since people with Parkinson's may rely on third-person visual compensatory strategies
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31 when doing tasks involving motor simulation or imagery, we predicted that people with Parkinson's
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33 would produce more gestures from a third-person, observer viewpoint than healthy controls. (3) Is
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35 action naming and motor imagery ability in Parkinson's related to the rate of gesture production
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37 and/or the viewpoint employed in gesture? We used a perceptual weight judgement task (Poliakoff,
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39 Galpin, Dick, & Tipper, 2010) as a proxy measure of motor imagery ability, and hypothesised that
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41 performance on this task would be related to gesture viewpoint. We also used a new version of the
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43 action naming task employed by Herrera et al. (2012), in which we asked participants to name not
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45 only static pictures of actions, but also dynamic video clips of actions. Participants completed this
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47 task in part to provide an initial exposure to the actions for the later description task, so they had
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49 already had the opportunity to name each of the actions that they later described. Our analyses here
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1 were more exploratory, and were motivated by the idea that action naming and action gesture
2 production may both rely on the same cognitive representations of action.
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10 **2. Materials and Methods**

11 **2.1 Participants**

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21 29 people with Parkinson's and 28 age-matched controls participated in the study, which was
22 approved by the local NHS research ethics committee (reference 11/NW/0143). Parkinson's patients
23 were recruited via referral from a consultant neurologist at a local Parkinson's clinic, or via
24 advertisements placed in the Parkinson's UK magazine and website. Some of the age-matched
25 controls were spouses or friends of the Parkinson's participants. The remainder were recruited via
26 advertisements at the University of Manchester and via community groups.
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37 Participants were excluded if they had an auditory or visual impairment rendering them incapable of
38 understanding verbal instructions or viewing images on a computer screen, a neurological disease
39 other than PD, if they scored outside the normal range on the Mini-Mental State Examination
40 (Folstein, Folstein, & McHugh, 1975) for dementia screening (<25/30), or if they had previously
41 suffered a serious head injury. All participants were native speakers of English.
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52 Two Parkinson's patients were excluded from the study entirely because of severe dyskinesias
53 (involuntary movements as a side effect of medication) which impaired their performance on all
54 tasks and made gesture analysis impossible. Two further Parkinson's patients were excluded from
55 the gesture-specific analyses because they misunderstood the communicative task (mistakenly
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believing that they were not allowed to mention the name of the action they were asked to describe, leading to the production of contrived, pantomimed actions as opposed to spontaneous co-speech gestures). Three controls were also excluded from the gesture-specific analyses. One person was unwilling to be video-recorded and two had missing video data because of technical errors. In total, 27 PD patients and 28 controls were included in the non-gesture analyses, and 25 PD patients and 25 controls were included in the gesture analyses.

All participants completed a battery of neuropsychological tests (see Table 1), including the Stroop test of executive function (Stroop, 1935), digit span forwards and backwards (Wechsler, 1997), the National Adult Reading Test as a measure of pre-morbid IQ (Nelson, 1982), the Mill Hill vocabulary scale as a measure of reproductive verbal intelligence (Raven, Raven, & Court, 1988), the Geriatric Depression Scale (Yesavage & Sheikh, 1986) and verbal fluency tasks (Lezak, 2004). The PD patients exhibited significantly higher levels of depression, and significantly lower verbal IQ than the control group.

Table 1. Mean (SD) Demographic Characteristics and Neuropsychological Assessment of the Parkinson's (PD) and Age-Matched Controls groups.

	PD patients	Controls	t	p
Gender	19 M, 8 F	12 M, 16 F		
Age	63.38 (6.59)	64.34 (5.65)	.581,	.56
Education	14.59 (3.53)	16.17 (3.13)	1.785,	.08
Geriatric Depression Scale	3.34 (2.66)	1.03 (1.22)	4.3	<.001 *
Digit Span Forwards	6.97 (1.02)	6.86 (0.98)	.386	.701
Digit Span Backwards	4.79 (1.44)	4.97 (1.01)	.513	.61
Mill Hill Vocabulary	22.14 (4.3)	25.1 (3.57)	2.936	.005 *
Verbal IQ (NART)	115.07 (7.93)	119.81 (5.29)	2.535	.014 *

Stroop Interference	0.19 (11.12)	-1.06 (9.16)	.096	.924
Phonetic Fluency	17.33 (6.99)	18.08 (3.89)	.474	.638
Semantic Fluency	25.62 (5.99)	27.9 (4.51)	1.555	.126

* indicates significant group differences

The Parkinson's patients completed the session on their normal medication, at a time of day selected by the participant to maximise a stable "on" period. All but two of the Parkinson's patients were taking dopaminergic medication and reported minimal on/off fluctuations. Motor symptom severity was rated using the motor subsection of the Unified Parkinson's Disease Rating Scale (UPDRS)(Fahn & Elton, 1987). All patients were recruited at Hoehn and Yahr stage III or less (Hoehn & Yahr, 1967). See Table 2 for the clinical features of the Parkinson's group.

Table 2. Clinical features of Parkinson's group.

	Mean	SD
Age of Onset	57.48	6.92
Disease Duration	6.28 years	3.47
Levodopa Equivalent Dose	568.6	302.42
Motor UPDRS	22.44	8.89
Laterality	14 L, 11 R*	

* 2 patients were unsure of side of onset, with both sides now equally affected

2.2 Procedure

After completing the battery of neuropsychological tests outlined above, participants completed an action naming task. Participants viewed 40 photographs and 40 short video clips which depicted every day actions and were required to name the actions as quickly as possible. The video stimuli

1 were collected from the Verb and Noun (VAN) test (Webster & Bird, 2000), whereas the
2 photographs were copyright-free images found on google. The verbs denoting the actions depicted
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4 in the stimuli in each condition (picture vs video) were matched on verb frequency, age of
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6 acquisition and imageability. The final stimulus set was made up of pictures and video clips which
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8 depicted verbs that were rated by 14 undergraduate students (see Herrera, et al., 2012) for the
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10 amount of movement required to perform the action on a 1-7 Likert scale, where 1 represented “no
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12 movement” and 7 represented “full movement”. Subsets of 20 “high” (>5) motion-content actions
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14 (e.g. skiing) and “low” (<3) motion-content actions (e.g. sleeping) were then selected for each
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16 stimulus type (pictures and videos). The stimuli were presented for four seconds each, using
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18 Presentation® software (Version 0.70, www.neurobs.com), and participants responded vocally via a
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20 microphone.
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28 Participants then completed a perceptual weight judgement task (for details see Poliakoff, et al.,
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30 2010), again using Presentation® software, where they viewed short video clips of a person’s hand
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32 moving to pick up a plastic box from a table and place it on a higher surface, and were asked to
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34 guess the weight of the box on a 9-point scale from 50g to 450g in increments of 50. The same box
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36 was seen in all the clips, but it varied in weight (either 100g, 200g, 300g or 400g), so the weight
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38 information could only be gleaned from the movement parameters of the actor.
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45 Finally, participants were video-recorded while they completed an action-description task. A
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47 randomly selected subset of 10 photographs and 10 video clips of actions that they had previously
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49 seen during the naming task were presented again, and participants were asked to describe the
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51 stimuli in as much detail as possible to a confederate addressee. The stimuli were presented in a
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53 randomised order and participants viewed all the photographs or all the videos first,
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55 counterbalanced across participants. The photograph or the final frame of the video remained
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57 onscreen throughout their description; however, the screen was positioned at the side of the
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1 participant to facilitate engagement with the addressee and to allow any gestures to be recorded
2 and visible to the addressee. To encourage rich descriptions and to make the situation appear
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4 communicative, the participant was told that the addressee was trying to match their description to
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6 a separate set of stimuli showing the correct option as well as a selection of similar alternatives. Two
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8 addressees were used in total (only one per participant). In order to ensure some degree of
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10 consistency across participants, the addressees did not talk back to the participant during their
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12 explanation (participants were told the addressee was not allowed to ask questions) but indicated
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14 their engagement and understanding through eye contact and backchannel responses (such as
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16 nodding and “mm-hmm” vocalisations, Yngve, 1970). Participants were fully aware that they were
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18 being video-recorded and that their communication would be evaluated, but they were unaware
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20 that the focus of the study was on gesture.
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28 **2.3 Analysis**

29 **2.3.1 Action Naming**

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37 We recorded participants’ vocal responses and examined both accuracy and reaction times. The
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39 sound files were imported into the phonetic software Praat (<http://www.praat.org>; Boersma &
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41 Weenink, 2015) so that we could accurately establish the onset of the vocal response using the
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43 beginning of the waveform of the sound. Responses were time-locked to the onset of the
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45 photograph or video-clip. We scored closely synonymous verbs as correct (e.g. crouching or
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47 squatting). However, only the participant’s first response was scored, even if they later self-
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49 corrected, so as not to confound reaction times. To take into account the fact that the video clips
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51 varied in terms of when the action became clear (e.g. some videos began with the action mid-flow
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53 whereas in others it took a second or two for the action to begin) 11 younger controls (mean age:
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55 28) completed both the picture and video action naming tasks to establish baseline mean
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“minimum” RTs. We then subtracted these mean RTs for each stimulus from the individual RTs generated by the actual research participants to provide baseline-corrected RTs.

2.3.2 Gesture Coding

The participant video recordings were imported into the software ELAN (<http://tla.mpi.nl/tools/tla-tools/elan/>; Sloetjes & Wittenburg, 2008) for the identification of all co-speech gestures. Unless they occur in direct sequence, gestures are usually triphasic and consist of preparation, stroke (the most meaningful component of the gestural movement) and retraction (McNeill, 1992). Each stroke phase was therefore considered as constituting one gesture. In cases where multiple gestures were produced in succession without the hands returning to rest, each separate gesture stroke was identified as a new gesture and annotated accordingly. Any non-communicative self-grooming movements were not included as gestures (such as rubbing or scratching the face). A second coder who was blind to the experimental hypotheses and to the group status of the participants, re-coded 25.49% of the data (367 gestures from 6 PD patients and 6 controls, randomly selected) for the purposes of establishing inter-rater reliability, which resulted in 91.22% agreement for gesture identification.

The speech produced by the participants during their descriptions was transcribed verbatim. Any speech and gestures produced that were not part of the action-descriptions (such as when asking for clarification of the task) were excluded. The total number of words used and the total number of gestures produced were counted for each participant and used to calculate the number of gestures produced per 100 words of speech for each participant, to take into account speech rate.

1 All gestures were classified according to four gesture types outlined in the Introduction (iconic,
2 metaphoric and deictic, with interactive gestures and beats collapsed into one final category
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4 summarising gestures with a pragmatic function (Kendon, 2004). For each participant, we calculated
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6 the proportion of each type of gestures that they produced out of their individual total.
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11 For the purpose of the gesture viewpoint analysis, only iconic gestures were considered as they are
12
13 the only gesture type that can demonstrate viewpoint in the context of action depiction. Iconic
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15 action gestures were classified as either C-VPT or O-VPT. As in Parrill (2011), gestures were classified
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17 as C-VPT if the speakers hands mapped directly onto the character's hands they were describing.
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19 Gestures were classified as O-VPT if the hands represented an entire body or object as though
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21 describing the scene from a third person perspective (see Introduction for examples of C-VPT and O-
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23 VPT "skiing" gestures found in this dataset). For each participant, the proportion of their total
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25 viewpoint gestures which were classed as character viewpoint was calculated (with O-VPT gestures
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27 constituting the complement of this).
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35 It is worth mentioning a special class of C-VPT gestures known as "body as reference point" (BARP)
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37 gestures identified by Holler and Beattie (2002). BARP gestures involve the speaker referring to their
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39 own body when describing the body of another, but without the speaker's hands mimicking the
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41 character's hands. For example, the speaker may describe the character's beard by "drawing" it onto
42
43 their own face, or may describe the length of a character's hair by touching their own head and
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45 moving the hands downward. We found many examples of BARP gestures in our dataset, but we did
46
47 not include them as C-VPT gestures as they were not representing the character's action, but the
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49 character's appearance. However, we re-ran our analysis with BARP gestures included as C-VPT
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51 gestures and the results did not change.
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A second, independent coder who was blind to the experimental hypotheses re-coded 33.5% of the iconic action-gesture data (162 gestures from 6 PD patients and 6 controls, randomly selected) for viewpoint, resulting in a percentage agreement of 85.19% and a Cohen's Kappa = .80, indicating a high level of agreement (Landis & Koch 1977).

3. Results

Table 3. Mean (SD) baseline-corrected reaction times for action-naming (in ms), weight judgement task performance summarised by R-squared, gesture rate per 100 words and the proportion of gestures classified as each different type for PD patients and controls.

	Parkinson's		Control		t	p	d	95% C.I.
	Mean	SD	Mean	SD				
Pictures-High	381.26	301.58	235.83	243.05	2.01	.05*	.53	.29-290.57
Motion								
Pictures-Low	402.14	271.73	296.68	250.36	1.53	.133	.40	-33.16-244.08
Motion								
Videos-High	380.86	311.76	216.5	222.12	2.3	.025*	.61	21.07-307.65
Motion								
Videos-Low	432.49	284.37	298.73	237.03	1.93	.06	.51	-5.01-272.52
Motion								
Weight	.16	.15	.27	.15	2.74	.008*	.75	-.19--0.03
Judgement R²								
Gestures per	1.7	1.92	2.17	3.05	.54	.595	.19	-2.28-1.38
100 words								
% Iconic	69.48%	.27	72.48%	.22	.41	.684	.12	-.18-.19
% Metaphoric	.08%	.01	1.23%	.03	1.65	.106	.5	-.03-.00

% Deictic	10.51%	.13	10.91%	.13	.10	.919	.08	-.07-.08
% Interactive	18.5%		15.38%		.53	.599	.16	-.09-.15

** Significant group differences*

3.1 Action Naming Task

Controls responded significantly faster than patients in high-motion conditions, but not in low-motion conditions, although the group difference for the video low-motion condition demonstrates a trend towards significance (Table 3).

3.2 Weight Judgment Task

Figure 1. Mean weight estimates (in grams) compared to the actual weights (in grams) of the blocks for PD patients and controls.

[figure 1 about here]

To analyse performance on the weight judgment task, each participant's mean response to each weight level was calculated (see Figure 1 above). Both groups were able to do the task in that their weight judgements increased as did the weights themselves. However, both groups showed a tendency to overestimate the lighter weights and underestimate the heavier weights, leading to a narrower range of estimates than the actual range of weights and suggesting that they found the task difficult. Performance on the task for each participant was summarized by the R² value of the linear regression between the actual weights and the participant's judgements and Figure 1 illustrates that the slope was steeper for the control than the PD group, suggesting that their

1 performance was more accurate. This was confirmed statistically with a significantly lower R^2 value
2 for the PD patients than controls (see Table 3).
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6 **3.3 Gesture Rate and Gesture Types**

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10 In total, 1440 gestures were identified and coded in ELAN. Five PD patients and two controls did not
11 produce any gestures. There were no group differences in the rate of gesture production (see Table
12 3). In the PD group, the rate of gesture production was not correlated with the level of motor
13 symptom severity as assessed by the UPDRS ($r = -.104$, $p = .61$).
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23 We asked whether gesture rate when describing actions could be predicted by performance on tasks
24 involving action representation. A multiple regression was performed to assess whether group (PD
25 patient or control), performance on the weight judgement task or mean action naming speed (static
26 actions only, baseline corrected) predicted gesture rate, however the overall model was not
27 significant ($R^2 = .073$, $F(3, 48) = .612$, $p = .657$). Evaluating each predictor individually also did not
28 reveal any significant effects.
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40 In addition, we did not find any group differences in the proportion of gestures classified as iconic,
41 metaphoric, deictic or interactive/pragmatic (see Table 3). Overall, the pattern of gesture type usage
42 was very similar between the groups.
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52 **3.4 Gesture Viewpoint**

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57 *Figure 2. Mean proportions of C-VPT and O-VPT gestures for PD patients and controls.*
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[figure 2 about here]

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4 For this analysis, 10 participants were excluded (7 PD patient and 3 controls) as they did not produce
5 any iconic action-gestures depicting viewpoint. In total, 491 viewpoint gestures were analysed. For
6
7 each participant, the percentage of iconic action-gestures categorised as observer and character
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9 viewpoint was calculated. An independent samples t-test revealed a significant group difference
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11 (t(38) = 3.395, p=.001), with controls producing proportionally more C-VPT gestures (mean =
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13 74.99%, SD = 23.28 than PD patients (mean = 48.21%, SD = 25.11) (see Figure 2). There was no
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15 relationship between motor-UPDRS score and the proportion of C-VPT gestures in the PD patient
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17 group (r = -.3, p = .27).
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26 A multiple regression was conducted to assess whether group (PD or control), performance on the
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28 weight judgement task or mean action naming speed predicted the proportion of C-VPT gestures,
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30 and whilst the overall model was significant ($R^2 = .27$, $F(3, 36) = 4.34$, $p = .01$), only group was a
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32 significant predictor ($\beta = .537$, $p = .001$). Weight judgement performance ($\beta = .036$, $p = .81$) and
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34 action naming speed ($\beta = .163$, $p = .3$) did not predict gesture viewpoint.
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44 **4. Discussion**

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49 The present study aimed to elucidate how changes in action-representation might affect gesture
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51 production in Parkinson's disease. We examined performance in tasks thought to engage these
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53 processes (weight judgement and action naming) and explored the manner in which action
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55 information is expressed in gesture in people with PD and healthy age-matched controls.
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1 In accordance with Cleary et al. (2011), no difference in the rate of gesture production per 100
2 words spoken was found between the Parkinson's patients and the controls. Furthermore, gesture
3 rate was not correlated with motor symptom severity in the Parkinson's group. This suggests that
4 there is not a straightforward reduction in gesture use in early Parkinson's disease, despite the fact
5 that movement generally is slowed and reduced in these participants. This finding shows that
6 gesture use is intrinsic to communication and speech production, even in a movement-impaired
7 sample. However, it is likely that reductions in gesture production would be seen in patients with
8 more severe motor symptoms.

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21 Whilst there was no quantitative change in gesture production in the Parkinson's patients, the
22 results suggest that PD can influence qualitative aspects of gesture production when describing
23 actions. We found that healthy older adults tended to produce more gestures from a character-
24 viewpoint when describing actions, whereas people with Parkinson's produced more gestures from
25 an observer-viewpoint. This suggests that the way actions are cognitively represented may have
26 changed in PD, and complements previous work demonstrating the effect of Parkinson's on verbal
27 language with an action component (Fernandino, et al., 2013; Herrera, et al., 2012; Signorini &
28 Volpato, 2006).

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42 One possible explanation is that PD patients are less able to cognitively simulate the action that they
43 are asked to describe. As described in the introduction, when PD patients mentally rotate hands, the
44 extrastriate body area (EBA) shows significant activation which is absent in controls (Helmich, et al.,
45 2007). The EBA is involved viewing body parts. It responds more to static aspects of the human form
46 rather than dynamic motion (Downing, Peelen, Wiggett, & Tew, 2006), and, critically, to allocentric
47 (third person) views of bodies more than egocentric (first person) views (Chan, Peelen, & Downing,
48 2004; Saxe, Jamal, & Powell, 2006). A study using continuous theta-burst stimulation (cTBS) to
49 interrupt brain function suggested that the EBA may be compensating for a function normally
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1 performed by the dorsal premotor cortex. Typically, mental rotation of hands improves when they
2 match the posture of the participant's own hand. However, when the EBA was inhibited with cTBS,
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4 the benefit of this posture congruency effect was lost in PD patients but not in controls. Conversely,
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6 cTBS of the dorsal premotor cortex reduced performance in the control group, but not the PD group
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8 (van Nuenen et al., 2012). This compensatory effect during motor imagery in PD may therefore
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10 underlie the gesture viewpoint finding reported in the present study. PD patients may be less able to
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12 imagine or cognitively simulate the actions from a first person perspective, and so rely more on
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14 third-person, visual information to represent the action, which then influences the viewpoint of the
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16 subsequent gesture.
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23 From a theoretical perspective, our results support the notion that action gesture production in
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25 healthy people relies on motor-based action-representations, in line with the Gesture as Simulated
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27 Action framework (Hostetter & Alibali, 2008). The GSA framework also predicts that gestures
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29 produced as a result of motor imagery are more likely to be C-VPT gestures, whereas gestures
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31 produced as a result of visual imagery are more likely to be O-VPT gestures. We propose that the
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33 viewpoint findings reported in this study reflect a reliance on, or preference for, visual imagery over
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35 motor imagery when representing or simulating actions in PD. Taken together, our findings
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37 corroborate the notion that while simulations of motor movements and visual imagery may underlie
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39 gestural actions, as predicted by the GSA framework, they also appear to be connected with the
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41 linguistic system in a way special way compared to goal-directed motor movements (Cole, Gallagher
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43 & McNeill, 2002). This may account for the preserved gesture rate in PD patients despite motor
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45 impairments.
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57 In relation to other measures of action representation, we did not find any relationship between
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59 action naming speed or performance on the weight judgement task and gesture rate or viewpoint.
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1 We hypothesised that if performance on the weight judgement task reflects motor imagery ability,
2 that this should be related to the ability to produce action gestures from a first person perspective.
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4 However, although we did find an overall group difference in performance on this task, PD patients
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6 are still able to do the task to a degree, that is, their weight estimates do increase in line with the
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8 increase in actual weight (Poliakoff, et al., 2010). Therefore, it is possible that patients are able to do
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10 the task by relying more on visual information than kinematics (cf. Helmich et al., 2007). Indeed, it
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12 has previously been shown that even healthy participants rely on a mixture of visual and kinematic
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14 cues to perform this task (Hamilton, Joyce, Flanagan, Frith, & Wolpert, 2007), which could account
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16 for why we did not find a relationship between weight judgement performance and gesture
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18 viewpoint.
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26 We also replicated the finding of Herrera, et al. (2012), that PD patients were significantly slower
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28 than controls to name actions with a high motor component (either in still or dynamic form), but not
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30 when naming actions with a low motor component. This is consistent with a difficulty in simulation,
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32 but we did not find a relationship between naming speed and gesture viewpoint. Speed was not a
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34 factor during the action-description task, however, as participants were given unlimited time to
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36 describe the actions in as much detail as they could. The fact that we did not find a relationship may
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38 be because the naming task reflects only the speed with which patients can simulate actions,
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40 whereas the viewpoint finding reflects the quality of the simulation itself. Hickok (2010) argues
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42 against the involvement of the motor system in action semantics, stating that motor information
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44 may contribute to but is not necessary for the understanding of action information. After all, with an
45
46 impaired motor system in PD it is not that people can no longer understand action concepts, but
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48 that their ability to access action representations is slowed down. Similarly, although we found that
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50 the production of C-VPT gestures was significantly reduced in PD, the patients in this study did still
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52 produce some gestures from a first person perspective. This could indicate that because of their
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54 impaired motor system, simulating others' actions from a first person perspective may be more
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1 demanding in PD but is certainly not impossible, and that the third person perspective may have
2 become an easier way of simulating others' actions and thus preferred. The viewpoint findings from
3 the present study are interesting because they suggest that whilst the involvement of the motor
4 system may not be critical for the understanding of action, it can still influence how people are able
5 to communicate and share information about actions.
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14 A potential criticism which could be levelled at this study, is that the gesture findings may not reflect
15 a change in action-representation as we propose, but may instead simply reflect the fact that some
16 types of movements are easier to perform than others, making them more preferred movements for
17 PD patients. This account is unlikely since the extent of movement required to perform either a C-
18 VPT or O-VPT gesture did not appear to favour O-VPT gestures in terms of simplicity. For example, a
19 C-VPT skiing gesture could be achieved by simply placing both hands roughly at the sides of the body
20 with a loosely closed fist, whereas O-VPT skiing gestures seen in this study involved one hand being
21 brought up high in front of the face with a pointed finger and moving down in an S-shape towards
22 the abdomen. Secondly, there was no relationship between general motor symptom severity and
23 any of our gesture outcome measures, suggesting that impaired motor function alone cannot
24 account for changes in gesture viewpoint. Overall, our results can be explained by a reliance on third
25 person visual action information, consistent with existing literature on action representation and
26 motor imagery in PD.
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47 This is the first comprehensive analysis of gestural action communication in Parkinson's, in which we
48 have demonstrated that Parkinson's disease reduces the production of action-gestures produced
49 from a first person perspective. We propose that this finding is related to a difficulty in simulating
50 actions from a first person perspective and a reliance on third person, visual features. Our
51 examination of action-gesture production in Parkinson's provided a window into the cognitive
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1 processes underlying action representation in PD, as well as the processes underlying action gesture
2 production in healthy participants.
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10 11 12 13 14 15 16 **Acknowledgements** 17

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25 reliability coding.
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Figure 1.

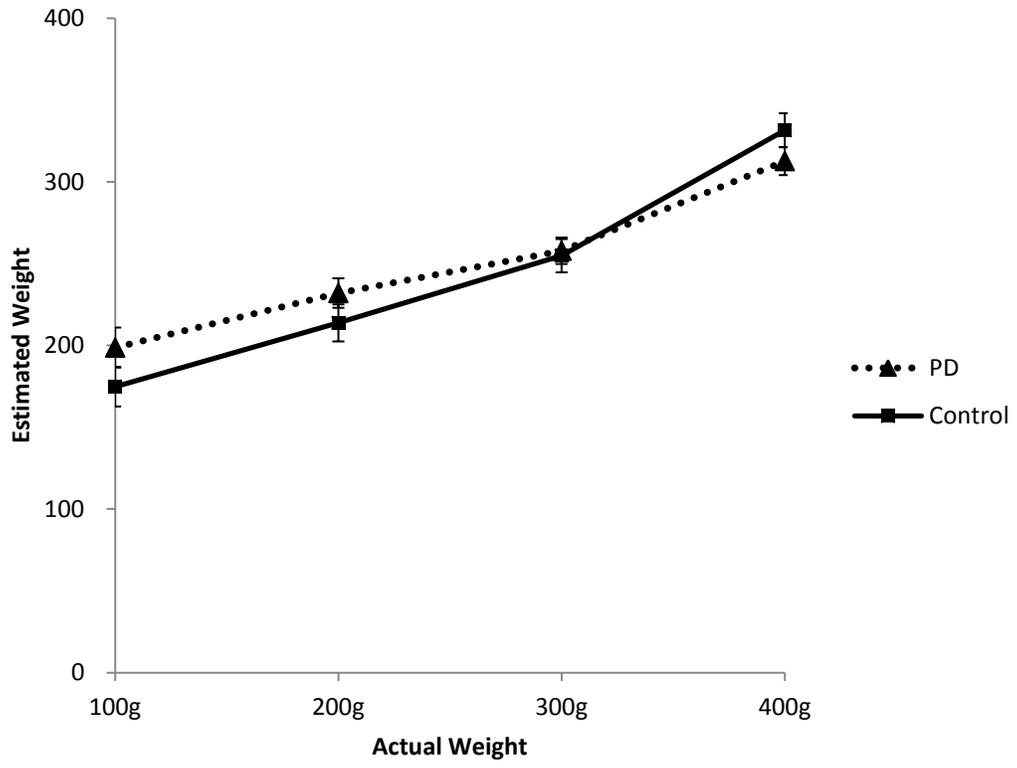
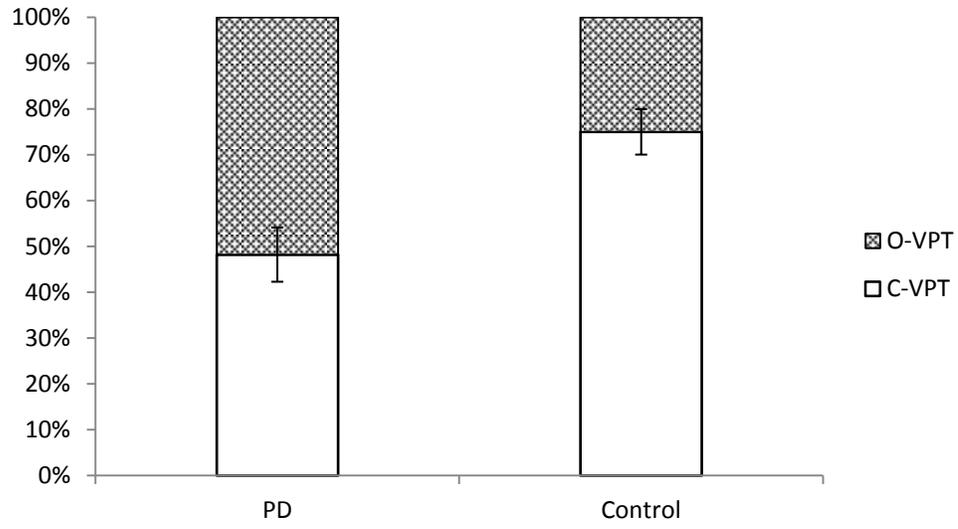


Figure 2.



Highlights

- Extending literature on action-language impairments in Parkinson's, this is the first analysis of action-gesture production in these patients.
- We examined the action-gestures produced by Parkinson's patients and healthy age matched controls on an action description task.
- Controls produce the majority of action-gestures from a first person perspective, where their own hands mimic the hands of the person being described to "act out" the action.
- This is significantly reduced in PD patients who produce more gestures from a third-person perspective, where their hand may represent an entire person moving through space.
- We interpret this in the light of motor imagery research in Parkinson's demonstrating that patients have difficulty with action simulation and rely more on third-person visual features of actions via compensatory mechanisms.