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Walking on a line: A motor paradigm using rotation and reflection symmetry to study mental body transformations

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ABSTRACT

Researchers have recently reintroduced the own-body in the center of the social interaction theory. From the discovery of the mirror neurons in the ventral premotor cortex of the monkey's brain, a human *embodied* model of interindividual relationship based on simulation processes has been advanced, according to which we tend to embody spontaneously the other individuals' behavior when interacting. Although the neurocognitive mechanisms of the embodiment process have started being described, the mechanisms of self-location during embodiment are still less known. Here, we designed a motor paradigm which allows investigating in ecologically more valid conditions whether we embody another person's intransitive action with an embodied or disembodied self-location. Accordingly, we propose a phenomenological model of self–other interaction showing how perspective-taking mechanisms may relate on mental body transformation and offering a promising way to investigate the different sorts of intersubjectivity.

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1. Introduction

Since the last decade, cognitive neuroscientists (Blanke & Metzinger, 2009; Gallagher, 2000, 2005; Metzinger, 2003, 2008; Ruby & Decety, 2001) have restored the own-body in the center of the theory of the self, revealing its importance for the development of a comprehensive selfhood theory. While providing us with the feeling of being positioned at a specific location in space, the own-body is immediately experienced as the spatial location of the self (Arzy, Thut, Mohr, Michel, & Blanke, 2006; Blanke et al., 2005), leading to the coherent and normal experience of the spatial unity between the self and the body – or "embodied self-location" (Blanke & Metzinger, 2009). In the same time, the own-body has also been reintroduced in the theory of social interactions, as phenomenologists at the beginning of the 20th had already assumed (Lipps, 1897, 1903, 1906, 1913; Vischer, 1927; Husserl, *Hua* XIII-XVI). First, the mechanisms of self-location have been hypothesized to be involved in the mechanisms of self–other distinction (Decety & Sommerville, 2003; Ruby & Decety, 2001, 2004). Indeed, the own-body as originate center of orientation mediates our own egocentered visuo-spatial perspective (Zahavi, 1994) that we can experience only in a direct way (Husserl, *Hua* XIII-XVI; Berthoz, 2004; Vogeley & Fink, 2003; Zahavi, 1994) whereas taking the other's visuo-spatial perspective has been hypothesized to rely on a mental translocation of the egocentric viewpoint (Vogeley & Fink, 2003), i.e., on a rather indirect process (Berthoz, 2004; Jorland, 2004; Jorland & Thirioux, 2008). Second, inspired by the discovery of the mirror neurons in the ventral premotor cortex of the monkey's brain (di Pellegrino, Fadiga, Fogassi, Gallese, & Rizzolatti, 1992; Rizzolatti, Fogassi, & Gallese, 2001), current theories of social interactions have proposed a human *embodied* model of interindividual relationship based on simulation processes (Carr, Iacoboni, Dubeau, Mazziotta, & Lenzi, 2003; Fadiga, Craighero, & Olivier, 2005; Gallese, 2007; Rizzolatti, Fadiga, Fogassi, & Gallese, 1999). Accordingly, understanding another individual's actions (Buccino et al., 2001), emotions (Carr et al., 2003) or intentions (Iacoboni et al., 2005) may require the observation of his (her) behavior in a specific context and then additional cognitive elements (Gallagher, 2008) such as the activation of internal models by which we simulate the other's behavior (see also Zahavi, 2008; for the rehabilitation of the direct perception in social cognition, see Gallagher, 2008). For instance, it has been shown that individuals change their breathing when observing other individuals performing effortful actions (Blakemore & Frith, 2005; Paccalin & Jeannerod, 2000) and a recent fMRI study on sense of touch revealed that touch observation activates the secondary somatosensory cortex, suggesting visuo-tactile mirroring mechanisms in this brain area (Ebisch et al., 2008). In the aggregate, the own-body may thus be involved in several phenomenological aspects of the self, such as self-location, self–other distinction, and self–other

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interaction, suggesting that embodied self-location may be somehow crucial for social cognitive abilities.

Therefore, the sole role of embodied self-location within self–other interactions has been recently discussed on the basis of data from neurological patients with experiences of disruption of the spatial unity between the self and the body, the so-called out-of-body experiences (OBEs; Blanke, Landis, Spinelli, & Seeck, 2004; Blanke & Mohr, 2005; Blanke, Ortigue, Landis, & Seeck, 2002; Brugger, Regard, & Landis, 1997; Devinsky, Feldmann, Burrowes, & Bromfield, 1989; Irwin, 1985; Kahane, Hoffmann, Minotti, & Berthoz, 2003; Lhermitte, 1939, 1951) and "Heautoscopic hallucinations" (HAS; Blanke & Mohr, 2005; Blanke et al., 2004; Brugger, 2002; Brugger, Agosti, Regard, Wieser, & Landis, 1994; Hécaen & Green, 1957; Lance, Cooper, & Misbach, 1974; Lhermitte, 1939, 1951; Menninger-Lerchenthal, 1935). During OBEs, neurological patients with lesions or epileptic discharges in a posterior brain region – i.e. predominantly in the right temporo-parietal junction (TPJ; Blanke et al., 2002; Kahane et al., 2003) – experience that their "self" is localized outside their bodily boundaries and see the world and their own-body from this perspective – or "disembodied self-location"[1] (Arzy et al., 2006; Blanke et al., 2002, 2004, 2005; Brugger et al., 1997). In HAS, patients with damages predominantly to the left TPJ see in front of them the reduplication of their own-body, (*Doppelgänger*; Brugger, 2002) with the preservation of lateral asymmetries (if the patient moves his own left hand, his reduplicated body moves his own left hand also, i.e., inversely to the left/right reversal as in a mirror; for remarks concerning this terminology, see Brugger (2002)), and alternatively experience of seeing their "body" from their own visuo-spatial perspective or from their double's perspective (Blanke & Mohr, 2005; Blanke et al., 2004; Brugger, 2002). Interestingly enough, in addition to the hypothesis of disturbed vestibular processing, (Kahane et al., 2003; Schwabe & Blanke, 2008), OBEs and HAS have also been hypothesized to relate on deviant perspective-taking abilities which occur under normal conditions when individuals are interacting (Brugger, 2002). Suggesting that visuo-spatial perspective-taking requires spatial cognitive abilities relying on bodily processing such as *mental* body transformations (Zacks, Rypma, Gabrieli, Tversky, & Glover, 1999) and notably *mental* imagery with *disembodied* self-location, this hypothesis was reinforced by data from electrical neuroimaging studies with healthy subjects showing that imagining oneself in the body position of another individual (own-body transformation task) activates also the TPJ (Arzy et al., 2006; Blanke et al., 2005), whereas embodied self-location activates the lateral occipito-temporal cortex, including the extrastriate body area (EBA; Arzy et al., 2006).

Therefore, this hypothesis led us here to address two observations. First, the human embodied model of social interactions remains unclear how the mechanisms of *self-location* (i.e., embodied or disembodied) are involved when individuals are interacting. To the best of our knowledge, it is still unknown whether individuals when embodying the behavior of another individual, embody it with an embodied or disembodied self-location. The only fact *that* the other's behavior is simulated or reproduced is per se not enough to infer which mechanisms of self-location are involved. We rather propose that focusing on *how* the other's behavior is simulated/reproduced may be useful in understanding the mechanisms of self-location within self–other interactions. Second, most studies on self-location do not investigate self-location when individuals are interacting *spontaneously* with each other and are often conducted in highly constant and constrained contexts rendering the experimental situations less ecologically valid. Typically, behavior and brain activity are tested in a prone/seated position, although most interactions with humans occur in the standing or walking position (Bavelas, Black, Chovil, Lemery, & Mullett, 1988; Bavelas, Black, Lemery, MacInnis, & Mullett, 1986; Bavelas, Black, Lemery, & Mullett, 1986; Bavelas, Black, Lemery, & Mullett, 1987; Parsons, 1987; Reed & McGoldrick, 2007; Scheflen, 1964). Moreover, participants are generally instructed explicitly on how to perform mental transformation of perspective (Ruby & Decety, 2001; Ruby & Decety, 2004; Vogeley et al., 2004) or to perform left–right judgments on static and schematic figures either by imagining themselves in the figure's body position (Own-Body-Transformation-task) or by imagining the figure as the reflection of their own-body (Mirroring-task; Arzy et al., 2006; Blanke et al., 2005; Zacks et al., 1999). Hence, the experimental investigation of *spontaneous* mental body transformations within self–other interactions is still missing.

Here, we applied the causal principle according to which "form follows function" (Bavelas et al., 1988) and asked whether the form of the motor behavior exhibited by the own-body may provide an empirical criterion to infer the multisensorial and namely the visuo-spatial function at work within social interactions. We propose a simple motor paradigm which, adapted from the rotation and reflection symmetry model by Bavelas et al. (1988), enables to investigate whether individuals automatically embody, without *explicit* task, another person's behavior and, if so either by keeping their embodied self-location or locating mentally themselves in the other's body position (disembodied self-location). Inspired by the *Einfühlung* Theory of Lipps (1906), who claimed that a typical case of embodied simulation processes occurs while observing a dancing tightrope walker, we designed a behavioral study in which participants interacted spontaneously with a life-sized virtual tightrope walker walking forward, backward and leaning to her left or right on a rope.

Here, we report results showing that participants automatically embodied the avatar's leaning movements. Moreover, the form of the participants' motor behavior (i.e., automatic leaning movements to their right and left when the tightrope walker was leaning to her own right and left, respectively) revealed that participants, using mental imagery, located spontaneously themselves in the avatar body position, suggesting that they embodied the avatar's visuo-spatial perspective. Our motor paradigm may thus be useful in understanding how spontaneous perspective-taking mechanisms may rely on mental body transformations.

2. Methods

2.1. Paradigm

To investigate *whether* individuals, under spontaneous conditions and without explicit instruction, embody another person's behavior and, if so, with either an embodied or disembodied self-location (*how*), we designed a motor paradigm which allows participants to employ spontaneously their own transformation strategy, comparable to strategies used in daily life. For this, we pursued the traditional psychological approach, an approach focusing on elementary mimicry that is used to investigate, from the body posture, how individuals act together without explicit task instructions (Bavelas, Black, Lemery, MacInnis et al., 1986; Bavelas, Black, Lemery, & Mullet, 1986; Bavelas et al., 1987, 1988; Chartrand & Bargh, 1999; O'Toole & Dubin, 1968; Scheflen, 1964; Stotland, 1969; Tessari, Rumiati, & Haggard, 2002). Notably, we adapted the rotation and reflection symmetry paradigm by Bavelas et al. (1988). According to Bavelas et al. (1988), if individuals A and B are facing each other and B is leaning to his right, A can copy B's tilt by leaning either to his left or right (Fig. 1a and b). In the first case, A reacts by mirroring B's tilts. We hypothesized that such

[1] The terms "embodied and disembodied self-location" have been proposed by Arzy et al. (2006).

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