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“Like the palm of my hands”: Motor imagery enhances implicit and explicit visual recognition of one's own hands

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ABSTRACT

A key point in motor imagery literature is that judging hands in palm view recruits sensory-motor information to a higher extent than judging hands in back view, due to the greater biomechanical complexity implied in rotating hands depicted from palm than from back. We took advantage from this solid evidence to test the nature of a phenomenon known as self-advantage, i.e. the advantage in implicitly recognizing self vs. others' hand images. The self-advantage has been actually found when implicitly but not explicitly judging self-hands, likely due to dissociation between implicit and explicit body representations. However, such a finding might be related to the extent to which motor imagery is recruited during implicit and explicit processing of hand images. We tested this hypothesis in two behavioural experiments. In Experiment 1, right-handed participants judged laterality of either self or others' hands, whereas in Experiment 2, an explicit recognition of one's own hands was required. Crucially, in both experiments participants were randomly presented with hand images viewed from back or from palm. The main result of both experiments was the self-advantage when participants judged hands from palm view. This novel finding demonstrate that increasing the “motor imagery load” during processing of self vs. others' hands can elicit a self-advantage in explicit recognition tasks as well. Future studies testing the possible dissociation between implicit and explicit visual body representations should take into account the modulatory effect of motor imagery load on self-hand processing.

1. Introduction

Motor imagery implies mental simulation of ones' own movements through re-enactment of sensorimotor representations, which are subject to actual biomechanical constraints (Hétu et al., 2013; Parsons, 1987, 1994; Sekiyama, 1982). A classical tool to assess motor imagery is the hand laterality task in which participants are required to decide whether a visual stimulus portrays a left or a right hand. Behavioural experiments on healthy individuals and neuropsychological studies on different clinical populations converge in demonstrating that participants solve this task by mentally retrieving movements of their own body parts (Conson et al., 2013, Conson, Pistoia, Sarà, Grossi, & Trojano, 2010, Gentilucci, Daprati, & Gangitano, 1998, Parsons, 1994). Indeed, laterality judgments are influenced by participant's posture during task and by the anatomic constraints limiting hand movements towards the displayed position of the to-be-judged hand (Conson et al., 2016; Conson, Mazzarella, & Trojano, 2011; de Lange, Helmich, & Toni, 2006; Ionta & Blanke, 2009; Parsons, 1987).

Several studies demonstrated an advantage when dealing with one's own body parts in motor imagery tasks. For instance, in the hand laterality task performed on self or other's hands presented at different angular orientations, Ferri, Frassinetti, Costantini, and Gallese (2011) showed faster responses when participants judged self-hands (i.e., self-advantage in implicit recognition of body parts); this effect was not present in a task where were participants explicitly required to decide whether hand images belonged to themselves. Indeed, in this latter task, participants performed better with others' compared to self-hands (i.e., self-disadvantage in explicit recognition of body parts). Since the hand laterality judgment implies activation of motor simulation processes (Parsons, 1987, 1994; Sekiyama, 1982), Ferri et al. (2011) suggested that the self-advantage was based upon recruitment of one's own body sensorimotor representation that, instead, was not recruited when the task tapped explicit recognition of self-hand images. Accordingly, in a neuroimaging study on right-handed healthy participants Ferri, Frassinetti, Ardizzi, Costantini, and Gallese (2012) found that the self-advantage was related to a specific activation of left sensorimotor areas and in particular of premotor cortex. More recently a neuropsychological study on brain-damaged patients showed that implicit and explicit recognition of self-body images was subtended by different neural substrates in the right hemisphere (Candini et al., 2016). These findings

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would imply that visual processing of one's own body is based on, at least, two different mechanisms (implicit vs. explicit; Candini et al., 2016), and that the sensorimotor mechanism would be selectively involved in the genesis of the self-advantage in implicit self-hand recognition (Ferri et al., 2011, 2012). However, it should be taken into account that all the above reviewed studies used hand images portrayed from back view only. Indeed, a key point of motor imagery literature is that the degree of activation of motor simulation during the hand laterality task is strongly related to whether the hand image is portrayed from back or palm view (Parsons, 1987, 1994; Sekiyama, 1982; ter Horst, van Lier, & Steenbergen, 2010). Judging hands in palm view recruits sensory-motor information to a higher extent than judging hands in back view, likely due to the greater biomechanical complexity implied in rotating hands depicted from palm than from back (Bläsing, Brugger, Weigelt, & Schack, 2013; Gentilucci et al., 1998; Lust, Geuze, Wijers, & Wilson, 2006; Parsons, 1987, 1994; Sekiyama, 1982; ter Horst et al., 2010; Zapparoli et al., 2014). Accordingly, combining back and palm hand images within the same stimulus set strongly facilitates engagement of motor imagery during the hand laterality task (ter Horst et al., 2010).

Taken together, these findings from motor imagery literature would rise the question of whether the same the pattern of self-advantage versus self-disadvantage ascribed to a dissociation between implicit versus explicit self-body representation could be also observed in tasks tapping visual processing of hand images when palm and back views are combined within the same stimulus set. If the self-advantage is related to the activation of the sensorimotor representation of one's own body (Ferri et al., 2011, 2012), it could be hypothesized that, by presenting palm and back images within the same stimulus set (Parsons, 1987, 1994; Sekiyama, 1982; ter Horst et al., 2010), i.e. by increasing motor imagery activation, two outcomes should be observed: i) the self-advantage in the implicit task would be stronger for palms than for backs, and ii) the self-advantage could be also found in explicit processing of palms. This second expected result would demonstrate that, by enhancing recruitment of motor imagery, it could be possible to find evidence of self-advantage even in conditions in which it has not been reported yet (i.e., explicit recognition of one's own hands). This would be the case, the idea of a clear-cut dissociation between implicit and explicit self-body processing, based on the exclusive recruitment of sensorimotor mechanisms in implicit (and not in explicit) self-body processing should be reappraised.

To test this hypothesis, we performed two behavioural experiments in which self and others' hands were randomly presented from back and palm view: Experiment 1 required a laterality judgment on either self or others' hands (implicit self-hands processing), whereas in Experiment 2 participants have to decide whether hand images belonged to themselves (explicit self-hand recognition). Our main expectation was to observe the *self-advantage* in both experiments. We also expected to observe a finding related to activation of sensorimotor self-body representation, i.e. the so-called biomechanical effect, that is the advantage for judging hand pictures showing physically comfortable versus physically awkward positions.

In the classical hand laterality task, participants are faster (and more accurate) in judging the laterality of hands oriented in medial positions (stimuli rotated towards the body mid-sagittal plane) when compared to lateral positions (stimuli rotated away of the body mid-sagittal plane). This effect is thought to reflect the influence of the body anatomic constraints that facilitate movements of one's hand towards medial than lateral directions (Funk & Brugger, 2008; ter Horst et al., 2010; Vannuscorps, Pillon, & Andres, 2012). Since the biomechanical effect in the hand laterality task is considered a hallmark of motor imagery (Funk & Brugger, 2008; Parsons, 1987, 1994; Pelgrims, Andres, & Olivier, 2009; ter Horst et al., 2010) we could expect to find such an effect in both implicit and explicit processing tasks, particularly when participants had to deal with self-hand images.

2. Methods

2.1. Participants

Thirty healthy male, right-handed volunteers (mean age = 22.2, SD = 3.6) participated in the study; the same participants took part in both Experiment 1 and Experiment 2. The participants had no self-reported history of neurological diseases and were naive to purposes and predictions of the study; we excluded individuals wearing rings or having easily recognizable marks (e.g. painted nails, tattoos or scars). The study was conducted in accordance with the ethical standards of Helsinki Declaration; written informed consent was obtained from all participants before the experiments.

2.2. Stimuli and procedure

The experimental stimuli were grey-scale pictures of the back and palm views of right and left hands. Participants' hands were photographed with a digital camera in a preliminary session, about one week before running the experiments. Hands were always photographed in the same position in a controlled environment with constant artificial light and at a fixed distance from the camera lens (30 cm). The hand images were large approximately 9.5 cm along the widest axis (10.7° of visual angle at a viewing distance of 50 cm). The original images (one picture per hand) with fingers pointing upward (0° orientation) were digitally rotated to obtain hand images in different orientations: 0°, 60°, 120°, 180°, 240° and 300°. Three orientations were compatible with a first-person view (0°—fingers pointing up, 60° and 300° clockwise), and three orientations were compatible with a third-person view (120°, 180° and 240°; Fig. 1). Stimuli depicted participant's left or right hand in half of the trials (self-trials), and other two males' (not involved in the experiment) right or left hands in the remaining trials (other-trials).

In *Experiment 1*, participants were required to decide whether each stimulus consisted of a left or a right hand; in *Experiment 2*, they had to decide whether the displayed hand depicted or not their own hand. The two experiments differed in their task instructions only, whereas stimuli and procedures were identical. Following previous studies (Conson et al., 2015; Ferri et al., 2011, 2012; Frassinetti, Ferri, Maini, Benassi, & Gallese, 2011), Experiment 1 was conducted before Experiment 2 (in two separate sessions 2–3 days apart) because Experiment 1 investigated the implicit and Experiment 2 the explicit processing of self-hands.

In both experiments, each trial started with a central fixation cross (500 msec duration), followed by the hand stimulus that remained on view until response completion. Participants were instructed to respond as fast and accurately as possible by pressing left or right keys on a foot pedal (X-Key PS2; P.I. Engineering, Williamston, Michigan): a left foot press was required in response to a left hand and a right foot press in response to a right hand. Both accuracy and reaction times (RTs in msec) were recorded.

Each experiment consisted of 288 trials: self and others' left and right hands in back and palm view for 6 orientations; each trial was repeated 6 times. Participants sat in front of the PC screen, with their feet placed on the two-key pedal and their hands, placed palm down on their thighs, covered with a cloth in order to prevent the participant from seeing them. The experimental stimuli were presented in random order through SuperLab v4.0 software.

Before each task, eight practice trials were given and discarded from statistical analysis. Participants were explicitly required to refrain from moving their head, hands or fingers, and the experimenter (seated behind participants) checked that they complied with this instruction for the whole task.

2.3. Data analysis

Two separate ANOVAs were performed on both RTs and percentage