**Accepted in Neuropsychologia, November 5, 2009**

# Embodied cognition and beyond: acting and sensing the body

Anna M. Borghi*^ & Felice Cimatti°

*Department of Psychology, University of Bologna

^ Institute of Cognitive Science and Technology, CNR, Rome

° Department of Philosophy, University of Calabria

Address correspondence to:

Anna Borghi

Department of Psychology

Viale Berti Pichat, 5

40127 Bologna – ITALY

Phone: +39-051-2091838

Fax: +39-051-243086

Email: annamaria.borghi@unibo.it

**Abstract**

Embodied cognition (EC) underlines that cognition is constrained by the kind of body we possess, and stresses the importance of action for cognition. In this perspective the body is always considered as an *acting* body. Here, we review EC literature discussing studies that show that body parts are not considered independent of their involvement in action. We propose to extend EC perspective through studying the body independently from its direct involvement in goal-directed action. Through this we aim to avoid the risk of limiting the notion of "sense of the body" to the restricted boundaries of the flesh of brain-body system. In our extended perspective language is considered as a form of action too. We propose that: a. internal language (i.e. social language used as an internal medium for thought and planning) can contribute to form a unitary sense of our body, and b. language can help to reshape the way we implicitly perceive our own body. Namely, it can modify our sense of body by extending its boundaries beyond the boundaries of the anatomical body. We argue for an integrated notion of bodily self suggesting that the internal sense and the boundaries of the human body coincide with the extensions that linguistic tools allow. In sum, the basic idea we hold is that human body is a social entity.

**Key words**

Sense of body; action, social action; embodied cognition; embodiment; language comprehension; body parts; categorization; extended mind; grounded cognition; sensation.

**Acknowledgements**

This work was supported by the European Community's Seventh Framework Programme FP7/2007-2013 - Challenge 2- Cognitive Systems, Interaction, Robotics -, project **ROSSI**: Emergence of communication in **RO**bots through **S**ensorimotor and **S**ocial **I**nteraction (Grant agreement n. 216125).

We would like to thank the members of the Embodied Cognition group (www.emco.unibo.it), Bologna, the Laboratory of Computational Embodied Neuroscience of ISTC-CNR, Rome, and Ilaria Gaudiello, Marco Mazzeo, Giovanni Pezzulo, and Luca Tummolini for discussions on this topic. A special thanks to Annalisa Setti for discussions and a careful revision of a first draft of the manuscript, to Claudia Scorolli for discussions and experimental suggestions on language and body extension, and to Kate Burke for the English revision of the text.

The order of authorship is alphabetical. The two authors contributed equally to the paper.

## INTRODUCTION

The label Embodied Cognition (EC) is typically used to refer to a number of theories in a variety of domains within cognitive science (artificial intelligence, robotics, psychology, cognitive neuroscience, philosophy, linguistics, cognitive anthropology). Within the EC approach, some authors emphasize the importance of action for cognition and the role played by bodily states, others highlight more generally the role of grounding for cognition and equate embodied cognition with situated cognition (see Goldman & de Vignemont, 2009, and Kiverstein & Clark, 2009, for discussion on this issue). According to the most radical version of EC, cognition is constrained by the specific kind of body we possess, and the key notion of embodied cognition is *action* (e.g., Gallese, 2008; Glenberg, 1997). The second version of EC recognizes the importance of the sensorimotor system for cognition, but it attributes more importance to grounding in multiple ways, not only in bodily states. As Barsalou (2008) states, "Grounded cognition reflects the assumption that cognition is typically grounded in multiple ways, including simulations, situated action, and, on occasion, bodily states". These two assumptions lead to the formulation of two slightly different views of cognition and of language grounding, the first of which ascribes a more crucial role to action. According to the first view, concepts are patterns of potential action and directly evoke action information (Glenberg, 1997; Gallese & Lakoff, 2005), whereas according to the second concepts are made up of "perceptual symbols" from which, depending on the current context, it is possible to quickly extract data that might inform action (Barsalou, 1999). Additionally, these two positions ascribe a different role to simulation. Note that the notion of simulation has been used in different ways (for a review, see Decety and Grezes, 2006). In philosophy of mind and developmental science, simulation refers to our mind-reading capabilities (e.g., Gallese & Goldman, 1998; Goldman, 2006); we would simulate in order to understand the

mental states of others. Other authors relate simulation to motor cognition. In the framework of motor cognition, some authors (e.g., Decety & Ingvar, 1990) see simulation as a conscious process, not aimed at understanding others' minds but rather depending on a deliberate reactivation of previously performed actions. Others intend simulation as a covert process. For example, according to Jeannerod (2007) simulation is the offline recruitment of the same neural networks involved in perception and action. In his view, simulating differs from overt action because the activation is weaker than in overt action, a blocking mechanism may take place and no sensorial feedback is provided. Along the same line, other authors (e.g. Gallese, 2009) intend simulation as an embodied and automatic mechanism, not an intentional way to understand others' behaviours and mental states. Within the EC theories, two slightly different notions of simulations are used: in one case simulation is a form of prediction which is useful to prepare an action and to comprehend it (e.g., Gallese, 2009), in another the role of prediction and anticipation of motor outcome is less relevant and simulation is mainly a form of re-enhancement of past sensorimotor experience (Barsalou, 1999).

As detailed in Borghi (2005) in relation to object concepts, our position is that both versions of the EC theory are true, depending on the context. Consider words. It is adaptive that a word like "cup" automatically activates motor information for simple interactions with its referent, particularly for manipulable objects. But when it comes to performing more complex actions, a higher flexibility might be required, and it might be useful to represent cups not only in terms of their handle and of their graspability, but also in terms of other perceptual and contextual properties. In this paper we intend to highlight two limitations of EC theories, and claim that they should be extended, and that new empirical evidence should be collected to cover phenomena that remain unexplained. The first limitation we will address is that EC theories do not seem to account for the existence of a body that can sense itself when no sensible external interaction,

active or passive, is taking place. For example, when we dance we might "feel" our body, even when no real interaction with external objects or entities takes place. But we can also "feel" our body when we simply perceive a sail at the horizon suggesting that even If no action is performed by our body, it does not prevent us from feeling it as *our* body.

We will also focus on a further constraint of EC theories: they limit cognitive activity within the boundaries of our body-brain system without considering that external supports, such as tools, may help augment and revise our body schema (we propose to consider "sense of the body" as equivalent to the notion of "body schema", as an on-line sense of the body as a unitary whole; see Head & Holmes, 1911; Holmes & Spence, 2004). In discussing external support we do not take a functionalist stance; rather we refer to external supports that, in close integration with the characteristics of our body and of our sensorimotor system, complement our bodily functions.

In order to address these issues, we first review literature on the body, and particularly on body parts. Namely, the knowledge of our body parts seems to be quite a crucial kind of knowledge, as shown by Kemmerer and Tranel (2008) who performed an extensive neuropsychological study investigating the neural substrate of body part representation. Interestingly, they found no impairment in body part comprehension, even in patients with body part anomia. Similarly to the ability to recognize smiling faces, the capability to comprehend body parts' names seems to be resilient to brain damage. In this review we will discuss studies in which behavioural effects and motor resonance phenomena elicited by images of body parts are investigated, then we will focus on work showing that during language comprehension a fairly specific simulation is activated, which is sensitive to the body parts action sentences refer to (e.g., Buccino, Riggio, Melli, Binkofsky, Gallese & Rizzolatti, 2005). The review is aimed at supporting the claim that current EC theories focus mostly on overt actions, and that they tend to overlook the importance of "passive" responses to environmental stimuli. Body parts are typically not

studied independently from their involvement in action, and this is particularly manifested in studies on language comprehension (for recent reviews on language and action, see Andres, Olivier, and Badets, 2008; Fischer and Zwaan, 2008; Zwaan and Taylor, 2006; for critical reviews see Mahon and Caramazza, 2008; for a critical review of EC theories the claim of which is that "language is beyond action", see Toni, de Lange, Noordzij, and Hagoort, 2008). In the second part of the paper we illustrate our view, moving from one basic assumption and formulating two proposals. In keeping with the literature, we assume that self-perception develops such that self-perception is not an all-or-none entity. A crucial aspect of this development is the shift from a partly fragmented sense of body ownership, which reflects discrete somatotopic coding in S1, and the sense of a unitary body derived from agency, in which different body parts are perceived as a whole, which involves the primary motor cortex (Tsakiris, Prabhu, & Haggard, 2006). Starting from this assumption, we formulate two proposals: a. *External* self-perception exists, that is, there is a form of human *self*-perception which is mediated by *external* and *social* entities such as words. In this respect, we propose that internal language might play a major role in shaping the feeling of the unity of our body (Morin, 2009). b) Due to the use of external and social entities the sense of our body might be modified. More specifically, we propose that words, intended as tools, might contribute to changing our body schema by extending the body boundaries.

## EC THEORIES: SEEING HANDS IN DIFFERENT TASKS

The brief review that follows is aimed at showing that body parts are typically studied in the context of overt action, and at substantiating the claim that EC theories should be extended to also study passive body states. We will restrict the review to studies in which not only a motor response (e.g., a reaching or a grasping one) is recorded, but in which participants perform either a categorization or a cognitive decision task.

### Hands as parts of the whole body system

Body parts are not perceived per se but they imply a sense of the whole body system, as evidence on the Sidedness effect (Ottoboni, Tessari, Cubelli, & Umiltà, 2005) reveals. Ottoboni et al (2005) presented a picture of a left or right hand with a colored circle in the center; participants responded by pressing a left or a right key to the color of the circle. A Simon effect was found for back views of the hand; a reverse Simon effect was found for palm views. This pattern of results was found when the forearm was present, and when the hand was linked to the body in a biomechanically plausible way; when the hands were cut at the wrist, no effect emerged. These findings suggest that simply seeing a hand implies a sense of the system composed by hand and forehand and by its links with the whole body.

**Hands interacting with objects**

Seeing an effector (e.g., hand) which performs an action evokes a resonance mechanism. The neural underpinning of this echoing mechanism is the mirror neuron system (MNS), which is activated both when the subject performs a purposeful movement toward objects as well as when the same movement executed by someone else is observed (for a review, see Rizzolatti & Craighero, 2004). At the behavioral level, a number of studies have demonstrated that seeing a hand activates the motor system even if the task does not require attention to be paid to it (e.g., Craighero, Bello, Fadiga, & Rizzolatti, 2002). In a typical paradigm employing categorization task, participants are presented with hands interacting with objects, or with hands working as primes followed by target objects; typically both the hand posture and the pragmatic characteristics of the objects are manipulated. For example, Yoon & Humphreys (2005) presented participants with pictures of objects either alone or associated with a handgrip congruent or incongruent with the standard object use. The congruent hand-posture led to faster responses in an action decision task, i.e. when participants were required to verify whether a name presented just below the image of the object described the way the object was usually

used (e.g., knife - "slicing"). A less systematic effect of congruency was also present in a name verification task, when participants had to decide whether the target- object matched a name presented below the target image. Borghi, Bonfiglioli, Lugli, Ricciardelli, Rubichi and Nicoletti (2007) used a categorization task (artifact vs. natural objects) and found a congruency effect between the prime hand posture (either a power or a precision one) and the grip evoked by the target-object; this effect was found only when the experiment was preceded by a motor training in which participants imitated the gestures displayed in the hand-pictures. Vainio, Symes, Ellis, Tucker, and Ottoboni (2008) found a stronger congruency effect between the hand posture and the grip evoked by objects replicating the study with videoclips instead of static images of hands (for similar congruency effects see also Fischer, Prinz & Lotz, 2008). Attention to fine-grained aspects of effectors is also demonstrated when the targets are words: a recent categorization study showed that uni- and bi-manual hand postures primed words differently when referring to self-moving and non self-moving entities (i.e., animals and plants) (Setti, Borghi & Tessari, 2009).

The behavioral studies described so far show that motor information is activated, when both a hand and an object (or a word referring to an object) are present and have the potential to interact. TMS evidence complements this picture showing that, when effectors without objects are presented, the motor system is maximally activated by the extrapolation of the future trajectory of body actions (Urgesi, Moro, Candidi, & Aglioti, 2006; for further evidence on the activation of the MNS on the presentation of a static images of effectors which imply motion, see Freyd, 1983; Kourtzi & Kanwisher, 2000; Nelissen, Luppino, Vanduffel, Rizzolatti, and Orban, 2005; Johnson-Frey, Maloof, Newman-Norlund, Farrer, Inati & Grafton, 2003).

**Hands in our own or in another perspective**

Action aside, the ability to distinguish between our own body and the body of others is of great importance for developing the sense of body. A number of recent studies have demonstrated that the perspective through which we perceive others' effectors influences performance. These studies (e.g., Vogt, Taylor & Hopkins, 2003) typically manipulate the perspective of the presented hand, which can either match the end posture of the observer's own hand (egocentric perspective) or the end posture of that of another person (non-egocentric perspective). For example, Bruzzo, Borghi and Ghirlanda (2008) presented hand-primes and target-objects in ego- or non-egocentric perspective and instructed participants to decide whether or not the action displayed by the hand was suitable for interacting with the object depicted. Results revealed an advantage of the egocentric over non-egocentric targets. In addition, the fastest responses were obtained with egocentric primes followed by egocentric targets. This is in line with the Theory of Event Coding (TEC, Hommel et al., 2001) which asserts that when there is a high degree of overlap between perceived events (the action of the effector we see) and events to be produced (the action produced by our own effector), processing of the seen stimuli is facilitated. The importance of the egocentric perspective has also been investigated with brain imaging studies. For example, Jackson, Meltzoff, and Decety (2006) found more activity in the left sensory motor cortex for the egocentric perspective, even during simple action observation, and in the lingual gyrus for the non-egocentric perspective. In addition, a number of neuropsychological studies on both normal subjects and patients have shown that shifts in perspective might lead to erroneous attributions of our own actions to others (e.g., Daprati, Frank, Georgieff, et al., 1997).

EC studies have also investigated how perspective is encoded in language. Recent behavioral studies confirm that readers form a simulation adopting the perspective they would take as if they were actors (Barsalou, 2005; Borghi, 2004; Borghi, Glenberg &

Kaschak, 2004; Lozano, Hard & Tversky, 2007). Interestingly, the perspective adopted can be modulated by the pronouns used: in keeping with the idea that the mirror neurons system is involved in simulations formed during reading, subjects use an actors perspective when the pronouns "I" and "you" are used, whereas they adopt an external perspective when the third person pronoun is used (Brunyè, Ditman, Mahoney, Augustyn, & Taylor, 2009). The studies revised show that different neural mechanisms are implied while observing actions and objects in our own and in the other's perspective, and that the egocentric perspective, more linked to direct action, is typically privileged.

**Hands and passive movement: what EC theories do not address**

The results described so far suggest that, while we observe effectors, a motor resonance phenomenon takes place, as we map the actions we see with our own actions. This is particularly true with video-clips rather than with static images, and when an object is presented. This might lead to the concurrent activation of the mirror neuron system, while observing others, and to the canonical neuron system, while observing objects (Rizzolatti & Craighero, 2004). In addition, we tend to represent actions in an egocentric perspective. As we will detail in the second part, action is crucial to distinguish our body from external objects. However, not only action is important. To our knowledge, no study focuses on the way we "feel" our body parts as passive perceivers, independently of involvement in voluntary action. A partial exception is represented by studies investigating passive responses to external stimuli, as it is the case in empathy for pain (e.g., Avenanti, Bueti, Galati, & Aglioti, 2005; Avenanti, Paulello, Bufalari, & Aglioti, 2006). However, the focus of these studies is on motor resonance evoked while seeing others, and typically no cognitive decision is required, thus we will not discuss them further here.

The main theoretical point the results on observation of effectors raise is the following: it seems as if this empirical evidence implicitly asserts that the body could not

sense itself as something existing when no external action is actually performed (Knöblich, 2002; van den Bos, Jeannerod, 2002; Sato, 2009). For example off-line cognition, one of the main components of the sense of the body we would like to stress, is typically considered as directly derived from and connected to action: "even when decoupled from the environment, the activity of the mind is grounded in mechanisms that evolved for interaction with the environment—that is, mechanisms of sensory processing and motor control" (Wilson, 2002, 626). We are not assuming the existence of some mysterious form of internal self-perception. We reviewed studies on body parts and objects because, as we will detail later, our sense of body relies on our ability to distinguish our own body from external objects, which resist our actions, and to distinguish our own body from the bodies of others. But we believe that if EC theories assume that the body could not perceive itself when no action is going on, they are missing a crucial phenomenological point, that the body can still sense itself as an autonomous entity even when no external action is actually performed (a developmental perspective that highlights an earliest autonomous form of sense of body is presented in Gallagher and Meltzoff, 1996). We can feel ourselves as a body even when we do not entertain any action. That is, voluntary action is not necessary to experience ourselves as a unitary body. The majority of EC theories do not fully consider this common experience. To try to give an account of this fact we propose to extend usual EC theories by including passive experiences and the use of language as a means to develop a unitary sense of body agency.

We will now turn to studies on language comprehension that focus on body parts. Many studies have shown that when we comprehend action sentences we activate the body parts the sentence implies (e.g., a manual action such as writing activates the hand effector). The brief overview we will provide will confirm that in language comprehension body parts are also studied mostly in the context of overt actions.

## EC THEORIES: BODY PARTS IN LANGUAGE COMPREHENSION

In the next section we briefly revise physiological, brain imaging and behavioural evidence collected in support of the idea that listening or reading of actions with a specific effector recruits the area that controls that effector. Physiological and neuroimaging studies have demonstrated that sentences involving action verbs activate the motor and the premotor cortices in a somatotopic manner. Pulvermüller, Härle and Hummel (2001) recorded neurophysiological (they calculated event-related current source densities from EEG) and behavioural responses (reaction times and errors) to verbs referring to actions performed with the face, the arms and the legs. They found topographical differences in the brain activity patterns generated by the different verbs in a lexical decision task, starting from 250 ms after word presentation. Further studies clarify the specific timing of somatotopic activation. Pulvermüller, Shtyrov and Ilmoniemi (2005), used magnetoencephalography (MEG) during passive reading of action words and pseudowords, and reported that a short-lived activation in frontocentral regions appeared within 200 ms after words appearance. Overall, many studies on time course of language processing report activation of motor regions less than 200 ms after word onset (see also Borreggine & Kaschak, 2006; and Hauk, Johnsrude & Pulvermüller, 2004), and new evidence reveals that arm reaching movements are activated with action verbs even when they are not consciously perceived (subliminal presentation, 50 ms) (Boulanger, Silber, Roy, Paulignan, Jeannerod, & Nazir, 2008). TMS studies complement these results by showing that motor evoked potentials (MEPs) were modulated in an effector specific manner (Buccino et al., 2005).

Finally, behavioural studies in which RTs are recorded confirm that the simulation activated during sentence comprehension is sensitive to the congruency between the effector (e.g., hand, mouth or foot) implied by the sentence and the effector involved during the motor response. Buccino et al. (2005) asked participants to respond with the hand or the foot to concrete sentences and to refrain from responding if the verb was

abstract. If subjects responded with the same effector necessary for executing the action described by the sentence, RTs were slower than if participants had to respond with the other effector. Scorolli and Borghi (2007) had participants evaluate whether pairs of noun-verb combinations referring to hand and mouth actions (e.g., to unwrap vs. to suck the sweet), or to hand and foot actions (e.g., to throw vs. kick the ball) made sense or not. Responses were recorded by means of a microphone or of a pedal. RTs were faster in case of congruency between the effectors – mouth and foot – involved in the motor response and in the sentence. Borghi and Scorolli (2009) found that, when verb-noun pairs referred to manual and mouth actions, participants responded faster with the dominant than with the non-dominant hand. This advantage of the right over the left hand was confined to sensible sentences. The result was opposite when pairs referred to manual and foot actions.

Overall, neuroimaging and behavioral studies confirm that motor system activation during comprehension of words (verbs) and simple action sentences is effector specific. Results converge in demonstrating that motor information is activated in a fast and automatic way, even when it is not relevant to the task (e.g., Glenberg & Kaschak, 2002), and that it has a somatotopic and fine-grained organization (Buccino et al., 2005**;** Kemmerer, Castillo, Talavage, Patterson & Wiley, 2008; Scorolli & Borghi, 2007). However, some issues are still unsolved and should be clarified. Namely, some studies found evidence of interference when the same effector used for the motor response was implied by the sentence, others found a facilitation effect. A possible solution to this problem can be found through analysing the time course of language processing. It is possible that after an early interference due to the concurrent activation of the same source, a later facilitation occurs (for discussion of this issue, see Boulenger et al., 2008; Buccino et al., 2005; Scorolli & Borghi, 2007). Further evidence is needed to better understand this controversial matter.

In spite of some controversial issues, the fast activation, the automaticity and the somatotopic organization of the motor system renders the hypothesis very unlikely, that information is first transduced in an abstract format and then influences the motor system. The hypothesis that the motor system is activated in a direct and straightforward way is much more plausible and economical. Further compelling evidence is given by studies on patients with impairments of the motor system, for example patients affected by Parkinson's Disease (e.g., Boulenger, Mechtouff, Thobois, Broussolle, Jeannerod & Nazir, 2008; Bak, Yancopoulou, Nestor, Xuereb, Spillantini, Pulvermüller & Hodges, 2006).

Even if results are compelling, it appears that within the EC approach body parts are taken into account precisely because they are implied to be in action, even if it is a form of covert action. It is probably not casual that studies on language comprehension investigate the role of effectors involved while voluntarily acting with objects rather than the role of body parts which are related to passive movements (e.g., being hurt, being caressed by the wind). Consider a sentence such as "She was caressed by the grass", or "The player was kicked by another player": would activation be effector-specific, or are effectors activated only when they are implied in active intentional actions such as "He kicked the ball?" To our knowledge no studies of this sort have been conducted.

## WHAT EC EVIDENCE TELLS AND DOES NOT TELL US ABOUT THE SENSE OF BODY

The studies we have reviewed clearly show that within the EC framework the role of body and, more specifically, of body parts is taken into account in at least two different ways:

a. Behavioral and brain imaging studies show that simply seeing the body parts of another person (e.g., the hand) might activate a motor resonance performance. However, it is debatable whether the effect of motor resonance is automatic or whether it requires either a motor preparation or a dynamic presentation of the picture (e.g., Borghi et al, 2007; Fischer et al., 2008; Vainio et al., 2008). Moreover, it

might be important that the seen effector is not perceived as isolated but rather as linked to a body with biomechanically plausible constraints (Ottoboni et al., 2005) and that, if no object is present, it is perceived in the framework of a dynamic action (e.g., Urgesi et al., 2006). In addition, it appears that different neural mechanisms are implied while observing our own actions and others actions, and actions in our own perspective and in a different perspective (e.g., Jackson et al., 2006; Daprati et al., 1997). Note that the motor resonance phenomenon does not imply that we are conscious of the fact that our body parts are activated while seeing others' body parts - it is rather a form of covert, implicit activation;

b. studies on language show that, while comprehending action sentences, body parts are automatically activated (e.g., Boulenger et al, 2008; Borghi & Scorolli, 2009; Scorolli & Borghi, 2007; Buccino et al., 2005; Pulverműller et al., 2001). This suggests that the simulation we form is sensitive to proximal aspect, i.e. to our body parts, even if the task does not require explicit activation of them. Again, this does not mean that we are conscious of the fact that our body parts are activated during comprehension - it is rather a form of covert, implicit activation.

Even if this review is far from exhaustive, it highlights the fact that, within the EC literature, the role of body is not considered independent from the involvement in some kind of action. This is probably due to the fact that MNS is activated only when a goal-directed action is performed. We do not intend to claim that EC studies have not investigated other domains besides the motor one, such as vision, olfaction, or emotion. They most certainly have. Rather, we intend to claim that the role of body (and, more specifically, of body parts) is taken into consideration only, or mostly, in studies which an active agent is involved. As we will detail in the second part of the paper, agency is crucial for developing the sense of our own body as distinct from surrounding objects and from other agents, and the literature we revised is important in this framework. However,

the sense of body ownership appears earlier, and it is not grounded in agency but rather in sensations. Namely, body ownership is present not only during voluntary actions but also during passive sensory experience (Tsakiris, Schütz-Bosbach, & Gallagher, 2007).

It seems that EC literature, focusing only on action, misses one important part of the story. Independently of the kind of EC theory we endorse, the claim we intend to defend here is that EC theories have the problem of how to conceptualize the very existence of an independent and self-sensing body (Clark, 2008). The danger that EC theories run is to exclude the very existence of a cognitive subject when he/she is not involved in an actual relationship with an external stimulus and more generally in a goal-directed action. This risk is testified by the fact that the majority of EC theories and evidence focus on covert or overt forms of actions. Even studies of movement that is independent of action with objects, as it happens in dancing, typically focus on the motor resonance / simulation evoked while observing others performing actions or moving (see for example, Calvo-Merino, Grezes, Glaser, Passingham, & Haggard, 2006). An external referent, either an object or an organism, is often included in the experimental setting; in any case, acting bodies rather than merely sensing bodies are studied.

## DEVELOPING THE SENSE OF THE BODY

The "sense of the body" is the very basic feeling that *I am* the body that does and is in control of what this same body is actually doing and perceiving. The "sense of the body" is not a cognitive state, nor an explicit thought: it is the very simple fact that I do not *have* a body, but that *this* body is the body that *I am* (Shenton, Schwoebel, Coslett, 2004; Maravita, Spence, Driver, 2003). Literature on sense of body indicates that bodily self perception is not all-or-none but that there is a development of forms of bodily awareness (Morin, 2006). The first and basic form of self-perception is the "interoceptive system", the "feelings" that "represent a sense of the physiological condition of the entire body" (Craig, 2003, p. 500). This system "consists of input-output loops at several levels" (p. 501)

which combine "fine homeostatic afferents" with "fine homeostatic efferents". Even the first form of self-perception is based on (intra)bodily actions: the sense of body emerges from the interaction of afferent (buttom-up) and efferent (top-down) internal stimulations. A hand dipped in cold water sends back a sensation that contributes to the formation of a sense of the body. But as this simple example shows, the hand is just a *part* of the body: how does a coherent and comprehensive image of the body emerge? How does a body develop a global sense of self?

Growing evidence supports the notion that there are two natural ways that the human body develops an integrated pre-reflessive sense of itself *as* a body (see for example Gallagher, 2000). The first is body-ownership, which refers to the sense that one's body is the source of sensations. "The sense of body ownership involves a strong afferent component, through the various peripheral signals that indicate the state of the body" (Tsakiris et al., 2006, p. 424). Each component of the body generates "sensory feedback" (Tsakiris et al., 2007) that 'informs' the brain about its sensory state. It is important to stress that the sense of body is not a reflexive or cognitive state, that is, it is not an explicit representation of itself: it is a state in which we directly and bodily *are*, it is not a state we think of (Carruthers, 2008). However some cases exist showing that proprioception is sufficient but not a necessary condition for developing a sense of one's own body. Bottini, Bisiach, Sterzi and Vallar (2002) described the case of a patient who attributed her hand to her niece. She could report a tactile sensation on her hand only when the experimenters told her that her niece's hand was going to be touched. Such a case confirms that a somatosensory sensation is not sufficient to recognize a body part as one's own.

The sense of body ownership does not imply that the body perceives itself as a *unitary* body, as *one* body which is *different* from other bodies. In order to develop this specific kind of sensation, another element has to enter our reconstruction: *action*. When

a body tries to reach an object, for example, it has to contemporarily take note of its own spatial and temporal position with respect to the temporal and spatial position of the object. In this case the action is the medium which allows the body to distinguish itself from the external object (Tsakiris et al., 2007). Similarly, we have seen in the first part that the perspective in which an effector is presented can allow us to distinguish our own body from the bodies of others. During every action (which is different from a simpler bodily movement) it is the body which moves itself as a unitary entity in order to satisfy the goal of the action. The external object allows the body to experience itself as a unitary entity which is different from the object simply because it resists the body's action. In every action there are two logical and physiological components, moving from the body to the object and from the object to the body. The body feels the object, for example the hand touches it, and this is the efferent action's vector; the object is heavy, is cold, is difficult to grasp, these are the actions' afferent vectors. There is a sort of progression in the development of the sense of body, from a more fragmented and internally-generated one, to a more coherent and unitary one. Note, however, that the claim that the unity of the body is reached through agency is not uncontroversial. Even if many authors consider agency as a necessary condition for forming minimal phenomenal selfhood, other scholars underline that there is one lower-level and simpler form of self-consciousness, a passive and multisensory experience of owning a unitary and spatiotemporally situated body, which is not necessarily characterized by agency (Blanke & Metzinger, 2008).

When only body ownership is present there is the possibility that, in particular situations, the body feels itself to be an *external* object, that is, an object that is not in physical continuity with the body. One of these cases is the so called Rubber Hand Illusion (RHI) (Botvinick & Cohen, 1998). A rubber hand watched and stroked synchronously with one's hand that is hidden to direct vision, causes the fake hand to be considered as belonging to one's own body. That is, when the vision of the real stroked hand is

precluded, the visible rubber hand whose movements are congruent with the real but unseen one is perceived as belonging to the body. In this case the visual information is stronger in order to attribute a body part to an actual body than the interoception of the very same body part (Fiorio & Haggard, 2005). The RHI case shows that 'simple' body ownership does not provide a unitary and coherent sense of the body. In this case a competition exists between interoception on one side and vision and central cognitive processes on the other side: "self-attribution of the rubber hand to one's own body arises as an interaction between bottom-up processes of visuo-tactile stimulation and top-down representations of a coherent body-scheme" (Tsakiris et al., 2006, p. 424). When there is a mismatch between feeling and seeing the hand, the hand is perceived where we see it: "we feel our hand where we see it, not the converse" (van den Bos & Jeannerod, 2002, p. 178). The RHI shows that the sense of body cannot be intended as a simple and immediate physiological starting point; on the contrary, it is a sense which has to be constructed unifying sparse physiological efferent and afferent information.

The sense of the body developmental course begins with body ownership; subsequently agency allows the body to begin to construct a unitary representation of itself. Another way to formulate the differences between these two basic forms of sensing the body is the following: the first form is a prereflexive and implicit way of being a body. Being a body implies that every body's part is a *part* of the body, it is connected in an efferent-efferent loop; being a body does not imply that such a body represents itself as a unitary body. When the body is capable of operating in the external world and when *action* is possible, a comprehensive sense of the body *can* emerge. This is a prereflexive sense of the body too (it is not a self-conscious representation), but it is a unitary one. RHI cases allow a general conclusion: the fragmented pattern of perceptual shifts following tactile and passive stimulation, suggests that the fragmented sense of body-ownership is local. During voluntary action, the perceptual shifts were generalised across the whole

hand. Therefore, the motor sense of agency influences the proprioceptive sense of body ownership. Agency is responsible for the coherence of body ownership. Sensory mechanisms generate a sense of body ownership based on fragmented local representation of individual body parts, but action provides a coherent sense of bodily self. It seems that the unity of bodily self-consciousness comes from action, and not from sensation (Tsakiris et al., 2006).

It is worth stressing the general conclusion of this approach: the sense of the body "comes from action, not from sensation". The body does not find out itself by an internal cognitive operation, quite the contrary, the fragmented sensitive body becomes a unitary body through action, that is, through an *external* cognitive operation (de Vignemont, 2007; de Vignemont & Fourneret, 2004). When the experimental paradigm makes the bodily attribution of an action difficult, the possibility of misattribution dramatically increases (van den Bos & Jeannerod, 2002): in such cases it becomes quite a difficult task to attribute a body part – for example a finger – to its own body or to another one. On the contrary, when the matching between action and object is accurate, no misattribution occurs: "it is common experience that our actions are readily self-attributed as a consequence of a normally perfect correlation between their expected effects and the flow of resulting (visual and proprioceptive) stimulation. This matching process provides the agent of an action with the "sense of agency", i.e. the sense that she is causing that action (van de Boos & Jeannerod, 2002).

According to the philosopher Merleau-Ponty the very idea of 'body schema' implies that any sensation of oneself outside an actual sensation of something cannot exist; that is, being a body implies to be a *particular* body which is situated in *some specific spatio-temporal context,* because "any sensation belongs to a certain *field*" (Merleau-Ponty, 2002, p. 251). In this radical embodied view the body cannot sense itself if it is not engaged in an actual perception/action. For Merleau-Ponty the body is always

undergoing activity: "my body appears to me as an attitude directed towards a certain existing or possible task" (p. 114) and "external perception and the perception of one's own body vary in conjunction because they are two facets of one and the same act" (p. 237). In this general program bodily self-consciousness does not exist as an autonomous psychological and internal entity, because "all consciousness is, in some measure, perceptual consciousness" (p. 459). The apparent problem this theory faces is that we feel that we can also sense our body even when no action occurs. Merleau-Ponty faces this problem sketching a developing model of bodily self-consciousness: "the body is our general medium for having a world. Sometimes it is restricted to the actions necessary for the conservation of life, and accordingly it posits around us a biological world; at other times, elaborating upon these primary actions and moving from their literal to a figurative meaning, it manifests through them a core of new significance: this is true of motor habits such as dancing. Sometimes, finally, the meanings aimed at cannot be achieved by the body natural means: it must then build itself an instrument and it projects thereby around itself a cultural world". (Merleau-Ponty, 2002, p. 168).

Our stance is sympathetic with Merleau-Ponty: we particularly want to stress the last point of the preceding quotation (a point that Merleau-Ponty never completely developed). We think that, in order to fully elaborate a theory of the development of the sense of the body, we have to include the cultural means and language in particular which is used by the human body to construe an embodied representation of itself.

## A SOCIAL AND LANGUAGE SENSE OF ONE'S BODY

The problem we want to face now is the following: how external can the medium through which the body develops a sense of body ownership be? There are many different possible sources that help the body to construct the sense of self as a unitary whole.

One of these sources is the mirror neuron system (Rizzolatti & Craighero, 2004). When a human body sees another body grasping an object, for example, in its own brain the very same areas are activated which codify for the watched action (Gallese, Craighero, Fadiga, & Rizzolatti, 1996). In such cases a *resonance* between different bodies is established; this automatic resonance might allow a body to immediately recognize the *sense* of another body's action; an implicit social recognition that establishes a mutual shared space (Gallese, 2001). It is an *indirect* and *external* way to feel ourselves as bodies capable of agency. However, it is worth noticing that a very important difference exists between observing another body and observing our own body: "observing another agent acting facilitates the observer's motor system, whereas observing one's actions tends to suppress the observer's motor system. A suppression of a tendency to 'imitate' oneself might reflect a natural reaction to avoid inappropriate perseverations or responses when viewing one's own actions" (Tsakiris *et al*., 2007, pp. 656-657). However, observation of others' actions alone is not sufficient to construe a coherent sense of *one*'s body. If mirror neurons alone modulated one's sense of the body no one could develop a sense of one's own *individual* body: "the 'mirror system' cannot account for a unique representation of one's own body" (p. 656). The specificity of the sense of our own body has been studied by Schütz-Bosbach and collaborators (Schütz-Bosbach, Mancini, Aglioti & Haggard, 2006; Schütz-Bosbach, Avenanti, Aglioti, & Haggard, 2009; Tsakiris et al., 2007) using the rubber hand illusion with single pulse TMS: this experiment demonstrates that we rely on different neural mechanisms for recognition of others' actions with respect to our own actions. Namely, whereas observations of actions attributed to another agent facilitated the motor system, observations of actions linked to the self provoked a cortical motor inhibition. This reveals the intrinsically social nature of the human motor system, due to the fact that representation of actions of others does not merely rely on representation of the

self (Schütz-Bosbach et al., 2009). That is, the recognition of the actions of the others does not presuppose the attribution to them of a previous knowledge of our own actions.

In keeping with this idea of the intrinsically social nature of our motor system, we propose to ascribe a crucial role to language in developing the comprehensive and explicit sense of our own unitary body. So far the role played by inner language in building our sense of body has not been fully recognized. Here we propose that the construction of the human sense of one's body might benefit from the use of another *external* and *social* component: language (Vygotskij & Lurija, 1984). In our proposal the ultimate completely social phase in the development of one's sense of the body is attained when a body uses language internally, *to speak to oneself* (Vygotskij & Lurija, 1984). The role of inner language can be multifold. When people speak to themselves, they not only inform themselves about what is going on, but at the same time they constitute themselves as autonomous entities: that is, when we say "I" we are not simply obeying to a grammatical rule (if the language we use provides for such a rule), it could be a way to construe the body which is speaking *as* an "I". In this case "I" is not the external sign for an internal "sense of the body", quite the contrary, an explicit and coherent "sense of the body" would be the effect of using the word "I" (Cimatti, 2000). An anonymous reviewer rightly observes that "the ability to direct and control complicated actions arises long before infants are able to verbalize". We agree with this observation, as shown in the section on the development of the sense of body. However, our point is quite different: we hold that there is a huge emotional and cognitive difference in a body which is able to sense itself while moving and acting in the world from a body who explicitly *knows* that it is a body which is moving and acting in the world. We think that in this second case the sense of body becomes somewhat different from the first one: when this body becomes an "I" it realizes that it has persistence in space and time. At a first level, internal, private language (that is, covert and internal use of language which is not necessarily explicitly articulated)

can help us to feel our body and to control our movements, for example when we actively learn new procedural routines, and before these routines become automatic. For example, consider a trainer who is teaching a child how to kick a soccer ball. At the very beginning she has to be explicitly and directly guided by the teacher: in this case social language is an *external* medium that shapes the sense of body of the child. With time, she no longer needs to be explicitly guided, because she can speak to herself in order to remember the teacher's advise. Egocentric (when the child speaks aloud to her/himself) and inner language have transformed an acquired and social ability in an internal capacity of her body (Karmiloff-Smith, 1992). What she now explicitly *feels* about her own body depends on language too. Research in the area of child development (e.g. Berk & Garvin, 1984; Winsler, Diaz, & Montero, 1997; Fernyhough, & Fradley, 2005) shows that children's private speech is aimed at directing and controlling their own actions. Importantly, whereas literature on inner language recognizes the role it plays for motor control and for complex action tasks, it does not underline the importance of private speech for forming a sense of body. A probable direct function of inner speech for developing a unitary sense of one's body has been discovered by Fernyhough and Russel (1997): in social contexts children's inner speech allows them to understand and sense themselves as speaking agents among other speakers. In this case inner speech represents a hybrid form of internal/external means to sense one's voice and therefore one's body. It is *internal* in that it is inner speech, it is *external* in that the language children use to speak to themselves is a public language.

At a different level, internal language helps us to perceive ourselves as autonomous entities. When someone *tells* me that I have to do something, I *explicitly* realize that I am an autonomous body, because an autonomous body only can actively do something or can passively be told of doing something. From a phenomenological point of view it is important to note that a big difference exists between an autonomous body and an

autonomous body who is *aware* of being an autonomous body. This is the difference between an I and an "I". An "I" is an I which *is aware of* being an I. We think that our perspective allows us to construe a more complete phenomenology of the human sense of body, from the first interoceptive forms to the more explicitly represented ones. This implies that the sense of my own body as an explicit and self-represented entity is mediated by a social entity, *language*. I realize that I am a body of my own just because through language I acquire an explicit knowledge of myself *as a body*. We want to stress the difference that exists between this linguistically mediated kind of "sense of the body" and the other kinds we previously have considered. In the latter case the body that I am not only acts as a unitary whole, but it is also able to explicitly represent itself as an "I". An explicit knowledge means that I am able to refer to myself as an autonomous body: for example, I can correct myself if my actions were wrong, or I can appreciate them if they were carried out correctly. I can think of myself just because I am speaking to myself. It is worth noting that this is still an action, that is, it is a sensible movement of my body, because to speak to oneself means to actively use lungs, breath, tongue, teeth and lips. It is worth stressing that in this case the "sense of the body" should be considered as an external mediated form of self-agency or self-construal.

Much evidence exists to confirm that the cerebral bases of the inner speech are the same as in external speech (Morin, 2009). For example, the accidental destruction of the left inferior frontal gyrus (Broca's area) disrupts inner speech too, and it is now ascertained that covert speech requires articulation. Thus, Broca's area represents the neurological basis of both outer and inner speech production. On the contrary, some first and very interesting evidence exists that, when inner speech is lost as a consequence of a left hemispheric stroke, dramatic consequences follow for the sense of one's body (Vygotskij, &Lurija, 1984; Morin, in press). A subject who experienced a left hemispheric stroke reported the loss of inner speech (luckily only temporary). As a consequence "she

describes a global self-awareness disturbance, corporeal awareness deficits, a distorted sense of individuality, problems with retrieval of autobiographical memories, and lack of self-conscious emotions" (Morin, in press). The loss of inner speech does not only represent a cognitive/communicative loss, but it implies that the very sense of being a unitary body is impaired. Inner speech is the last way of socially constructing and integrating the body we are. To summarise, a body which recognizes itself as a body through the mediation of a social action, through an external and social detour, and through language use.

## LANGUAGE AND THE BROADENING OF THE BODY BORDERS

EC theories have highlighted that cognition is bodily grounded. It has come to our attention that these theories are restricted in that they rarely conceive cognition and "sense of the body" in particular as independent from action. A second limit of EC theories we intend to address is that they seem to imply that cognition is constrained within the boundaries of our individual brain-body system. In different fields, and in particular in philosophy, the idea that cognition might be extended beyond our brain and our body, in the environment, is gaining more interest. "We are already at home in the environment. We are out of our heads" writes Alva Noë (2009), while Andy Clark (e.g., 2003) speaks of "natural born cyborgs" referring to the fact that we extend our cognitive abilities through the use of instruments. Also defenders of enactivist approaches suggest that the body and the brain can modify their composition in a plastic and flexible way by incorporating processes, tools, resources etc. (Thomson & Stapleton, 2009). Importantly, effects such as the RHI suggest that we can feel sensations in objects that are not attached or connected to our own body. At the same time, some authors (e.g., Vygotskij & Lurija, 1984; Clark, 1998) have defined words as instruments, "tools", which help us to perform actions in the world. Words can be conceived of as tools at a basic level. Namely, they can contribute to enlarge the boundaries of our body. Psychological and

neuroscientific studies have demonstrated that, when we use an instrument to reach a target-object, our peri-personal space is extended. The peripersonal space isolates the spatial portion within which direct action is possible, it separates what is directly reachable thanks to human action, without moving the body, from what is not reachable. These effects have been demonstrated with monkeys and humans, with neglect patients and with controls, and with a variety of paradigms (e.g., Farnè & Ladavas, 2000; Pavani, Spence & Driver, 2000; Spence, Kingstone, Shore, & Gazzaniga, 2001; for a review see Maravita & Iriki, 2004; see also studies on projecting sensations to external objects, e.g. Carrie Armel & Ramachandran, 2003). For example, monkeys using a rake to reach for objects have a larger cortical representation of their arms and hands, as cells sensitive to visual and tactile stimulations extend their receptive fields incorporating the rake. As some authors speculate, our ability to interact with tools might represent a clear advantage for our species, at the basis of the distinctively human ability to develop language (e.g., Johnson- Frey, 2003). In this respect, the way different languages encode spatial information is of particular interest. As pointed out by Kemmerer (1999), although several languages have two basic types of demonstrative terms (proximal and distal), language allows specification of a virtually unlimited range of spatial distances. Therefore linguistic distinctions do not correspond to the perceptual distinction between near and far space, and probably rely on different neural circuits. However, an interesting parallel has been proposed between tool-use and language: "By bridging proximal and distal space, tool-use might represent the sensorimotor counterpart of those communicative features that allow us to modulate near and far space along a continuum in language." (Farnè, Iriki & Ladavas, 2005, p. 246). Some recent studies have investigated the relationships between language and space. Coventry, Valdès, Castillo and Guijarro-Fuentes (2008) had English and Spanish-speaking participants engage in a game with an experimenter; subjects were instructed to produce either "this" or "that" to identify the position of coloured

geometrical shapes on a table. Results showed that when they could reach the object, either with or without a tool, they tended to use "this" more often; in addition "this" was used more often when the participant rather than the experiment placed the object. In a kinematics study Bonfiglioli, Finocchiaro, Gesierich, Rositani and Vescovi (2009) have recently demonstrated that "this" and "that" have distinct referents also within the peripersonal space. In this study participants, upon hearing the Italian pronouns "questo"("this") and "quello" ("that"), had to perform reach-to-grasp actions towards objects located within reaching space at different distances from their body. Reaction times were faster when the pronoun "this" referred to near objects and the pronoun "that" to far objects. This reveals a different effect of the two pronouns on movement planning even within the reaching space, and it suggests that the two pronouns allow a richer representation of space than that limited to the distinction between peri- and extrapersonal space (Kemmerer, 1999).

These studies suggest that the use of words such as demonstratives is modulated by the distance between our own body and objects. Along the same line, our proposal extends beyond the use of demonstratives and focuses more generally on the role language might play. In keeping with the view that tool use might be the motor counterpart of language, we propose that, similarly to tools, word use can contribute to amplify and enlarge our peripersonal space, in particular in collaborative tasks. So far the idea that words might work as tools that enlarge the possible space of our actions is only a theoretical claim, which would need empirical validation. Namely, to our knowledge there are no studies which investigate the extent to which words help to enlarge the perception of our body and to overcome the borders between ourselves and the other, particularly in collaborative tasks.

A question we arise is as follows: is this extension due to the fact that we can ACT with tools or does it happen because the tool can be perceived as an extension of our

body, from a perceptual perspective? It is worth mentioning the effects of visuo-tactile cross-modal extinction with neglect patients found by Farnè and Ladavas (2000) and by Farnè et al. (2005). These results are obtained only if patients are required to hold a rake to perform a goal directed action, namely to reach objects located outside from the peripersonal space. The simple fact of holding a rake in the right hand without using it to reach objects, or the act of doing a pointing rather than a reaching task, has no effect on extinction. In other words, a change of the bodily schema occurs only after the instrument is actively used. Let us suppose that there is an object which is immediately beyond our peripersonal space. If words were similar to tools, then the object name should allow us to somewhat "capture" the object, to perceive it as nearer to us than it really is, thus leading to an extension of the peripersonal space, as seen in the previous example with the stick. However, there should be a difference between words and sticks: namely, differently from sticks, words should be more effective when we call another person to share a representation of what we intend to do (Sebanz, Bekkering, & Knöblich, 2006) and to help us to reach our aims (e.g. "give me the object name").

Now consider these very simple experimental situations we are currently working on in our laboratory. During a training phase participants are shown an object located either in the peripersonal or in extrapersonal space and they are told that they have to reach for it. During training participants can be exposed to different experimental conditions. For example, they might be told that someone else is in front of them, and they might tell him/her "Give me the object name", or they can pronounce the object name, when they are not able to directly reach the object. This condition could be contrasted with a condition in which they can use a tool to reach for the object. If the expansion of the peripersonal space occurs only when the tool is perceived as a physical extension, such as a prosthesis, of our body, then using a tool should be more effective than pronouncing a word in modifying the perception of our reaching space. If what counts is not the

instrument we use but rather the goal and the effect of the action, then both words and tools should have the same effect on our bodily space perception (Farnè et al., 2005). Further experiments might explore whether a modification of reaching space perception occurs only if the word is associated with the presence of another person, and of another person having a collaborative attitude, or whether the effect is simply due to the referentially correct linguistic label (the name) per se. Effects could be studied using kinematics parameters. For example, if after the training phase the object in the extrapersonal space is perceived as closer than it originally was, then participants should protrude their body less in order to reach for the object in comparison with a baseline condition. The effect could also be tested by analysing differences in saccadic movements before and after the training phase. Finally, a possibility would be to ask participants to estimate the distance of objects with an apparatus that does not allow them to use prospectic indexes; this will allow us to determine whether the border between peripersonal and extrapersonal space has moved after the training phase.

The examples we provide show that the capability to act upon space can lead to a novel conceptualization of our body schema. In this respect words, which allow us to act in the surrounding environment, including the very same body which uses language, represent a powerful means to enlarge and modify our body schema. Note that a lot of discussions concern whether the extended mind view can be defined as embodied. For example, it has been argued that extended mind approaches adopt a functionalist stance, as the body is simply identified with its functional role, and the fact that the body is also a metabolic entity is purely contingent. However, as argued by Rowlands (2009), functionalism is a big church, and not all versions of functionalism assume body neutrality. We believe one possible solution to this problem is advanced by Thomson and Stapleton (2009) who distinguish between EXTENSION and INCORPORATION. The authors propose a transparency constraint which argues that "For anything external to the body's boundary

to count as a part of the cognitive system it must function transparently in the body's sense-making interactions with the environment" (Thomson & Stapleton, p. 29); in other words, the body is perceived as a subject (Legrand, 2006) or a structure of experience, which is transparent because we look at the world through it without noticing that we act on world *through* the body. Therefore, tools and words are means with which we experience the world, they are not objects we perceive as external to us. With regards to this, in our view the extended mind views are not in conflict with enactivist approaches. Thus, tools can be perceived as somehow natural prosthesis that extend our body and become part of it. A similar story can be told for words, which represent other ways to extend our body boundaries and respond to the transparency constraint. Obviously words might be conceived of as tools at a more general level than that concerning the broadening of our perceived body boundaries and the reshaping of our body schema. Proponents of distributed cognition and of extended mind views argue that part of our cognitive activity lies outside of our body boundaries but within the artefacts we use. In addition, we can say that words metaphorically extend our body, thus extending our cognitive activity. This last point pertaining words is worth stressing, because it encourages us to consider language not simply as a means of communication, as it is usually seen in cognitive sciences, but as a unique way of *acting* in the world. Using Wittgenstein's claim we would want to literally assume language to be a set of instruments: "Language is an instrument. Its concepts are instruments" (Wittgenstein, 2001, I, § 569). According to Wittgenstein when we use a word we are not translating an inner thought to an external word. This is a classical dualist position, typical of the orthodox cognitivism, which separates mind and body, thinking and action, the inner and the outer. On the contrary, in Wittgenstein's embodied theory meanings are not mental entities, but kinds of *actions*: "for a *large* class of cases – though not for all – in which we employ the word 'meaning' it can be defined thus: the meaning of a word is its use in the language" (I, § 43). Language

is a set of external and social instruments which extend body's natural boundaries and abilities. A sentence is an actual or possible action in the world. Each word, in this model of language as a form of acting, entails different and unique ways of doing (or preparing to do) something: "now perhaps one thinks that it can make no *great* difference which concepts we *employ*. As, after all, it is possible to do physics in feet and inches as well as in meters and centimeters, the difference is merely one of convenience. But even this is not true if, for instance, calculations in some system of measurement demand more time and trouble than it is possible for us to give them" (I, § 569). Different words entail different ways of thinking and acting *in* the world. This conception allows us to discard the traditional assumption according to which language is either a cognitive or a communicative medium. It may be understood as the species-specific way of blending together body and mind, that is, the unique way humans *do* things. "Concepts", also described as the words in action, "lead us to make investigations; are the expression of our interest, and direct our interest" (I, § 570). In this respect, the very idea of the specialty of the body due to the peculiarity of its sensorimotor system falls into pieces. Namely, the body is special because it is a sort of bridge allowing us to use the external world for our internal processes, so its specialty lies in its idiosyncratic function rather than in its peculiar bodily structure. In principle, even another being, or a robot, endowed with partially different sensorimotor system, could have the ability to perform the same computations that we do (Clark, 2008), even if the similarity in the sensorimotor system might result more probably in similar cognitive processes (ROSSI project, 2007). This does not imply the assumption of any form of body neutrality, nor we do intend to claim that external and internal resources are the same, instead we claim that external resources might become deeply integrated with internal ones (Clark & Chalmers, 1998), and that, even if they are radically different from internal ones, they might complement each other (Menary, 2009; Sutton, in press).

The proposal we advance in this article assumes words and sentences as means through which human beings construe the sense of their own bodies. Firstly, we think that using an inner language can help us to control our movements and to perceive our body as a unit. Then, we argue that a body can sense itself as a coherent and integrated whole that persists in time and space when it is capable to internally use the linguistic forms developed from childhood. For example, we think that when a child firstly uses the pronoun "I" she explicitly *realizes* that she is an integrated body. In this proposal "I" is not a description of a preexisting internal psychological entity, it is quite the contrary, while saying "I" the child explicitly assembles the body parts she experiences in a coherent and unitary entity. The point we want to stress is that this is a form of externally mediated body action: "It is in language that an expectation and its fulfillment make contact" (Wittgenstein, 2001, I, § 445). This externally mediated bodily action, language use, not only helps us to have a sense of body as a whole but can also change the way we conceive our body, extending its boundaries and modifying its relationship with the so-called external world. At the same time, through inner language the body becomes a subject - a body who perceives itself as an autonomous entity using external and internal language. Here the self-sensing body *explicitly* realizes being an autonomous entity by itself. At the end of the developing course we imagined the body senses itself independently from the actions it can entertain with objects, and other subjects, of the world. Through its actions in the world the body constitutes itself as an autonomous entity, that is, a body which is a body even when no action occurs.

## CONCLUSION

In this paper we addressed two potential limitations of EC theories, and proposed to extend them. Our review of literature showed that previous EC studies typically account for body parts only in relation to overt or covert actions. On the basis of this review, we argue for a potential extension of the embodied cognition perspective that should

consider the role played by the body independent from its involvement in goal-directed action, and that new experimental evidence should be collected. We then briefly examined how the *human* sense of one's body might develop. The link between the review part of the paper, in which we highlighted that EC theories have focused mainly on voluntary action, and our proposal lies in the adoption of a developmental perspective. It has been shown that we attain such a sense through a *continuum* of different kinds of action: the first one is known as *interoception*, a nest of afferent-efferent physiological loops. Interoception allows for a first representation of the body, a sense of body ownership. It is a fragmented representation without the construction of a unitary sense of the body. Such a possibility only emerges with agency, i.e. when the body engages itself in actions which involve *external* objects. The friction with the object furnishes the body with feed-back that indirectly allows the body to feel itself as another entity faced with an external entity. From this moment on the body recognizes itself through an external mediation. A particular case of externally mediated self-perception is through the mirror neuron system, which allows the body to resonate to external bodies. We propose that the last form of self-perception is mediated by social language: the universal capacity to use language to refer to itself (personal pronouns are present in all languages; Benveniste, 1966) allows the body to *explicitly* recognize itself as an individual body. The body who *says* "I", that is, uses language to perform its own subjectivity, is the last historic-natural form of self-perception. This form of self-perception is only possible because the body is now capable of internally using an external and social object, language. Our point is that EC theories should adopt a developmental perspective: we highlighted that our sense of body is grounded first in sensation, then in action, and finally in language as a further form of internal and external action. On this basis, we do not understand why EC theories focus only on parts of this unitary process. It is as if EC theories do not account for the intrinsic temporality of the building process out of which our sense

of body emerges. Finally, we argue that EC theories risk limiting cognition to the brain-body system, without taking into account recent extended mind theories. We discuss a basic level in which language can help to reshape our body schema and modify our sense of body through extending its boundaries.

Our work shows how a reconsideration of the role played by the social experience of language can help extend EC theories, going beyond some of their limitations. On one side, internal language can contribute to form a unitary sense of body, alternatively words as tools can contribute to extend it, thus representing a bridge between our body, the external word, ourselves and the environment.

## References


Andres, M., Olivier, E., & Badets, A. (2008). Actions, words, and numbers. *Current directions in psychological science, 17*, 313-317.

Avenanti, A., Bueti, D., Galati, G., Aglioti, S.M. (2005). Transcranial magnetic stimulation highlights the sensorimotor side of empathy for pain. *Nature Neuroscience, 8*, 955–960.

Avenanti, A., Paulello, I.M., Bufalari, I., & Aglioti, S.M. (2006). Stimulus-driven modulation of motor-evoked potentials during observation of others' pain. *NeuroImage, 32*, 316 – 324.

Bak, T.H., Yancopoulou, D., Nestor, P.J., Xuereb, J.H., Spillantini, M.G., Pulvermüller, F., & Hodges, J.R. (2006). Clinical, imaging and pathological correlates of a hereditary deficit in verb and action processing. *Brain, 129*, 321–332.Barsalou, L. W. (1999). Perceptual Symbol Systems. *Behavioral and Brain Sciences,* 22**,** 577-609.

Barsalou, L. (2005). Situated conceptualization. In H. Cohen & C. Lefebvre (Eds.)., *Handbook of categorization in cognitive science* (pp. 619-650). St. Louis, MO: Elsevier.

Barsalou, L.W. (2008). Grounded Cognition. *Annual Review of Psychology*, 59, 617-645.

Benveniste, É. (1966). *Problèmes de linguistique générale, I*. Paris : Gallimard.

Blanke, O., & Metzinger, T. (2008). Full-body illusions and minimal phenomenal selfhood. *Trends in cognitive science, 13,* 7-13.

Bonfiglioli, C., Finocchiaro, C., Gesierich, B., Rositani, F., & Vescovi, M. (2009) . A kinematic approach to the conceptual representation of this and that. *Cognition, 111*, 270-274.

Borghi, A.M**.** (2004). Objects concepts and action: Extracting affordances from objects' parts. *Acta Psychologica, 115, 1,* 69-96.

Borghi, A.M. (2005). Object concepts and action. In D. Pecher & R.A. Zwaan (Eds). *Grounding Cognition: The role of perception and action in memory, language, and thinking.* Cambridge: Cambridge University Press.

Borghi, A., Bonfiglioli, C., Lugli, L., Ricciardelli, P., Rubichi, S., & Nicoletti, R. (2007). Are visual stimuli sufficient to evoke motor information? Studies with hand primes. *Neuroscience Letters, 11,* 17-21.

Borghi, A.M.**,** Glenberg, A., & Kaschak, M. (2004). Putting Words in Perspective. *Memory and cognition,32,* 863-873.

Borghi, A.M.**,** & Scorolli, C. (2009). Language comprehension and hand motion simulation. *Human Movement Science, 28,* 12-27.

Borreggine, K.L., & Kaschak, M. (2006). The Action-sentence Compatibility Effect: Its all in the timing. *Cognitive Science, 30*, 1097-1112.

Bottini, G., Bisiach, E., Sterzi, R., & Vallar, G. (2002). Feeling touches in someone else's hand. *Neuroreport*, *13*, 249-252.

Botvinick, M., & Cohen, J. (1998). Rubber hands 'feel' touch that eyes see, *Nature, 391*, 756.Borreggine, K.L., & Kaschak, M.P. (2006). The Action–Sentence Compatibility Effect: It's All in the Timing. *Cognitive Science, 30*, 1097–1112.

Brunyè, T.T., Ditman, T., Mahoney, C.R., Augustyn, J.S., & Taylor, H.A. (2009). When you and I share perspectives. *Psychological Science, 20,* 27-32.

Boulenger, V., Mechtouff, L., Thobois, S., Broussolle, E., Jeannerod, M., & Nazir, T.A.(2008). Word processing in Parkinson's disease is impaired for action verbs but not for concrete nouns. *Neuropsychologia, 46*, 743–756.

Boulenger, V., Silber, B.Y., Roy, A.C., Paulignan, Y., Jeannerod, M., & Nazir, T.A. (2008). Subliminal display of action words interferes with motor planning: A combined EEG and kinematic study. *Journal of Physiology – Paris, 102* 130–136.

Bruzzo, A., Borghi, A.M., & Ghirlanda, S. (2008). Hand-object interaction in perspective. *Neuroscience Letters, 441,* 61-5.

Buccino, G., Riggio, L., Melli, G., Binkofski, F., Gallese, V., & Rizzolatti, G. (2005). Listening to action related sentences modulates the activity of the motor system: A combined TMS and behavioral study. *Cognitive Brain Research, 24,* 355-63.

Calvo-Merino, B., Grezes, J., Glaser, D.E., Passingham, R.E., & Haggard, P. (2006). Seeing or doing? Influence of visual and motor familiarity in action observation. *Current Biology, 16*, 1905-1910.B.,

Carrie Armel, K., & Ramachandran, V.S. (2003). Projecting sensations to external objects: evidence from skin conductance responses. *Proceedings of the Royal Society London B, 270*, 1499-1506.

Carruthers, G. (2008). Types of body representation and the sense of embodiment. *Consciousness and Cognition, 17*, 1302-1316.

Cimatti, F. (2000). *La scimmia che si parla. Linguaggio, autocoscienza e libertà nell'animale umano*. Torino: Bollati Boringhieri.

Clark, A. (1998). Magic Words: How Language Augments Human Computation. In P. Carruthers and J. Boucher (Eds.). *Language And Thought: Interdisciplinary Themes* (pp. 162-183). Cambridge: Cambridge University Press.

Clark, A. (2003). *Natural-Born Cyborgs: Minds, Technologies and the Future of Human Intelligence*. New York, NJ: Oxford University Press.

Clark, A. (2008). Pressing the flesh: A tension in the study of the embodied, embedded mind? *Philosophical and Phenomenological Research, 76*, 37-59.

Clark, A., & Chalmers, D. (1998). The Extended Mind. *Analysis, 58*,1.

Craig, A.D. (2003). Interoception: the sense of the physiological condition of the body. *Current Opinion in Neurobiology, 13*, 500-505.

Coventry, K. R., Valdès, B., Castillo, A., & Guijarro-Fuentes, P. (2008). Language within your reach: Near-far perceptual soace and spatial demonstratives. *Cognition, 108*, 889-895.

Craighero, L., Bello, A., Fadiga, L., & Rizzolatti, G. (2002). Hand action preparation influences the responses to hand pictures. *Neuropsychologia, 40*, 492-502.

Daprati, E., Frank, N., Georgieff, N., et al. (1997). Looking for the agent: an investigation into consciousness of action and self-consciousness in schizophrenic patients. *Cognition, 65*, 71-86.

Decety, J. & Grèzes, J. (2006). The power of simulation : Imagining one's own and other's behaviora. *Brain Research, 1079*, 4-14.

Decety, J., Ingvar, D.H., (1990). Brain structures participating in mental simulation of motor behavior: a neuropsychological interpretation. *Acta Psychologica, 73*, 13–24.

de Vignemont, F. (2007). Habeas Corpus: the sense of ownership of one's own body. *Mind and Language*, *22*, 427-449.

de Vignemont, F., & Fourneret, P. (2004). The sense of agency: A philosophical and empirical review of the "Who" system. *Consciousness and Cognition*, *13*, 1-19.

Farnè, A., & Ladavas, E. (2000). Dynamic size-change of hand peripersonal space following tool use. *Neuroreport, 11*, 1-5.

Farnè, A., Iriki, A., & Ladavas, E. (2005). Shaping multisensory action space with tools: evidence from patients with cross-modal extinction. *Neuropsychologia, 43*, 238-248.

Fiorio, M., & Haggard, P. (2005). Viewing the body prepares the brain for touch: effects of TMS over somatosensory cortex. *European Journal of Neuroscience*, *22*, 773-777.

Fischer, M., Prinz, J., Lotz, K. (2008) Grasp cueing shows obligatory attention to action goals. *Quarterly Journal of Experimental Psychology, 61*, 860-868.

Fischer, M. & Zwaan, R. (2008). Embodied Language: A Review of the Role of the Motor System in Language Comprehension. *The Quarterly Journal of Experimental*

*Psychology*, 61, 825-850.

Freyd, J. J. (1983). The mental representation of movement when static stimuli are viewed. *Perception and Psychophysic, 33*, 575-81.

Gallagher, S. (2000). Philosophical conceptions of the self: Implications for cognitive science. *Trends in Cognitive Science*, 4, 14-21.

Gallagher, S. Meltzoff**,** A. N., (1996). The earliest sense of self and others: Merleau-Ponty and recent developmental studies. *Philosophical Psychology*, 9 (2), 211 – 233.

Gallese, V. (2001). The 'shared manifold' hypothesis: from mirror neuron to empathy. *Journal of Consciousness Studies*, *8*, 33-50.Gallese, V. (2009). Motor abstraction: a neuroscientic account of how action goals and intentions are mapped and understood. *Psychological Research, 73*, 486-98.

Gallese, V., Craighero, L., Fadiga, L., & Rizzolatti, G. (1996). Action recognition in the premotor cortex. *Brain*, *119*, 593-609.Gallese, V., & Goldman, A.I., (1998). Mirror neurons and the simulation theory. *Trends in Cognitive Science, 2*, 493–501.

Glenberg, A.M. (1997). What memory is for. *Behavioral and Brain Sciences, 20,* 1-55.

Glenberg, A. M., & Kaschak, M. P. (2002). Grounding language in action. *Psychonomic Bulletin & Review*, 9, 558-565.Goldman, A. (2006). *Simulating minds*. Oxford: Oxford University Press.

Goldman, A., & de Vignemont, F. (2009). Is social cognition embodied ? *Trends in Cognitive Science, 13,* 154-159.

Hauk, O., Johnsrude, I., & Pulvermüller, F. (2004). Somatotopic representation of action words in human motor and premotor cortex. *Neuron, 41*, 301–307.

Head, H., & Holmes, G. (1911). Sensory disturbances from cerebral lesions. *Brain*, *34*, 102-254.

Holmes, N. P., & Spence, C. (2004). The body schema and the multisensory representation(s) of peripersonal space. *Cognitive Processes, 5*, 94–105.

Hommel, B., Müsseler, J., Aschersleben, G., & Prinz, W. (2001). The theory of event coding (TEC): A framework for perception and action planning. *Behavioral and Brain Sciences, 24*, 849-878.

Jackson, P.L., Meltzoff, A.N., & Decety, J. (2006). Neural circuits involved in imitation and perspective taking. *Neuroimage, 31*, 429-439.

Jeannerod, M. (2007). *Motor Cognition: What actions tell the self*. Oxford: Oxford University Press.

Johnson-Frey, S. (2004). The neural basis of complex tool use in humans. *Trends in Cognitive Science, 8*, 71-78.

Johnson-Frey, S., Maloof, F., Newman-Norlund, R., Farrer, C., Inati, S., & Grafton, S. (2003). Actions or Hand-Object Interactions? Human Inferior Frontal Cortex and Action Observation *Neuron, 39*, 1053-1058.

Karmiloff-Smith, A. (1992). *Beyond Modularity*. Cambridge, MASS: The MIT Press.

Kemmerer, D. (1999). ``Near'' and ``far'' in language and perception. *Cognition, 73*, 65-73.

Kemmerer, D., Castillo, J. G., Talavage, T., Patterson, S., & Wiley, C. (2008). Neuroanatomical distribution of five semantic components of verbs: Evidence from fMRI. *Brain and Language, 107*, 16-43.

Kemmerer, D., & Tranel, D. (2008). Searching for the elusive neural substrates of body part terms: A neuropsychological study. *Cognitive Neuropsychology, 25*, 601-629.

Kiverstein, J. & Clark, A. (2009). Introduction: Mind Embodied, Embedded, Enacted: One Church or Many? *Topoi, 28*, 1-7.

Knöblich, G. (2002). Self-recognition: body and action. *Trends in Cognitive Sciences, 6*, 447-449.

Kourtzi, Z., & Kanwisher, N. (2000). Activation in human MT/MST by static images with implied motion. *Journal of Cognitive Neuroscience, 12,* 48-55.

Legrand, D. (2006). The bodily self: The sensori-motor roots of pre-reflective self-consciousness. *Phenomenology and the cognitive science, 5*, 89-118.

Lozano, S.C., Hard, B.M., & Tversky, B. (2007). Putting action in perspective. *Cognition, 103*, 480-490.Mahon, B.Z., & Caramazza, A. (2008). A critical look at the embodied cognition hypothesis and a new proposal for grounding conceptual content. *Journal of Physiology, Paris, 102*, 59-70.

Maravita, A., & Iriki, A. (2004). Tools for the body (schema). *Trends in Cognitive Science, 8*, 79-86. Maravita, A., Spence, C., Driver, J (2003). Multisensory integration and the body schema: close to hand and within reach. *Current Biology- 13* (13), R531-R539.

Menary, R. (2009). Intentionality, cognitive integration and the continuity thesis. *Topoi, 28*, 31-43.

Merleau-Ponty, M. (2002) [1945], *The Phenomenology of Perception.* Routledge: London and New York.

Morin, A, (2006). Levels of consciousness and self-awareness: A comparision and inteegration of various neurocognitive views. *Consciousness and Cognition, 15*, 358-371.

Morin, A, (2009). Inner Speech and Consciousness. *Encyclopedia of Consciousness*, vol. 1, pp. 389-402.

Morin, A. (in press). Self-awareness deficits following loss of inner speech: Dr. Jill Bolte Taylor's case study. *Consciousness and Cognition*.

Noë, A. (2009). *Out of our heads. Why you are not your brain, and other lessons from the biology of consciousness.* New York, NJ: Hill & Wang.

Ottoboni, G., Tessari, A., Cubelli, & Umiltà, C. (2005). Is handedness recognition automatic? A study with a Simon-like paradigm. *Journal of Experimental Psychology: Human Perception and Performance, 31*, 778-789.

Pavani, F., Spence, C., & Driver, J. (2000). Visual Capture of Touch: Out-of-the-Body Experiences With Rubber Gloves. *Psychological Science, 11*, 353-359.

Pulvermüller, F., Härle, M., Hummel, F., (2001). Walking or talking? Behavioral and electrophysiological correlates of action verb processing. *Brain and language, 78*, 143-168.

Pulvermüller, F., Shtyrov, Y., & Ilmoniemi, R. (2005). Brain signatures of meaning access in action word recognition. *Journal of Cognitive Neuroscience, 17*, 884-892.

Rowlands, M. (2009). Enactivism and the extended mind. *Topoi, 28*, 53-62.

Rizzolatti, G., & Craighero, L. (2004). The mirror neuron system. *Annual Review of Neuroscience, 27,* 169-192.

Sato, A. (2009). Both motor prediction and conceptual congruency between preview and action-effect contribute to explicit judgment of agency**.** *Cognition*, 110 (1), 74-83.

Shenton, J., Schwoebel, J., & Coslett, H. B. (2004). Mental motor imagery and the body schema: evidence for proprioceptive dominance. *Neuroscience Letters*. 370 (1), 19-24.

Scorolli, C., & Borghi, A.M. (2007). Sentence comprehension and action: Effector specific modulation of the motor system. *Brain research, 1130,* 119-124.

Sebanz, N., Bekkering, H., & Knöblich, G. (2006). Joint action: Bodies and minds moving together. *Trends in Cognitive Sciences, 10*, 70-76.

Setti, A., Borghi, A.M., & Tessari, A. (2009). Moving hands, moving entities. *Brain and Cognition, 70,* 253-258.

Spence, C. , Kingstone, A., Shore, D.I., & Gazzaniga, M.S. (2001) Representation of Visuotactile Space in the Split Brain. *Psychological Science, 12*, 90-93.

Sutton, J. (in press). Exograms and Interdisciplinarity: history, the extended mind, and the civilizing process. In R. Menary (ed.). *The Extended Mind*. Ashgate.

Thompson, V., & Stapleton, M. (2009). Making sense of sense-making: Reflections on enactive and extended mind theories. *Topoi, 2*8, 23-30.

Toni, I., de Lange, F.P., Noordzij, M.L., Hagoort, P. (2008). Language beyond action. *Journal of Physiology, Paris, 102*, 71-79.

Tsakiris, M., Prabhu, G., & Haggard, P. (2006). Having a body *versus* moving your body: How agency structures body-ownership. *Consciousness and Cognition*, 15, 423-432.

Tsakiris, M., Schütz-Bosbach, S., & Gallagher, S. (2007). On agency and body-ownership: Phenomenological and neurocognitive reflections, *Consciousness and Cognition, 16*, 645-660.

Urgesi, C., Moro, V., Candidi, M., & Aglioti, S.M. (2006). Mapping implied body action in human motor system. *The Journal of Neuroscience, 2*6, 7942-7949.

van den Bos, E., Jeannerod, M. (2002). Sense of body and sense of action both contribute to self-recognition. *Cognition,* 85, 177–187.

Vainio, L., Symes, E., Ellis, R., Tucker, M., & Ottoboni, G. (2008). On the relations between action planning, object identification, and motor representations of observed actions and objects. *Cognition, 108,* 444-465.

van den Bos, E., & Jeannerod, M. (2002). Sense of the body and sense of action both contribute to self-recognition, *Cognition*, *85*, 177-187.

Vogt, S., Taylor, P., & Hopkins, B. (2003). Visuomotor priming by pictures of hand pictures: perspective matters. *Neuropsychologia, 41,* 941-951.

Vygotskij, L.S., &Lurija, A. (1984). *Orudie i znak v razvitii rebënka* In *Sobranie sočinenij*, vol. VI (PP. 5-90). Moskwa: Pedagogika .

Winsler, A., Diaz, R.M., & Montero, I. (1997). The role of private speech in the transition from ccollaborative to independent task performance in young children. *Early Childhood Research Quarterly, 12*, 59-79.

Wilson, M. (2002). Six views of embodied cognition. *Psychonomic Bulletin & Review, 9,* 625-636.

Wittgenstein, L. (2001). *Philosophical Investigations. The German Text, with a Revised English Translation*, translated by G. E. M. Anscombe. Oxford: Blackwell Publishing.

Yoon, E.Y., & Humphreys, G.W. (2005). Direct and indirect effects of action on object classification. *Memory & Cognition, 33*, 1131-1146.

Zwaan, R., & Taylor, L.J. (2006). Seeing, acting, understanding: motor resonance in language comprehension. *Journal of Experimental Psychology: General, 135*, 1-11.