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Letter

Motor adaptation and distorted body representations

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I thank Bassolino and Becchio for their letter [1] highlighting the issues that distorted body representations, particularly those underlying proprioceptive position sense, pose for effective action. I agree that the three hypotheses they outline are plausible approaches to thinking about this problem, and are likely to be fruitful guides for future research. However, I also wish to suggest that the coexistence of dextrous action alongside distorted body representations may be less paradoxical than Bassolino and Becchio suggest.

When we put on a long-sleeved shirt or a jacket, there are all sorts of changes in the weight of our arm, and in the forces and torques acting on it, that are not part of our long-term representations of our arm. The same is true when we put on a watch or hold a coffee cup in our hand. But sleeves and watches do not pose any problems to action at all. Similarly, when our muscles are fatigued we need to increase the central command to muscles to produce the same behavioural response [2]. Yet, fatigue does not result in systematic misreaching, indicating that the brain is able to effectively estimate and make adjustments for the present state of the body.

Such considerations suggest that the sensorimotor system is not critically dependent on stored long-term memories of all bodily properties. Rather, the brain is able to produce constant adjustments to motor output to maintain accurate behaviours in the face of changing circumstances. Indeed, a large literature on motor adaptation has investigated responses to sensorimotor perturbations and distortions, showing that the sensorimotor system is quickly able to identify and correct for distortions in the sensory information available to control movements. This includes distortions such as those induced by prisms [3], by alterations of the location and dynamics of a visual cursor representing the hand [4], by novel force fields induced with a robotic manipulandum [5], and by Coriolis forces induced by a rotating room [6]. Such motor adaptation occurs quickly and independently of conscious awareness and control.

The effects of such adaptation have traditionally been measured in terms of their effects on the motor system. This is the converse situation from distortions of mental body representations, which – as Bassolino and Becchio note – have primarily been studied in sensory contexts. However, recent studies have shown that motor adaptation also alters proprioceptive estimates of perceived hand location. Such effects have been seen following adaptation to both visuomotor [7] and force-field [8] distortions. Moreover, such changes can occur extremely rapidly, with one recent study finding evidence of implicit motor adaptation on perceived hand location within three trials [9]. Indeed, one recent model has argued that proprioception is central to motor adaptation, even in situations that have traditionally been interpreted in terms of visuo-motor congruence [10].

Motor adaptation thus allows the sensorimotor system to deal flexibly with constantly changing contextual and physiological factors which must be navigated in order to generate skilled and effective behaviours. Given this ability to deal with rapidly changing distortions and perturbations, it should not be surprising that the system is also able to accommodate distortions which are largely constant across time, such as the distorted body representations I reviewed in my article [11]. Indeed, distortions which are consistently present in the same way should be comparatively easy to accommodate. Motor adaptation is believed to be implemented in the sensorimotor system as a 'gain field', which provides an implicit internal model including factors related to the body itself and the external context [12]. In the same way, correction for systematic distortions of body size and shape could be implemented in these same gain fields. In this sense, the 'hand paradox' may be resolved by the same mechanisms that constantly monitor and adjust our actions throughout our daily activities to let us act effectively in the world.

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