Human Movement Science 33 (2014) 343–353

Contents lists available at ScienceDirect

Human Movement Science

journal homepage: www.elsevier.com/locate/humov

The role of embodied simulation in mental transformation of whole-body images: Evidence from Parkinson's disease

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ARTICLE INFO

Article history:
Available online 26 November 2013

PsycINFO classification:
2520 Neuropsychology & Neurology

Keywords:
Embodied cognition
Action simulation
Mental transformation
Parkinson's disease
Mental rotation
Motor imagery

ABSTRACT

It has been repeatedly demonstrated that mentally performing an action and mentally transforming body-parts entail simulation of one's own body movements, consistent with predictions of embodied cognition theories. However, the involvement of embodied simulation in mental transformation of whole-body images is still disputed. Here, we assessed own body transformation in Parkinson's disease (PD) patients with symptoms most affecting the left or the right body side. PD patients were required to perform left–right judgments on front-facing or back-facing human figures, and a letter rotation task. Results demonstrated that PD patients were selectively impaired in judging the side of back-facing human figures corresponding to their own most affected side, but performed as well as healthy subjects on mental transformation of front-facing bodies and on letter rotation. These findings demonstrate a parallel impairment between motor and mental simulation mechanisms in PD patients, thus highlighting the specific contribution of embodied cognition to mental transformation of whole-body images.

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0167-9457/$ - see front matter © 2014 Published by Elsevier B.V.
http://dx.doi.org/10.1016/j.humov.2013.10.006

1. Introduction

Classical psychophysical studies showed that when healthy participants have to judge whether a hand image with a specific spatial orientation is left or right (i.e., the hand laterality task) they imagine their own hand moving to match the stimulus orientation for responding (Parsons, 1987a, 1994; Sekiyama, 1982). Moreover, making hand laterality judgments and executing a hand movement follow the same temporal profile and the same hand-specific joint-constraints (Conson, Mazzarella, & Trojano, 2011; de Lange, Helmich, & Toni, 2006; Parsons, 1987a, 1994; Sekiyama, 1982). Accordingly, specific impairments on the hand laterality task and spared mental transformation of object images have been reported in patients with severe motor disorders, such as locked-in syndrome (Conson, Pistoia, Sarà, Grossi, & Trojano, 2010; Conson et al., 2008), amyotrophic lateral sclerosis (Fiori et al., 2013a) or spinal cord injury (Fiori et al., 2013b). These observations consistently support the model of embodied cognition according to which cognitive processes are grounded in bodily states (Gallese & Sinigaglia, 2011). In this view, the same sensorimotor representations activated when performing an actual action are also involved in different "action-related phenomena" such as motor imagery (i.e., mental simulation of body-parts movements), action observation and imitation (Decety & Grèzes, 2006; Gallese & Sinigaglia, 2011; Jeannerod, 2001).

No clear data are available instead on the role of embodied simulation in mental transformation of whole-body images. In a seminal neuroimaging study, Zacks, Rypma, Gabrieli, Tversky, and Glover (1999) presented participants with front-facing or back-facing schematic human figures with one outstretched arm; in order to judge which arm was outstretched (i.e., left–right judgment), participants imagined themselves in the position of the figure. This own body transformation led to increased cortical activity in the temporo-parietal junction, as well as in other areas including the frontal cortex. Subsequent neurofunctional studies employing the same paradigm (Arzy, Mohr, Michel, & Blanke, 2007; Arzy, Thut, Mohr, Michel, & Blanke, 2006; Blanke et al., 2005) confirmed the involvement of the temporo-parietal junction in whole-body processing and suggested that whole-body transformations imply some sort of "rotation of the self" (Arzy et al., 2006, 2007; Blanke et al., 2005). This evidence would suggest that, analogously to body-parts transformation, mental transformation of whole-body is grounded on embodied cognitive processes (Kessler & Thomson, 2010). However, other studies demonstrated that whole-body transformation can also be accomplished by resorting to an object-based, visuospatial transformation not related to one's own body representation (Gardner, Brazier, Edmonds, & Gronholm, 2013; Kessler & Wang, 2012). For instance, Kessler and Wang (2012) reported that healthy individuals with low empathic abilities were more prone to rely on object rotation strategies to solve the own body transformation task. These findings would undermine the idea that whole-body transformation is dependent on actual sensorimotor information available in the agent's brain.

In synthesis, the role of embodied simulation in whole-body transformation is not supported consistently. Strong clues on this issue could be provided by a behavioral study on patients with a well-defined damage of the motor system, such as Parkinson's disease (PD).

Neuropsychological studies investigating mental transformation of body-parts in PD patients by means of the hand laterality task reported motor imagery asymmetries: patients mentally simulated movements more slowly with their most affected hand (Amick, Schendan, Ganis, & Cronin-Golomb, 2006; Dominey, Decety, Broussolle, Chazot, & Jeannerod, 1995). These results were confirmed by recent experiments in which PD patients performed the hand laterality task while keeping their arms in different postures (Helmich, de Lange, Bloem, & Toni, 2007; van Nuenen et al., 2012). Taken together, available evidence supported the strong relationships between motor disorders and mental transformation of body-parts in PD patients. However, no evidence is available about mental transformation of whole-body images in this clinical population.

In the present study we required PD patients to perform own body transformation tasks requiring laterality judgments on a schematic human figure. If sensorimotor information is causatively involved in processing of whole-bodies, we can predict that PD patients would be impaired on own body transformation task, and that the side of motor impairment would affect behavioral performance, with opposite patterns in patients with left or right most affected side. More precisely, consistent with previous studies on mental transformation of body parts (Helmich et al., 2007; van Nuenen et al., 2012),