Letter to the Editor

Typical biomechanical bias in the perception of congenitally absent hands

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There is compelling evidence that our perception of others’ bodies and movements is shaped by several rules and constraints, such as the biomechanics of body movement, originally thought to affect only the control and execution of actual movements (Grosjean, Shiffrar, & Knoblich, 2007; Parsons, 1987; Shiffrar & Freyd, 1993). For numerous authors, this demonstrates that the perception of others’ bodies and movements is supported by somatosensory and motor representations of our own body (Grush, 2004; Hommel, Müsseler, Aschersleben, & Prinz, 2001; Wilson & Knoblich, 2005). Accordingly, the presence or absence of effects of body constraints on body perception is increasingly used as an index of, respectively, the integrity or impairment of covert stages of action production in patients with motor execution disabilities (e.g., Conson et al., 2013; Conson, Pistoia, Sarà, Grossi, & Trojan, 2010; de Lange, Roelofs, & Toni, 2008; Fiorio, Tinazzi, & Aglioti, 2006; Helmich, de Lange, Bloem, & Toni, 2007; Munzert, Lorey, & Zentgraf, 2009; Nico, Daprati, Rigal, Parsons, & Sirigu, 2004). For example, because the response latencies of patients with left cerebral palsy in judging the laterality of presented hand drawings are positively correlated with biomechanical difficulty of the hand configurations, but not those of patients with right cerebral palsy, it was concluded that only the latter group of patients suffer from a motor planning deficit (Mutsaarts, Steenbergen, & Bekker, 2007).

However, these biomechanical constraints biases might simply reflect how the visuo-perceptual system processes and represents human bodies (Shiffrar & Freyd, 1993; Tessari, Ottoboni, Symes, & Cubelli, 2010; Vannuscorps, Pillon, & Andres, 2012). Evidence for this alternative comes mainly from the observation that two individuals born with severely reduced upper limbs (congenital bilateral upper limb dysmelia) also showed biomechanical biases when asked to provide perceptual judgments about hand postures and upper limb movements (A.Z.: Brugger et al., 2000; Funk & Brugger, 2005; Funk, Shiffrar, & Brugger, 2005; D.C.: Vannuscorps et al., 2012). The evidence from those studies, however, could be challenged on the ground that D.C. and A.Z. had upper limb stumps and, therefore, were not totally deprived of motor experience with the upper limbs (and motor representations thereof). In addition, A.Z. presented with a rare profile of very vivid phantom sensations of the missing body parts that she was able to intentionally “move”, making her case difficult to interpret.

Here, to overcome the ambiguity of the previous studies with dysplasic individuals and test these alternative accounts, we asked a 27 year-old woman (P.M.) born without upper limbs (bilateral upper limb amelia, i.e., no arm, no forearm, no hand) and no history of upper limb prosthetics or phantom limb sensations to judge as fast as possible the laterality of successively presented drawings of left and right hands displayed in 2 different postures and 7 angles of...
rotation (see Fig. 1a). In this Hand Laterality Judgment (HLJ) task (Parsons, 1987) the influence of body constraints on perception is typically unveiled by three features of participants’ response latencies. First, response latencies are characterized by a three-way interaction between LATERALITY, POSTURE, and ANGLE of rotation of the hand, reflecting the different clockwise rotational range of movement of left and right hands in different hand postures. Second, response latencies are shorter for hands oriented in medial (stimuli rotated toward the mid–sagittal plane) than lateral (away of the mid–sagittal plane) directions (the Medial-Over-Lateral-Advantage effect), in congruence with the fact that it is easier to orient one’s own hand in medial than lateral directions (see Fig. 1a). Third, response latencies are positively correlated with estimates of the awkwardness of the different hand positions (i.e., the difficulty to place the appropriate limb into the orientation of the stimulus) even after controlling for the part of variance explained by the effect of visual familiarity with the stimuli (Vannuscorps et al., 2012). We reasoned that if the influence of body biomechanical constraints on perception reflects the recruitment of participants’ somatosensory and motor representations of their own body, then, these features should not characterize P.M.’s performance. If, however, this bias reflects a property intrinsic to how the visuo-perceptual system processes observed body parts, then, P.M.’s response profile should be analogous to that of typically developed participants.

During the experiment, P.M. was seated at about 60 cm of a computer screen. She performed 5 blocks of 28 trials (2 sides × 2 postures × 7 angles). In each block, stimuli were mixed in different orders. The first block included 10 practice trials. Each trial started with the presentation of a central cross for 200 msec followed by a hand drawing displayed until a response was recorded. Trials were separated by a blank screen of random duration between 500 msec and 1000 msec. The experiment was controlled with the E-Prime software (Psychological Software, 2002, Pittsburgh, PA). PM responded verbally (“right” or “left”) and the post-stimulus onset latency of the subject’s vocalization was recorded by a voice-key. The accuracies of responses and of the voice-key vocalization detection were monitored on-line by the experimenter. The study was approved by the biomedical ethics committee of the Cliniques Universitaires Saint-Luc, Brussels, Belgium.

P.M.’s results are shown in Fig. 1. There were no voice key failures. Response errors (10%) were discarded from response latency analyses. P.M.‘s response latencies showed the three typical indexes of an influence of the body biomechanical constraints: a three-way interaction between LATERALITY, ANGLE (30°–150° vs. 210°–330°), and POSTURE [F(1, 100) = 10.62, p < .01] (Fig. 1a) of the hand (data from the angles 30–150 and 210–330 were collapsed and then log transformed to satisfy the homoscedasticity and normality assumptions of ANOVA); shorter response latencies for hands oriented in medial (stimuli rotated toward the
The existing evidence, however, suggests that the dysplastics limb movements to support their judgment of hand laterality. Plastics from using (innate) motor representations of the upper criticims. A first objection that could be raised is that a "sensory and motor cortices that would normally represent the while the medial rotation of the palm of the hand viewed from hands and feet make it virtually impossible to imitate all the features and degrees of freedom of the arms and legs and body parts (Funk et al., 2008; Stoeckel, Pollok, Witte, Seitz, Buetefisch, 2009). Rather, the specific parts of their somato-motor cortex does not contain a representation of the missing limbs (Funk et al., 2008; Reilly & Sirigu, 2011; Stoeckel, Seitz, & Bueteřñís, 2009). Rather, the specific parts of their somato-sensory and motor cortices that would normally represent the “absent” limbs are allocated to the representation of adjacent body parts (Funk et al., 2008; Stoeckel, Pollok, Witte, Seitz, & Schnitzler, 2005, Stoeckel et al., 2009).

A second possibility is that P.M.’s response profile may arise from her imagining moving her lower limbs to the position of the hand drawings. The very different skeletal and muscular features and degrees of freedom of the arms and legs and hands and feet make it virtually impossible to imitate all the observed hand postures with the feet, however. For example, while the medial rotation of the palm of the hand viewed from the back can easily reach 180°, the corresponding rotation with the foot is limited to approximately 30° (Nordin & Frankel, 2001). The observation that A.Z. also showed the same effect despite the fact that she had no feet (Brugger et al., 2000; Funk & Brugger, 2008) and that D.C. was slower at judging the laterality of the hands and feet make it virtually impossible to imitate all the features and degrees of freedom of the arms and legs and body parts. In any case, our results constitute existence proof that using one’s own body motor and somatosensory representations is not needed to obtain the performance profiles that have been used to support theories claiming that our perception of others’ bodies and movements is supported by somatosensory and motor representations of our own body (Crush, 2004; Hommel et al., 2001; Wilson & Knoblich, 2005).

This conclusion does not conflict with previous evidence showing that the performance in the HLJ task can be delayed, and the effect of the biomechanical constraints hindered, in patients suffering from motor disorders. Evidence for the influence of motor disorders in the HLJ task are compelling and have been found in different populations of patients (Conson et al., 2013, 2010; Fiorio et al., 2006; Helmich et al., 2007; de Lange et al., 2008; Munzert et al., 2009; Nico et al., 2004). Within the classical interpretation of the HLJ task, it is hypothesized that performance in the HLJ task is supported by both a perceptual analysis of the hand shape providing a first estimate of the hand laterality and then by a verification strategy involving an implicit simulation of this hand posture and orientation (Parsons, 1987). On this theoretical account, motor disorders interfere with the verification process, thereby affecting participant’s performance. In contrast, participants, such as P.M., who cannot use a motor verification strategy judge the hand laterality based only on visuo-perceptual processes.

In sum, our finding encourages a shift in the focus of future research away from motor simulation as a necessary component of human movement perception and toward the interesting question of how the visuo-perceptual system represents and processes articulated objects and their movements. In addition to its theoretical significance, this finding also serves as a cautionary note in the use of the Hand Laterality Task as a tool to study the integrity of covert stages of action production in neurological and psychiatric conditions.

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REFERENCES


