Published in Trends in Cognitive Sciences, 27(1), 7–8. which should be cited to refer to this work. https://doi.org/10.1016/j.tics.2022.09.010

The "hand paradox": distorted representations guide optimal actions

Michela Bassolino[1,2,3], Cristina Becchio[4, 5]

[1]Institute of Health, School of Health Sciences, HES-SO Valais-Wallis, Sion, Switzerland
[2]The Sense Innovation & Research Center, Sion and Lausanne, Switzerland
[3]Department of Clinical Neuroscience, Centre Hospitalier Universitaire Vaudois (CHUV), MySpace Lab, Lausanne, Switzerland
[4] Department of Neurology, University Medical Center Hamburg-Eppendorf, Germany
[5] Cognition, Motion and Neuroscience, Italian Institute of Technology, Genoa, Italy

Corresponding author: michela.bassolino@hevs.ch

Keywords: body representations, motor control, manual action, body distortions, neurorobotics, neuroprostheses

Distortions of body representations are not the exception but the rule. In his authoritative review, Longo[1] describes how there is a general tendency to overestimate the body width relative to the body length. For example, the perceptual representation of the hand features shortened fingers and a widened palm in a number of tasks and modalities (e.g.[1,2]). This raises an interesting paradox. Effective motor control requires accurate information about the structure, dimension, and position of the hand. How can the highly distorted representation of the hand be compatible with skilled manual action? [1,3]

We consider three hypotheses. We focus on hand distortions, but the same considerations can be applied to other body parts.

Distorted hand representations are not used to guide action

This hypothesis states that perception and action use different, functionally independent representations of the body and the hand. Since distortions apply to representations used for perception but not to representations used for action, manual action should be unaffected by hand distortions. However, as discussed by Longo[1], recent evidence shows that distortions are present, although reduced in magnitude, during a dynamic proprioceptive matching task requiring participants to actively displace their unseen, tested hand to match the position of visual targets[4]. This suggests that motor control is not immune to distortions.

Distorted hand representations are corrected to guide action

A second hypothesis, consistent with the above evidence obtained during dynamic tasks, is that hand representations are corrected to guide action. The correction would be partial[4], would only apply to the tested arm[4] (the distortions are unchanged when the motor responses are provided by the contralateral arm[5]), and would not outlast the dynamic task (the hand distortion as measured post-movement using the static landmark task is unchanged[4]). Peviani et al.[4] interpret the lack of aftereffects to indicate that the representation of the hand is not updated during active motor control. Rather, a motor plan is assembled based on the distorted representation of the hand and then adjusted based on sensorimotor feedback. In this view, the correction would be applied to the trajectory of the movement rather than to the representation of the hand. However, more work is needed to confirm this possibility. Skilled motor behavior relies on flexible predictive models that are updated through learning and experience[6]. For example, when interacting with a tool (e.g., a rake), the model of the hand is modified to incorporate the tool[2]. This leaves open the question of why distorted representations that need constant corrections are not updated.

Distortions facilitate motor control

A third hypothesis is that distortions are not errors in need of correction but reflect a representational anisotropy in service of motor control. This hypothesis resonates with the parallel about London tube map suggested by Longo[1]. The London tube map is distorted to guide passengers' path choices. In a similar vein, the representation of the hand is distorted to facilitate accurate motor control. In discussing the possible functional role of distortions, Longo suggests that hand distortions may serve to increase the individuation of fingers. Going one step further, one might speculate that hand distortions serve to increase the representation of covariation patterns in finger joint angles during manipulative control. Specifically, the overestimation of hand width and the underestimation of finger length may reflect the abduction-adduction and flexion-extension of proximal and distal finger joints during a power grasp[7]. This conceptualization of hand distortions would eliminate the need for correction and suggest that distortions reflect, at least in part, patterns of actuation of the human hand. Support for this hypothesis comes from recent findings showing that sensorimotor cortical maps obtained from both sensory and motor tasks encode a distorted hand representation[8].

This third hypothesis could explain (and possibly predict) the specific patterns of distortions found in experts (e.g., magicians show reduced distortions[9], whereas baseball players underestimate hand dimension[10]) and in patients (e.g., stroke patients with unilateral motor deficits show higher distortions on the affected side[11], recovering to the ipsi-lateral level of distortion after sensorimotor training[12]). However, further studies need to examine whether and to what extent changes in hand representations covary with changes in dynamic and kinematic parameters associated with motor abilities (and inabilities) at the single-subject level. An intriguing, untested possibility is that the optimal level of distortion depends on the specific motor ability.

Concluding remarks

Body distortions have been considered almost exclusively from a perceptual perspective. We propose that investigating distortions through the lens of motor control could help to unveil their origin and function: what factors contribute to the emergence of distortions, and what function do distortions play in mental life? Addressing these questions is not only of theoretical significance but could open the way to exploit body distortions in areas ranging from prosthetic control to assistive robotics and motor training.

REFERENCES

1 Longo, M.R. (2022) Distortion of mental body representations. *Trends Cogn. Sci.* 26, 241–254

2 Bassolino, M. and Serino, A. (2021) Representation and perception of the body in space. *Encycl. Behav. Neurosci. Second Ed.* 2–3, 640–656

3 Wong, H.Y. (2017) On Proprioception in Action: Multimodality versus Deafferentation. *Mind Lang.* 32, 259–282

4 Peviani, V. *et al.* (2020) The motor system (partially) deceives body representation biases in absence of visual correcting cues. *Acta Psychol. (Amst).* 203, 103003

5 Longo, M.R. (2018) The effects of instrumental action on perceptual hand maps. *Exp. Brain Res.* 236, 3113–3119

6 Wolpert, D.M. and Flanagan, J.R. (2001) Motor prediction. *Curr. Biol.* 11, 18

7 Leo, A. *et al.* (2016) A synergy-based hand control is encoded in human motor cortical areas. *Elife* 5, e13420

8 Mastria, G. *et al.* (in press) Morphology, connectivity and encoding features of tactile and motor representations of the fingers in the human precentral and postcentral gyrus. *Cortex*

9 Cocchini, G. *et al.* (2018) The magic hand: Plasticity of mental hand representation. *Q. J. Exp. Psychol.* 71, 2314–2324

10 Coelho, L.A. *et al.* (2019) Long- but not short-term tool-use changes hand representation. *Exp. Brain Res.* 237, 137–146

11 Bassolino, M. *et al.* (2022) Body and peripersonal space representations in chronic stroke patients with upper limb motor deficits. *Brain Commun.* 4, 1–15

12 Crema, A. *et al.* (2022) Neuromuscular electrical stimulation restores upper limb sensory-motor functions and body representations in chronic stroke survivors. *Med* 3, 58-74.e10