



Is the body in the eye of the beholder? Visual processing of bodies in individuals with anomalous anatomical sensory and motor features

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ABSTRACT

Neuropsychological and neuroimaging studies suggest distinct body representations involved in coding one's and others' body. Other influential theories, however, instead posit a unique model behind coding multisensory information about one's own body and visual information about others. An efficient way to further investigate this issue can be through testing individuals with anomalous anatomical and sensorimotor bodily features. In these people, the representation of their own body is held to be different with respect to the average population due to the peculiar properties of their body, and any experimental finding supposedly mediated by this representation should reflect such difference. We reviewed the most relevant studies reporting individuals with anomalous anatomical and sensorimotor bodily features engaged in (a) handedness task, (b) visual processing of biological motion and (c) visual processing of body shape. The performance in all three kinds of cognitive processes is affected by anomalous body features of the tested populations. However, the reviewed data are also in favor of a body model extrapolated by visual experience of others which mediates processing of biological stimuli and which operates in parallel, or as an alternative, to the representation of one's own body. In light of these results, pure visual and pure embodied accounts behind visual processing of biological stimuli should be reconsidered.

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1. One's own vs. others' body representation

The human brain receives information about the human body through many sources. One is the body in which it is kept: indeed, the cerebral cortex integrates sensory input (e.g., visual, somatosensory, proprioceptive, vestibular), as well as information about the outgoing movements, which are revealing of the body's states and of the changes thereof. A second source of information is the bodies of other human beings. Thus, the body is not only something that the brain owns and regulates, but it is as well a highly familiar visual stimulus as it is seen in everyday contact with other members of one's family, friends, colleagues, etc.

The large heterogeneity of information about the concept of human body has frequently been associated with the presence of multiple body representations in the human brain. These vary according to the reference frame which body-related informa-

tion is coded in, the sensory channel which this information is extracted from and, ultimately, the body (one's own vs. another person's) from which this information originates. In particular, studies investigating patients with damage to either the central or the peripheral nervous system lead to different models proposing how the concept of body could be represented in the human brain (see, Berlucchi & Aglioti, 2009; Corradi-Dell'Acqua & Rumiati, 2007, for reviews). Is this the case for the dichotomy between Body Schema vs. Body Image (Paillard, 1999; Paillard, Michel, & Stelmach, 1983), developed on the study of deafferented patients, who distinguishes between a sensorimotor map of the body space mainly based on proprioception (Body Schema) and a pictorial description of the body based on a mainly visual exteroception (Body Image). Recent scholars, proposed similar (although not identical) models, among which the dichotomy between Body Schema vs. Body Structural Description (Buxbaum & Coslett, 2001; Schwoebel & Coslett, 2005; Sirigu, Grafman, Bressler, & Sunderland, 1991), developed on the study of patients with pointing disorders, or, more recently, the dichotomy between Online vs. Offline Body Representation (Carruthers, 2008), developed through the observation of patients who either suffered hemiplegia. Despite their differences, these dichotomies converge in distinguishing between a representation

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of how one's own body is at each given moment, and a representation of how the body (either one's own or others') is usually like.

1.1. Evidence from brain damaged patients

Recently, Felician and colleagues (Felician, Ceccaldi, Didic, Thinus-Blanc, & Poncet, 2003; Felician & Romaiquère, 2008) proposed the dichotomy between One's Own vs. Others' Body Representation, who distinguishes between a sensorimotor map coding the relative position of one's body parts at each given time-point, and a map coding the position that body parts have with respect to a body model built on visual experience of others. The most convincing evidence in favor of such account is offered by the observation of those patients who, following brain damage to the posterior portion of the left inferior parietal cortex, exhibit *heterotopagnosia* (Auclair, Noulhiane, Raibaut, & Amarenco, 2009; Cleret de Langavant, Trinkler, Cesaro, & Bachoud-Lévi, 2009; Degos & Bachoud-Levi, 1998; Felician et al., 2003). These patients are unable to point to parts of the body of the examiner, or of another person. However, they are able to identify the body parts that they cannot locate, suggesting that their deficit lies neither at the level of visual processing of isolated body parts, nor at the level of the semantic knowledge of the body. Furthermore, they are able to locate parts of a non-human object (e.g., an animal or a bicycle), ruling out the account that the deficit reflects a general spatial impairment (Auclair et al., 2009; Felician et al., 2003). These patients are also able to point to small objects placed over the examiner's body, being still unable to point to the parts underneath (Felician et al., 2003), thus suggesting that their pointing ability was flawless as long the aimed target was not a body part. Crucially, they show flawless performance in locating parts of their own body (Auclair et al., 2009; Cleret de Langavant et al., 2009; Degos & Bachoud-Levi, 1998; Felician et al., 2003), thus confirming that the deficit is limited to bodies of others.

The behavioral pattern exhibited by patients affected by *heterotopagnosia* contrasts quite sharply with the one observable in patients affected by *pure autotopagnosia*, who are unable to point to parts of their own body despite being flawless at pointing parts to the body of the examiner¹ (Felician et al., 2003; Pick, 1922). In particular, Felician et al. (2003) reported a double dissociation between (a) a patient with damage at the level of the left angular gyrus exhibiting *heterotopagnosia*, thus able to locate parts of his own (but not the examiner's) body, and (b) a patient with damage at the level of the left superior parietal cortex with a mild proprioceptive deficit (i.e., he was unable describe the position of his body segments when slowly and passively moved by the examiner) and exhibiting *pure autotopagnosia*, thus mistakenly locating parts of his own (but not the examiner's) body. The authors suggested the presence of two independent body models, one drawing most of its information from visual experience of others, and the other from one's sensorimotor signals. Felician et al. (2003), accordingly, advocated the psychological reality of "one's own" and "others'" body representation.

1.2. Evidence from healthy individuals

The data from brain damaged patients converge with the findings from recent neuroimaging experiments testing healthy participants. For instance, Corradi-Dell'Acqua, Hesse, Rumiati, and

¹ *Pure autotopagnosia* should not be confused with a much better known neuropsychological syndrome, called *autotopagnosia* or *somatotopagnosia*, in which patients' pointing inability pertains both one's own and others' body (see Corradi-Dell'Acqua & Rumiati, 2007, for a review).

Fink (2008) found significant activation of the left posterior intraparietal sulcus when participants were asked to assess the distance between body parts visual stimuli, controlling for the identification thereof and for spatial competences *per se*. Most recently, Felician et al. (2009) asked participants to point to parts of body visual stimulus, being this a human or a dog; they found a significant activation of the left angular gyrus specifically when the parts of a human body were located. This region was inferior with respect to the superior parietal region Felician et al. (2004) found when asking participants to point to parts to their own body, rather than to parts of the external space. Although, Felician and colleagues did not compare pointing to one's/others' body directly in the same experimental paradigm, the results are compatible with the ones from brain damaged patients (Felician et al., 2003), according to which superior portions of the left parietal cortex code the position of one's own body parts, whereas more inferior portions code the spatial location of the body of others. Recently, Corradi-Dell'Acqua, Tomasino, and Fink (2009) asked participants to compare a visual stimulus of a hand with either the hand of their own body, or the hand of a visual template of a body. Authors found differential neural networks associated with the two conditions: the left parietal operculum (previously implicated in high level tactile processing, multisensory integration and coding proprioceptive signals about one's own body—e.g., Bremmer et al., 2001; Fitzgerald, Lane, Thakur, & Hsiao, 2004, 2006a, 2006b) was specifically active whilst comparing the body part to their own body, whereas the posterior portion of the left intraparietal sulcus (over and around the regions identified by Corradi-Dell'Acqua et al., 2008) was active whilst comparing the body part to the visual template.

1.3. Shared or dissociated neural substrates?

The account of two distinct representations, one involved specifically in coding information about one's own body, and the other involved in coding visual information about the body of others, is in apparent contradiction with many influential theories positing a unique model behind processing of both one's own and others' body. For instance, the *common-coding theory* (Hommel, Müsseler, Aschersleben, & Prinz, 2001; Prinz, 1997) postulates that observing an action facilitates its execution because perception and action planning share a common representational code, and that, at a neural level, perception of an action activates motor-related regions directly. This account is supported by the existence of a bilateral fronto-parietal brain network known as the *mirror neuron system*, which has been proposed to be engaged during both the observation and execution of purposeful actions (see Cattaneo & Rizzolatti, 2009; Decety & Grèzes, 1999; Rizzolatti, Fogassi, & Gallese, 2001, as reviews). More recently, scholars suggested that a model of one's own body (holding information about the spatial relation between one's parts, biomechanical constraints, the orientation of body segments in the external space, and even its kinematics—Wilson & Knoblich, 2005) might be used by the visual system as model information for either one's own body, that of a third person, or even as top-down information to help interpret incoming visual signals (Grush, 2004; Wilson & Knoblich, 2005). Thus, perception of biological stimuli, even if pertaining others', might be then mediated by the activation of homologous body portions of a model of one's own body.

Understanding to which extent visual processing of biological stimuli is mediated by a representation of one's own body or a model of other bodies extrapolated from visual experience about others is far from being a trivial issue, as most of the times the putative properties of these models can hardly be distinguished one with respect to the other. This does not happen, however, when testing individuals whose body has physical, sensory and motoric features which diverge from the average population. This is the

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