



Shared body representations and the 'Whose' system

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ABSTRACT

Mirroring has been almost exclusively analysed in motor terms with no reference to the body that carries the action. According to the standard view, one activates motor representations upon seeing other people moving. However, one does not only see movements, one also sees another individual's body. The following questions then arise. To what extent does one recruit body representations in social context? And does it imply that body representations are shared between self and others? This latter question is all the more legitimate since recent evidence indicates the existence of shared cortical networks for bodily sensations, including pain (e.g., Singer et al., 2004) and touch (e.g., Keysers et al., 2004; Blakemore, Bristow, Bird, Frith, & Ward, 2005). But if body representations are shared, then it seems that their activation cannot suffice to discriminate between one's body and other people's bodies. Does one then need a 'Whose' system to recognise one's body as one's own, in the same way that Jeannerod argues that one needs a 'Who' system to recognise one's actions as one's own?

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1. Introduction

A recent trend in the neuroscientific and philosophical literature suggests that we have representations that are shared between self and others. It all started in 1992 when researchers in Parma found that the same neurons fired both when a monkey was grasping a peanut and when it was watching the experimenter grasping it (Di Pellegrino, Fadiga, Fogassi, Gallese, & Rizzolatti, 1992; Rizzolatti, Fadiga, Gallese, & Fogassi, 1995; Grezes & Decety, 2001). More generally, the motor system is activated not only when an agent executes a goal-directed action, but also when an observer perceives the same action performed by another agent. What makes action mirroring special is that it goes beyond mere conceptual sharing. In Jeannerod (1994)'s terms, one does not share only semantic knowledge about the action; one shares the agent's pragmatic perspective. As such, action mirroring allows the observer to internalise another individual's actions as if she were the agent by a kind of motor simulation.

Most people have drawn the implications of those shared action representations for 3rd person mindreading (do they allow direct understanding of other people's intentions?). By contrast, Marc Jeannerod focuses his interest on their implications for self-awareness and more specifically, for the sense of agency (how do I recognise my actions as my own?). With Elisabeth Pacherie, he

argues that shared motor representations consist in what they call naked intentions, that is, intentions that are neutral relative to the agent (Jeannerod & Pacherie, 2004). The naked content can take two forms: either impersonal of the type <action, goal> or personal of the type <x, action, goal>, with x as the parameter of the agent still to be determined (de Vignemont, 2004; Jeannerod & Pacherie, 2004). In any case, the activation of shared motor representations cannot suffice to differentiate whether it is the agent moving or another person moving. Further processes based on extra information are needed: "Given the existence of shared representations, something more than the sole awareness of a naked intention is needed to determine its author" (Jeannerod & Pacherie, 2004, p. 140). The lack of differentiation between self and others seems indeed to indicate that one needs a specific mechanism to take apart one's actions and other people's actions. Georgieff and Jeannerod (1998) call this mechanism the 'Who' system.

Jeannerod analyses mirroring exclusively in motor terms, with no reference to the body that carries the action. However, it seems that in some situations, we need to establish a correspondence between the representation of our body and the representation of other people's bodies. How do we achieve such correspondence? Are there *shared body representations*? These questions are all the more legitimate since recent evidence indicates the existence of shared cortical networks for vicarious bodily sensations. Brain activity partially overlaps when one experiences touch or pain and when one observes another individual receiving a tactile or a painful stimulus (e.g., Singer et al., 2004; Keysers et al., 2004).

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Strikingly, people with mirror-tactile synaesthesia even consciously feel tactile sensations on their face upon perceiving another person touched on the face (Blakemore et al., 2005). As in action, shared cortical networks for vicarious bodily sensations have been systematically considered from the perspective of the understanding of other people, and especially in relation to empathy (Goldman, 2011; Banissy & Ward, 2007; Keysers, Kaas, & Gazzola, 2010; Ebish et al., 2009; Wood, Gallese, & Cattaneo, 2010). But what consequences do they have for the sense of bodily ownership?

All together, these findings may be taken as evidence of shared body representations. But if body representations are shared, then it seems that their activation cannot suffice to discriminate between one's body and other people's bodies. Should we then extend Jeannerod's conclusion to the sense of bodily ownership? In other words, does one need a 'Whose' system to recognise one's body as one's own?

2. A 'Whose' system?

In the recent philosophical and empirical literature on agency, the prominent view is that the sense of agency at least partly results from the comparison between the prediction of the sensory consequences of one's actions and their actual consequences (for review see Bayne & Pacherie, 2007). It may then be tempting to generalize the comparator model to the sense of bodily ownership. But then what are the different types of information to compare? In the case of the sense of agency, there is efferent information that can be matched to sensory information, but this is not true in the case of the sense of ownership. Arguably, one can feel one's body as one's own although one is not moving. What type of information can help differentiate one's body from other bodies?

The dominant model of the 'Whose' system is entirely drawn from the Rubber Hand Illusion (RHI). In the RHI, synchronous stroking of one's own occluded hand and an anatomically congruent visible rubber hand leads to a sense of ownership over the rubber hand. On the basis of the RHI, it has been suggested that intermodal matching plays a key role for ownership (Botvinick & Cohen, 1998; Makin, Holmes, & Ehrsson, 2008, but also Rochat, 1998 for developmental evidence): "the body is distinguished from other objects as belonging to the self by its participation in specific forms of intermodal perceptual correlation" (Botvinick & Cohen, 1998, p. 756). In support of this view, it was found that the ownership rating in questionnaires was correlated with the activity in brain regions that are classically involved in multisensory processes: "the detection of correlated multisensory signals by these regions [premotor cortex and posterior parietal area] is the mechanism for body ownership." (Ehrsson, Holmes, & Passingham, 2005, p. 10571).

However, the hypothesis of intermodal matching leaves many questions unanswered. As pointed out by Botvinick and Cohen (1998), one still needs to determine the "special ingredient" for ownership. Indeed, the sense of bodily ownership cannot derive from any kind of intermodal correlation. Imagine that you see and hear two hands clapping. Despite visuo-auditory correlation, you do not feel these hands as your own. You also need the visuo-auditory information to correlate with proprioceptive and tactile information indicating that you, and nobody else, are clapping your hands. In other words, there must be information that is self-specific (e.g. somatosensory information or efferent information) for intermodal correlation to play a role for ownership. Furthermore, there are some specific constraints that lay upon the RHI. For instance, visuo-somatosensory correlation fails to elicit an ownership illusion when the rubber hand is replaced by a wooden spoon (Tsakiris & Haggard, 2005). Hence, Tsakiris (2010) argues in

favour of a multi-layered 'Whose' system that involves three distinct comparators: between the visual form of the viewed object and a pre-existing body model, between the current state of the body and the postural and anatomical features of the body-part that is to be experienced as one's own, and between the vision of touch and the felt touch and their respective reference frames.

Although the RHI has been used as the experimental paradigm to investigate bodily ownership, one can question whether the same type of mechanisms is at stake for the ownership of the rubber hand, which is merely seen, and for the ownership of a biological hand, which can be moved and experienced from the inside independently of any visual feedback. For example, a recent lesion study showed dissociation between patients who failed to experience the RHI and patients who denied ownership of their own hand (Zeller, Gross, Bartsch, Johansen-Berg, & Classen, 2011). The authors concluded that the RHI recruits different brain regions than those involved for the sense of ownership of one's biological body. Consequently, the fact that a 'Whose' system may be required for the embodiment of an extraneous object does not necessarily imply that there must be a similar 'Whose' system in ordinary circumstances for one's biological body. One needs independent support for the hypothesis of the 'Whose' system.

If we draw further the parallel between agency and ownership, then we might find firmer ground for the hypothesis of a 'Whose' system in the possibility of representations shared between self and others. Jeannerod and Pacherie (2004) indeed conclude that the sense of agency results from a specific dedicated system, the 'Who' system, on the basis of the existence of *shared action representations*: "If, however, we can be aware of both our intentions and those of others in the same way, namely as unattributed or 'naked' intentions, the problem of self-other discrimination does indeed arise (...) this cortical network provides the basis for the conscious experience of goal-directedness—the primary awareness of intentions—but does not by itself provide us with a conscious experience of self- or other-agency." (Jeannerod & Pacherie, 2004, p. 139–140). If we can show that there are *shared body representations*, then we can ask whether a similar argument applies to the sense of bodily ownership.

The argument could go along the following lines. If there are shared body representations, then the same representations are activated both for one's body and for other people's bodies. In order for body representations to fulfil their intersubjective function, they must represent what one's body and other bodies have in common, and only that. In Jeannerod and Pacherie's terms, they must have a naked content. Their content is neutral relative to whose body it is. They leave the body unattributed and represent indifferently one's body and other people's bodies. They can be either impersonal representations of the type < body part, bodily property > or personal representations with the owner *x* left unspecified of the type < *x*, body part, bodily property >. Thanks to their naked content they enable the perceiver to imitate another individual's actions and to map her sensations onto the perceiver's body.

If this is the right way to characterize shared body representations, then they can hardly ground the sense of bodily ownership. Because of their naked content, shared body representations cannot suffice to distinguish between one's body and other people's bodies. The impossibility lies in the fact that they cannot solve two opposite problems: the correspondence problem in intersubjective situations and the ownership problem. If at some level the representation of one's body is similar to the representation of other people's bodies, then how could it ground the sense of ownership? It seems that the naked body representation would have to play two incompatible roles: grounding self-awareness and grounding other-awareness. It thus follows from the existence

of naked body representations that further processes are needed to discriminate between one's body and other people's bodies. It then seems that one cannot dispense with a 'Whose' system, even for one's biological body.

To recap, Jeannerod and Pacherie's argument (hereafter, the Naked argument) can be articulated into four steps:

- (i) There are representations shared between self and others.
- (ii) Thus, those shared representations must be endowed with a naked content.
- (iii) Thus, they can lead to confusion between self and others.
- (iv) Thus, one needs a specific system dedicated to the discrimination between one's action/body and other people's action/body.

I shall argue that as far as bodily ownership is concerned, the argument is not a valid one.¹ The problem is not that there is no shared body representation. As I will argue, there is convincing evidence that somebody representations are interpersonal. Rather I will argue that the existence of shared body representations does not commit one to posit a 'Whose' system. I will consider two ways to escape the Naked argument. First, one may object to the second step: there is no naked representation, but only a coupling of self-specific and non self-specific representations. Second, one may object to the transition from the second step to the third step: naked representation does not necessarily open the door to confusion. But let me first review the literature in favour of shared body representations.

3. A bodily approach to the correspondence problem

A classic problem in the imitation literature is known as the intersubjective correspondence problem: how does one map another person's movements to one's own movements (Goldenberg, 1995; Heyes, 2001)? The classic way to approach the correspondence problem has been in *sensorimotor* terms: how does one map visual information to motor command (e.g., Brass & Heyes, 2005)? Alternatively, one can consider that the main challenge is a problem of *intermodal* correspondence: how does one map visual information to somatosensory information (e.g., Meltzoff & Moore, 1995)? This latter problem can be found not only in imitation (and especially in the case of opaque movements like tongue protrusion for which one has no visual feedback), but also in vicarious bodily sensations experienced when observing other people receiving tactile (or painful) stimulation. However, the question that interests us here is whether there is a further approach to the correspondence problem. In other words, is there a *bodily* correspondence problem? In imitation, one maps the movement of another body onto one's body, and in mirror-tactile synaesthesia, one maps the location of touch on another body to one's own body. For all that, is intersubjective correspondence mediated by bodily correspondence? Shared motor, affective and somatosensory representations have recently been taken as evidence in favour of embodied social cognition. But this is not the same to say that social cognition is embodied and to say that it exploits representations that carry information about the body, and in particular about its spatial properties (Goldman & de Vignemont, 2009). Here I shall leave aside the obscure notion of embodiment and focus exclusively on the notion of shared body representations. I will assess the degree of their involvement in imitation, vicarious sensations and the perception of other people's peripersonal space (see Table 1).

3.1. Shared body representations in action

"Body part coding reduces the visual appearance of the demonstrated gestures to simple spatial relationships between a limited set of discrete body parts. Body part coding facilitates imitation because it produces equivalence between demonstration and imitation that is independent of the different modalities and perspectives of perceiving one's own and other persons' bodies, and because it reduces the load on working memory in which the shape of the gesture must be held until motor execution is completed" (Goldenberg, 2009, p. 1455).

Goldenberg defends a bodily approach to imitation, according to which one uses knowledge about the body to decode the other's movement and copy it. The special role of body representation in imitation is especially salient for some specific types of actions. This is the case for instance when one imitates meaningless gestures. Upon seeing a military salute, one can recognise it as such and use a stored motor schema of the salute to replicate it. But when one sees a person putting her thumb above her eyebrow, the only solution is to encode the movement in terms of the body parts that are seen and their spatial relations. Hence, it is classically assumed that there are two routes for imitation: one that involves the recognition of the seen action and the other that does not, and only the latter uses 'body part coding' (for review, see Rumiat, Carmo, & Corradi-Dell'Acqua, 2009). Deficits in imitation are then sometimes explained in terms of deficits of body representation. This is the case for instance in patients with ideomotor apraxia who are most affected in the imitation of meaningless gestures (Goldenberg, 1995; Buxbaum, Giovannetti, & Libon, 2000; Schwoebel & Coslett, 2005).

Imitation is often considered as the key mechanism for acquisition of new skills. But the use of imitation is not restricted to explicit learning context. Rather, we have a permanent tendency to automatically imitate other people's movements, which we need to inhibit (Brass, Bekkering, & Prinz, 2001). This can be shown if subjects simultaneously perform a movement. For example, participants are faster in moving their index finger when observing an index finger movement than a middle finger movement. Motor facilitation effect is driven by the bodily congruency between the effectors and cannot be reduced to a mere spatial congruency effect. For instance, Brass and coll. (2001) asked participants to observe an index finger tapping and lifting, but the image was inverted (upward motion for tapping and downward motion for lifting). Yet, participants were faster in tapping when observing tapping in spite of the fact that tapping responses (downward motion) were spatially incompatible with tapping stimuli (upward motion) and were spatially compatible with lifting stimuli (downward motion). This study is only one among many other experiments that indicate that how parts of the body are located and move relative to one another is mirrored when observing other people's actions (e.g. Gillmeister, Catmur, Liepelt, Brass, & Heyes, 2008). Interestingly, it was found that the mere observation of coloured patches on another person's static body parts (head, hand or foot) sufficed to prime action with the same body parts (Bach, Peatfield, & Tipper, 2007). The authors concluded in favour of a "body schema that represents locations on the observer's body and on the bodies of others in a common format" (p. 515). Hence, in some cases, what is shared is not only the representation of the goal or the movement, but the representation of the effector itself that performs the movement. This is confirmed at the neural level. For example, observation of hand, foot and mouth actions selectively activates distinct regions of human ventral premotor and parietal cortex (Buccino et al., 2001). Importantly, Wheaton, Thompson, Syngienotis, Abbott, & Puce (2004) showed this somatotopic pattern of activation even when movements were held constant across effectors (opening and

¹ This is not to deny that there is a 'Who' system for the sense of agency.

Table 1
Involvement of shared body representations in various intersubjective situations.

		Action	Vicarious pain	Vicarious touch	Peripersonal space
Shared body reps	Yes	Imitation	Vicarious sensory pain	Vicarious passive touch	Peripersonal space
	No	Emulation	Vicarious affective pain	Vicarious active touch	Reaching space

closing movements of a hand and a mouth, respectively). Hence, correspondence between self and others can be encoded in bodily terms.

However, it should be noted that this is true in some situations only. It depends at what level the visually perceived action is analysed and copied. It is useful here to draw the parallel with the distinction between imitation and emulation. In imitation, one copies the bodily movement to reach the goal of a perceived action. But in emulation, one copies only the goal. Then there is no bodily correspondence problem. The distinction between imitation and emulation can be found within the mirroring system itself. It is true that mirroring can be effector-specific, but it seems that the majority of mirror neurons are only broadly congruent, encoding the motor goal rather than the specific bodily movement (Csibra, 2007). For example, *different bodily movements* performed for the same intention (grasping with the mouth and grasping with the hand, cf. Gallese, Fadiga, Fogassi, & Rizzolatti, 1996; grasping food with one's hand and with a stick, cf. Ferrari, Rozzi, & Fogassi, 2005) activate the *same brain area*. On the other hand, *the same bodily movement* performed for two distinct intentions (grasping a mug for drinking or for cleaning for instance, cf. Iacoboni et al., 2005) activates *two distinct brain areas*. What is shared is not the representation of the specific limb to move, but rather some motor representation higher in the motor hierarchy. Intersubjective correspondence is then achieved exclusively in motor terms, and not in bodily terms.

3.2. Shared body representation in vicarious pain

At first sight, one may expect the involvement of shared body representation more systematic, or even necessary, in vicarious pain and in vicarious touch insofar as they are vicarious versions of *bodily* sensations. However, as in action, it depends on the situation. Let us consider the case of pain first. The pain matrix includes two functionally specialized networks. The sensory-discriminative component involves the experience of the intensity of pain and its bodily location. It recruits primary and secondary somatosensory areas (SI and SII) as well as the posterior insula. Since SI has a somatotopic organisation, different regions of SI are activated according to whether one experiences standard pain in one's hand, in one's foot, or in one's mouth. In addition, the sensory-discriminative component has a motor counterpart: its activity underlies specific automatic localised motor responses whose function is to avoid (or decrease) the pain. For instance, the muscles adjacent to the location of the painful stimulus freeze, so to speak. The affective component involves the experience of the unpleasantness of the painful experience. It recruits the anterior insula, the anterior cingulate cortex, the thalamus, and the brain stem. It lacks somatotopic organisation.

Now if one experiences vicarious pain, then what happens? Are both components active? More particularly, is vicarious pain localised in a part of one's body that matches the body part that is seen injured? Vicarious pain can be of two distinct kinds: vicarious sensory pain and vicarious affective pain (de Vignemont & Jacob, 2012). In *vicarious sensory pain*, one responds to the perception of another's bodily part subjected to painful stimulation by expecting specific sensorimotor consequences of pain at

the same location on one's own body. For instance, it was found activation of the somatotopically organised SI upon seeing the back of another's hand being deeply penetrated by a needle (Bufalari, Aprile, Avenanti, Di Russo, & Aglioti, 2007). Motor responses to vicarious sensory pain are even muscle-specific, similar to those found when one is injured: when one sees another's hand being hurt, one automatically freezes one's own hand, as if one's own hand were injured (Avenanti, Buetti, Galati, & Aglioti, 2005; Avenanti, Minio-Paluello, Sforza, & Aglioti, 2009). These experimental results strongly suggest that in experiencing vicarious sensory pain, one recruits a representation of the body shared between self and others. By contrast, in *vicarious affective pain*, one experiences a vicarious version of bodily feeling of the type "It hurts" that is quite unspecific and spatially indeterminate (de Vignemont & Jacob, 2012). Most brain imaging studies indeed report a selective activation of the affective component only, with no associated activation of SI when participants observe cues indicating that another individual is receiving a painful stimulus, (e.g., Singer et al., 2004). For instance, the same brain activation was found whether the hand or the foot was injured (Jackson, Meltzoff, & Decety, 2005). Vicarious affective pain is thus indifferent to the bodily location of pain. This is why one can vicariously experience pain upon either perceiving another's facial expression, which does not reveal the bodily location of the other's pain (Botvinick et al., 2005) or imagining another's non-located painful experience (Jackson, Brunet, Meltzoff, & Decety, 2006). In this sense, vicarious affective pain does not recruit shared body representations.

3.3. Shared body representations in vicarious touch

Touch is also characterised by its dual nature, although of a different kind from pain. Touch can be active (*touchant*) or passive (*touché*), or both at the same time in self-touch. One can then distinguish between vicarious active touch and vicarious passive touch, although they are confounded in most experiments.

The most striking evidence of *vicarious passive touch* can be found in mirror-touch synaesthesia (and in some patients with phantom limbs, see Ramachandran & Brang, 2009). Individuals with this condition consciously feel tactile sensations on their own body when they see another person's being touched (Blakemore et al., 2005; Banissy and Ward, 2007). Upon seeing another being touched on the left cheek for example, they experience a sensation of touch on their own cheek. If at the same time they are touched on the right cheek, they either report feeling touch on both sides or they make mistakes (they report feeling touch on the left). This is not a mere attentional effect. They do not make mistakes if they see a visual flash on the left of the face rather than receive a tactile stimulus (Banissy & Ward, 2007). When compared to normal subjects, a more intense activity of the somatosensory cortex was found when subjects with mirror-tactile synaesthesia saw people being touched (Blakemore et al., 2005). Arguably, individuals with mirror-tactile synaesthesia exploit body representations in order to map the location of the tactile stimulation of another's body onto their own body.

The interpersonal dimension of body representations in the sensory domain is confirmed by results in the multisensory

literature. It is well known that viewing the body part that is touched (without viewing the touching object) enhances tactile acuity so that one's judgements about tactile sensations are both faster (Tipper et al., 2001) and more accurate (Kennett et al., 2001). Importantly, the effect of visual enhancement of touch is as effective when seeing one's own body part as when seeing another person's body part (Haggard, 2006). Likewise, Thomas, Press, and Haggard (2006) found that participants were faster in detecting touch when they saw before a non-predictive visual cue on another person's body at the corresponding location. The authors concluded: "We believe that our results provide the first behavioural evidence in normal subjects for interpersonal body representation based on a somatotopic spatial map, at the purely sensory level." p. 328).

There is, however, a different type of vicarious touch, which is related to the movement of touching. *Vicarious active touch* can be interpreted in terms of the mirroring of tactile consequences of action (Keyser et al., 2010). In support of this view, several brain imaging studies found activity only in SII, and not in SI, when participants observed another person being touched (Keyers et al., 2004; Ebisch et al., 2008). Interestingly, SII was activated even when participants watched an object being touched, rolls of paper for instance. It thus seems that most of the time vicarious active touch takes into account primarily the act of touching: "What is being touched does not matter as long as touch occurs" (Keyers et al., 2004, p. 339).

3.4. Shared body representations in peripersonal space

There is a last series of evidence that argues in favour of shared body representations, which is at the crossroad between vicarious bodily sensations and action. We know that the space immediately surrounding one's body, namely peripersonal space, is processed differently than extrapersonal space (for review, Brozzoli, Makin, Cardinali, Holmes, & Farnè, 2012). A large number of studies with monkeys have now found bimodal neurons in several brain structures (putamen, parietal and premotor area), which are activated both by touch and by vision (or audition). Interestingly, they are activated even when the visual stimulus is not on the body part itself, but up to 30–50 cm off the body part (e.g., Cooke & Graziano, 2003). Moreover, the visual (or auditory) activity follows the position of the tactile receptive field associated to a specific part of the body when the part is moved. It is thus body-centered. Several studies support the existence of a similar multimodal representation of peripersonal space in humans, which results in the interaction between visual (or auditory) stimulus near the body and tactile processing (Brozzoli et al., 2012). Interestingly, a series of evidence indicates that the perception of other people's peripersonal space recruits the same resource as the representation of one's peripersonal space. Ishida, Nakajima, Inase and Murata (2010) found in monkey parietal areas that some visuo-tactile neurons fired when a visual stimulus was close both to a part of the monkey's body and to the experimenter's equivalent body part. The effect was body part specific. Likewise in humans, it was found that SI was activated when the experimenter stroked with a paintbrush the region of space close to a hand visually presented from a third-person perspective (Schaefer, Heinze, & Rotte, 2012).

The representation of the space surrounding one's body has also consequences for action. It then corresponds to how far one can reach for an object without moving one's torso. Some recent evidence indicates that to some extent one represents other people's reaching space in the same way as one represents one's reaching space. For example, it has been shown that the spatial alignment of the object with the body affects the subsequent motor response only if the object is within the reaching space

(e.g., one is quicker in using the left hand than the right hand to grasp the handle of a mug is aligned with the left hand, Costantini, Ambrosini, Trier, Sinigaglia, & Committeri, 2010). Now a recent study showed that the effect worked as well if the mug was in a virtual individual's reaching space, although it was not in the participants' own reaching space (Costantini, Committeri, & Sinigaglia, 2011). Cardellicchio, Sinigaglia and Costantini (2012) further showed that motor-evoked potentials were higher when the mug was close either to the participants or to the avatar. The authors concluded: "Our proposal is that such sensitivity can be explained by means of an interpersonal bodily space representation allowing one to map the body of other people in terms of their actual motor possibilities" (p. 4).

To conclude, there are several ways to solve the intersubjective correspondence problem, and not all of them involve the use of shared body representations (see Table 1). One can map the other onto oneself while bracketing the spatial properties of the body. However, what is interesting for the sake of this paper is that in other cases, one needs to exploit a representation of the body to map other people's bodies to one's own body. The body is then the common "currency" between self and others. And this is so both in the motor and in the perceptual domains. We can now turn back to our original question. What implications do shared body representations have for the sense of bodily ownership?

4. A matter of coupling?

The first step of the Naked argument was that there are shared representations. We have just validated it. Intersubjective correspondence can be encoded in bodily terms. It may then seem that the rest of the argument follows: the sense of bodily ownership is similar to the sense of agency; it relies on a specific dedicated system to disambiguate naked representations. But this is not true. It does not follow from the fact that there are shared representations that those representations are naked. When one considers the notion of shared representation, one generally assumes that it consists in a single representation exploited for both one's body and other bodies. However, there is an alternative model that can account for the evidence reviewed above. Intersubjective correspondence can also be achieved by the automatic association of distinct representations. This latter view has been defended among others by Heyes (2001). According to the Associative Sequence Learning (ASL) model, imitation is based on past experiences of the systematic coupling between the action one performs and its sensory consequences. Typically, when I wave my hand, I see it waving. I can thus learn the sensorimotor association so that when I see another person waving, the sensory input can automatically elicit the associated motor output. Another example can be found in Gallagher and Meltzoff (1993). They argue that imitation depends on the systematic association between the body schema, which is primarily proprioceptive and motor, and the body image, which is primarily visual. One can also interpret some of the multisensory results along these lines. On the basis of their findings that the vision of non-predictive cues of another person's body could interfere with tactile processing on one's own body, Thomas and coll. (2006) defined shared body representations in terms of "a special, automatic mechanism for associating sensory body events" (p. 327, my underline). What consequence does the associationist model have for the sense of bodily ownership? Unfortunately, these different conceptions do not directly address the question of the specific content of the representations that are associated. In particular, are those representations naked? Are they neutral relative to the owner of the body?

Q3

4.1. What is associated

Let us consider the ASL model in more detail. The two terms of the association are (i) a motor representation, which consists in the activity of the mirror system at the neural level, and (ii) a visual representation of the movement. The visual representation can represent either one's own movement or another person's movement. In this sense, it can be said to be naked. The seen movement is unattributed. The motor representation, on the other hand, is always used for one's own motor system. It plays a role for one's own actions, and one's own actions only. Hence, one may argue that it is first-personal (although not necessarily reflexively). The association can thus be reformulated as follows: an intention <I raise my finger> associated to a visual representation <a finger raising>. The association was built on the basis of past experiences of seeing my finger raising when I have the intention to raise my finger. But it has generalised to any raising finger. Hence, when I see you raising your finger, this activates my mirror system and I have an automatic tendency to imitate the movement. On this view, the motor representation is activated by another person's actions, but for all that it does not represent intentions other than one's own. Only the visual representation has a naked content, not the motor representation. We can apply the same analysis to mirror-tactile synaesthesia. Then the association is between a visual representation <tactile stimuli on a cheek> and a tactile representation <touch on my cheek>. Again, only the visual representation has a naked content, even if the tactile representation is activated by another person being touched.

If this is the right interpretation, then the results described in the previous section have no implication for the content of motor and somatosensory representations. All they imply is that visual representations have a naked content, but this is hardly surprising. What is interesting is that the body representation associated to the visual representation of other people's bodies can remain self-specific. Discriminating one's body from other bodies is then not an issue. As Gallagher & Meltzoff, 1996, p. 225–226) noted, "Thus there is a coupling between self and other, and this coupling does not involve a confused experience". One can thus dispense with a 'Whose' system. The possibility of bodily correspondence has no consequence for the sense of bodily ownership.

4.2. From self to other, from other to self

However, one may challenge Gallagher and Meltzoff's conclusion: coupling can lead to confusion if it is mandatory. If the activation of one representation automatically and systematically induces the activation of the other, and vice-versa, then the coupled representations behave as if they constitute a unique representation.² It would be like marriage: after a while, you can never invite one spouse without the other; they have lost their individuality. More than coupling, one should then talk of fusion, which can lead to confusion. And if this is the case, then we are back to our original problem. If the couple is activated both by seeing one's body and other people's bodies, then the activation of the couple can no longer suffice to discriminate among bodies.

The question is thus whether the coupling is mandatory or not. If it is, then it does not make much functional difference whether there is a single representation or an association of representations. To settle the debate, one must look at the empirical data. However, the evidence is not straightforward. On the one hand, some results indicate that the association can allow for some flexibility and plasticity. For example, it has been shown that

automatic imitation is sensitive to sensorimotor learning (Cook, Press, Dickinson, & Heyes, 2010). Body part priming in imitation was reduced following the repeated exposure to incongruent sensorimotor associations such as observing a hand action while performing a movement with the foot. On the other hand, other findings indicate a tight coupling, so tight that there are bidirectional relations between the two terms of the association.

Most studies have investigated the effect of the observation of others upon oneself, but a few studies showed that the representation of one's body influences the perception of other people's bodies. For example, when participants observe two photographs that differ only in the position of one limb that alternates, they see an illusory movement of the limb. If the photographs are flashed in rapid succession, they perceive the limb traversing the shortest possible path of visual apparent motion, although it is biologically impossible because of joint constraints. But if the presentation rate slows down, they perceive paths of apparent limb movement that follow natural human limb trajectories (Shiffrar & Freyd, 1990). This result indicates that knowledge of one's joint constraints determines how one perceives other people's bodily movements. This effect is not driven by mere visual familiarity of other people's movements, as shown by a study with two apraxic patients born with no arm (Funk, Shiffrar, & Brugger, 2005). They shared the same visual familiarity of the movements that are biologically possible, but only one of the patients experienced phantom arms, and thus, had bodily familiarity with joint constraints. Interestingly, it was found that only this patient showed the same perceptual pattern as normal subjects. Hence, the representation of one's bodily constraints can affect the perception of another individual's bodily movements. Another study showed that healthy participants were more efficient in detecting changes in a model's leg posture than in the model's arm posture if they were moving their legs, and conversely that they were more efficient in detecting changes in a model's arm posture if they were moving their arms (Reed & Farah, 1995). Hence, not only does the perception of another person's movement affect one's own movements (other-to-self), but one's own movements can also facilitate the perception of another's body (self-to-other). These results do not offer a definite reply about the strength of the association, if association there is. Still they argue in favour of a strong coupling, or even of actual sharing. Let us now consider the implications of the hypothesis that the same body representations can be shared between self and others.

5. The Janus head hypothesis

As said earlier, if the same representations are activated both for one's body and for other people's bodies, then they must thus represent what one's body and other bodies have in common, and only that. They must represent an unattributed body. But if we grant that they have a naked content, it may then seem that we must also grant the next step of the Naked argument: the existence of naked body content necessarily leads to confusion between self and others. However, I will show that this is not true. To do so, I will first describe in more details what bodily information is represented in shared body representations.

5.1. What is shared

One may ask what kind of body representation is shared. Goldenberg (1995) argues that imitation recruits abstract conceptual knowledge of the human body. By contrast, Chaminade, Meltzoff and Decety (2005) as well as Buxbaum et al. (2000) consider the primitive body schema as the most likely candidate in virtue of its sensorimotor content. This may be so in the context of

² I would like to thank Wolfgang Prinz for this objection.

action, but since shared body representations are also found in the perceptual domain, one may expect body representations that are not sensorimotor to be also involved, like the body image (Gallagher & Meltzoff, 1996). Given the confusion around these various notions (de Vignemont, 2010), I shall leave them aside and instead specify what bodily information needs to be encoded in intersubjective contexts.

A first point is that the content of shared body representations must be quite rough-grained, both in the motor and in the perceptual domains. There are many differences between bodies, differences in gender, posture, limb size, muscle strength, joint flexibility, and so forth. Yet, these differences do not prevent intersubjective correspondence. Typically a child can imitate an adult. The brain must thus abstract from major bodily differences. It then seems that what remains in common between all bodies is the configuration of the various body parts, i.e. the fact that we have two hands and two feet and they are respectively located at the end of our arms and legs.

Now I want to argue that the representation of the spatial organisation of body configuration differs in imitation and in vicarious bodily sensations (de Vignemont, Tsakiris, & Haggard, 2005). In a nutshell, the body representation that is used in imitation represents *functionally* defined body parts; the body representation that is used in vicarious bodily sensations represents *anatomically* defined body parts. Unfortunately, there is little evidence in the case of vicarious bodily sensations. In particular, few body parts (hand, cheek and neck) have been tested in mirror-tactile synaesthesia and the localisation of vicarious touch has been analysed only in terms of anatomical congruency (observation of touch on the left cheek causes tactile sensation on the left) versus specular congruency (observation of touch on the left cheek causes tactile sensation on the right) (e.g., Banissy, Walsh, & Ward, 2009). Hence, we do not know how fine-grained the bodily mapping is (e.g., does one map touch to a specific body part or to a specific location within this body part?). We know more in the case of action mirroring. For example, observing hand, foot or mouth actions selectively activate brain areas for hand, foot, and mouth even if the movement is performed by non-conspecifics such as monkeys or dogs (Buccino et al., 2004), or robots (Gazzola, Rizzolatti, Wicker, & Keysers, 2007a; Press, Bird, Flach, & Heyes, 2005). What matters to mirroring is the type of movements the body part can afford, and not the visual appearance and shape of the body part. This is well illustrated by the following finding in aplasic individuals who were born without hands and who perform with their feet and their mouth actions normally performed with hands. It was found that they activated regions of the mirror system recruited in mouth and foot movement execution when observing hand movements (Gazzola et al., 2007b). Hence, in mirroring, one matches functional bodily units dedicated to specific types of movements. Functional body parts consist in parts of the body that are normally regrouped by their role in action (e.g., grasping unit of fingers and hand; kicking unit of foot and leg). Arguably, this level of segmentation of the body into parts is the most relevant for action in general, and for imitation and mirroring in particular. For most gestures one can dispense with more detailed bodily specification. All that needs to be represented is the dynamic position of functionally defined body parts with respect to one another (Buxbaum et al., 2000).

5.2. What is not shared

To recap, shared body representations are both pervasive and limited. They are pervasive because both body representation for action and body representation for perception are shared. But they are also limited because their content is sketchy, encoding information about bodily configuration only. I shall now argue that it is

because of their informational poverty that the existence of shared body representations does not threaten the boundary between self and others.

The debate here is actually far broader than about some putative 'Whose' system. What is at stake is whether the exploitation of common resources prevents or reduces the modularity of the mind. According to the modular view, the brain is organised in specialized separately modifiable cognitive abilities that use specific, dedicated neural resources. A modularist may for example claim that some are dedicated to the self and others are dedicated to social cognition. However, more and more evidence indicates that brain regions are not recruited by a single task. Rather, they are recycled to support numerous cognitive functions (e.g., Anderson, 2010; Dehaene & Cohen, 2007; Goldman, 2012). In other words, they are originally established for one purpose and reused for a different cognitive purpose. Recycling makes sense from an evolutionary perspective insofar as it is more parsimonious than developing new neural systems. One may then believe that it challenges the modular conception of the mind. But the fact that there are modules does not preclude those modules from sharing parts wherever possible (Carruthers, 2006, p. 23): "As a result, what we should predict is that while there will be many modules, those modules should share parts wherever this can be achieved without losing too much processing efficiency". This may work along the "time-sharing model" offered by Jungé & Dennett, 2010, (p. 278): "(1) At any given time, one high-level process uses the 'workings' of multiple lower-level areas, and (2) numerous high-level processes are hypothesised to alternately access a common pool of specialized lower-level resources". The point is that modules are not exhausted by the parts that are shared. If the parts that are not shared are disrupted or modified, then it alters only one module and not the other.

Likewise, shared body representations do not mean the end of the boundary between self and others. What is shared is the representation of the rough structure of the body, either for action or for perception. But this rough structure needs to be filled in for a full-fleshed spatial representation of one's body, including information about body metrics for example, which is highly specific and can hardly be shared. Hence, some processing of bodily information constitutes a common resource between self and other people, which can in turn be used for one or the other. But what is shared, and thus naked, is only one component of more complex representations of the body that are not shared. Those more complex body representations may be called "superficial schema" (Head & Holmes, 1911), "body structural description" (Schwoebel & Coslett, 2005) or "long-term body image" (O'Shaughnessy, 1980). All refer to more or less the same notion, that is, the representation of the spatial configuration and the dimension of the body, what I call myself a *body map*.

To recap, some components of the body map are shared between self and others, but some components only. This is confirmed by brain imaging studies, which never show perfect identity between activation for the self and activation for others. For instance, vicarious touch can activate SI, but this hardly exhausts the neural basis of the representation of the spatial properties of one's body, which includes brain areas at a higher level, including the parietal area. There are differences even in visual representations of the body. For example, it was found that in the extrastriate body area in the visual cortex, different brain regions selectively responded to images of one's own body parts or other people's body parts (Myers & Sowden, 2008). Furthermore, it was found an implicit self-advantage in body visual recognition (Frassinetti, Maini, Romualdi, Galante, & Avanzi, 2008; Frassinetti et al., 2012). Participants were asked to match pictures of body parts together. Their performance improved when the pictures displayed their own body parts from an egocentric perspective

compared to when they display other people's body parts from the same perspective. Hence, they were better in visually processing their own body than any other bodies.

The fact that self and others are not fully confounded is also confirmed by neuropsychological dissociations. For example, patients with anorexia nervosa were asked to imagine walking through a door-like aperture and then to judge whether or not they would be able to walk at a normal speed without turning sideways (Guardia et al., 2012). Alternatively they were asked to imagine another person of the same size walking through the aperture and to judge whether she could pass. It was found that the patients mistakenly judged that they could not pass in apertures in which they accurately judged other people could pass. One way to interpret the results is that the map of their own body was impaired with no consequence on the representation of other people's bodies. Conversely, patients with heterotopagnosia have selective difficulties in locating another individual's body parts on her body, but no difficulty on their own body. Rather than pointing on another's body, they indicate the location of the named body part on their own body (Felician, Ceccaldi, Didic, Thinus-Blanc, & Poncet, 2003). Consequently, deficits of the map of one's body do not necessarily lead to intersubjective impairments.

We can then propose the following hypothesis:

Janus head hypothesis: Intersubjective correspondence is achieved by time-sharing processing of bodily information that is common to the map of one's body and the map of other people's bodies.

On this view, neural resources that were originally designed to represent one's bodily states and were later shaped to represent other people's states are Janus-faced. They face inward as representation of one's body and they face outward as representation of other people's bodies. They can thus bridge the gap between one's body and other people's bodies, but without losing the distinction between self and others. At the level of the body map, representations of one's body still differ from representations of other people's bodies. They are not shared, and thus, they cannot lead to confusion. It then seems that one can dispense with a 'Whose' system despite the existence of shared body representations. The content is not naked at all levels. The map of one's body is not exhausted by what is shared. It can thus keep its self-specificity, and thus, suffice to ground the sense of body ownership.

6. Conclusion

Do we need a 'Whose' system like we have a 'Who' system? Here I have addressed these questions by analysing the implications of intersubjective correspondence for the content of body representations. I have argued that intersubjective correspondence is encoded in bodily terms in some – but not all – situations. There are shared body representations endowed with naked content, both in the motor and in the perceptual domains, but that they do not exhaust the maps of the body, that is, the representations of the spatial properties of the body. Some components of the body maps are naked, but others are not. Hence, body maps do not leave the body unattributed. They are thus susceptible to ground the sense of body ownership. It thus seems that one can dispense with a 'Whose' system despite the existence of shared body representations.

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