

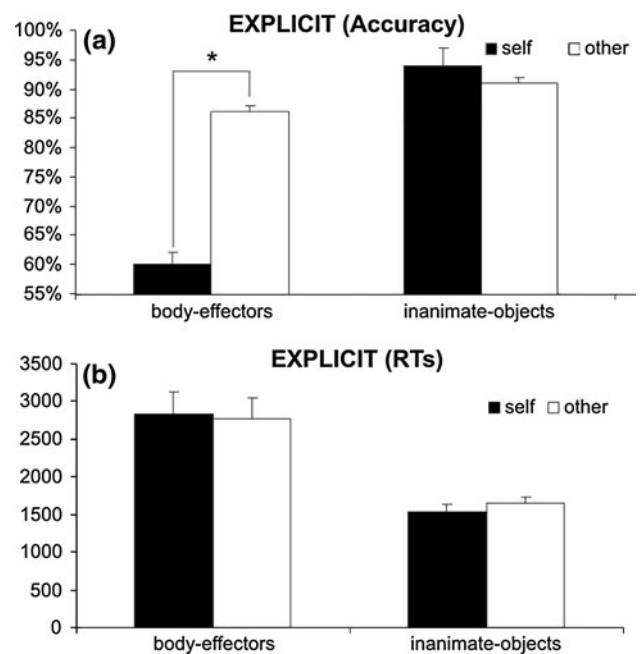
## Erratum to: Bodily self: an implicit knowledge of what is explicitly unknown

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Unfortunately, Fig. 3a in the original version of this article contains an error. The figure legend (graph key) of the Fig. 3a is wrong. The white bars represent the mean percentages of correct responses (accuracy) for self and the black bars represent the mean percentages of correct responses (accuracy) for others' body-effectors and inanimate-objects in the explicit task. Therefore the correct version of Fig. 3 can be found here.



**Fig. 3** Mean percentages of correct responses (accuracy) (a) and mean reaction times (RTs) (ms) (b) for self and others' body-effectors and inanimate-objects in the explicit task. Error bars depict the standard error of the mean

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# Bodily self: an implicit knowledge of what is explicitly unknown

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**Abstract** We tested the hypothesis that the body self-advantage, i.e., the facilitation in discriminating self versus other people's body-effectors, is the expression of an implicit and body-specific knowledge, based mainly on the sensorimotor representation of one's own body-effectors. Alternatively, the body self-advantage could rely on visual recognition of pictorial cues. According to the first hypothesis, using gray-scale pictures of body-parts, the body self-advantage should emerge when self-body recognition is implicitly required and should be specific for body-effectors and not for inanimate-objects. In contrast, if the self-advantage is due to a mere visual-perceptual facilitation, it should be independent of the implicit or explicit request (and could be extended also to objects). To disentangle these hypotheses, healthy participants were implicitly or explicitly required to recognize either their own body-effectors or inanimate-objects. Participants were more accurate in the implicit task with self rather than with others' body-effectors. In contrast, the self-advantage was not found

when an explicit recognition of one's own body-effectors was required, suggesting that the body self-advantage relies upon a sensorimotor, rather than a mere visual representation of one's own body. Moreover, the absence of both self/other and implicit/explicit effects, when processing inanimate-objects, underlines the differences between the body and other objects.

**Keywords** Self · Body · Implicit · Explicit knowledge

## Introduction

In the ongoing debate about the definition and understanding of the notion of "self," one of the central issues is the contribution of the "sense of body" to the constitution of the "sense of self." Recent evidence suggests that a specific neural network is dedicated to self-body recognition. This brain network seems to be, at least partially, distinct from that responsible for general body-related information processing (Sugiura et al. 2006; Myers and Sowden 2008; Hodzic et al. 2009). As argued by Myers and Sowden (2008), from our own body, we combine visual information with, at least, somatosensory, proprioceptive, and motor information, in order to guide our interpretation of sensory events and our actions upon the world. For others' bodies, we have only visual information available to us. This idea is supported by evidence provided by the same authors (Myers and Sowden 2008) that the right extrastriate body area (EBA), a region of the lateral occipitotemporal cortex and specific for images of the human body (Downing et al. 2001), contains separate neural subpopulations being selectively sensitive to images of our own or others' body-parts. Based on their functional neuroimaging (fMRI) data, Myers and Sowden proposed that the right EBA may perform an

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The authors F. Frassinetti and F. Ferri are contributed equally to this work.

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important sorting of body-part images by identity (including self-recognition). More direct evidence for the hypothesis that in the self-related processes, we combine visual, somatosensory, proprioceptive, and motor information comes from the literature based on behavioral and imaging studies on the rubber hand illusion (RHI) and the full body ownership illusions (Ehrsson et al. 2005; Tsakiris and Fotopoulou 2008; Makin et al. 2008; Aspell et al. 2009; Slater et al. 2009). There seems to be consensus in this literature that the processing of one's own body relies on multisensory integration mechanisms. The possible related neural mechanisms likely involve neural populations in the premotor and parietal regions, insular cortex, and the temporal-parietal junction.

Previous behavioral studies have demonstrated the human ability to implicitly recognize one's own body. When performing a visual matching task using gray-scale pictures, participants show the so-called self-advantage, that is, a better performance with self rather than others' body-parts (Frassinetti et al. 2008, 2009, 2010). Our hypothesis is that the implicit self-advantage revealed by the visual matching task is not merely due to visual perceptual facilitation, but may be due to a combination of visual, somatosensory, proprioceptive, and motor information.

The present study started from the idea that, whereas the implicit request to recognize self body-parts taps into different sources of information (mainly sensorimotor), an explicit request for self-body recognition mainly taps into visual processing. Indeed, when an explicit discrimination between self and others' body-parts is not required, as for the visual matching task by Frassinetti et al. (2008, 2009, 2010), the presence of a picture depicting participant's body improves participants' performance, suggesting that a sort of self-body recognition must implicitly occur. In this specific case, participants have to look for visual information to match details between pictures, rather than to recognize self-images. Thus, the implicit self-body recognition must rely on other than visual information. Conversely, when the recognition of self body-parts is explicitly required, participants focus on the visual cues, that are crucial for this task. To our knowledge, there is no evidence from other papers suggesting such a division between implicit and explicit self (body)-related processing in healthy subjects. However, there are examples of dissociations between implicit and explicit sense of body ownership in neuropsychological domain, for example in patients with hemisomatagnosia or with personal neglect (for a review, see Vallar and Ronchi 2009).

If our hypothesis is true, the body self-advantage should be particularly evident when participants are performing an implicit self-body recognition task, as in the previous studies (Frassinetti et al. 2008, 2009, 2010), whereas it should not necessarily arise when the same participants are explic-

itly required to recognize their own body, since the performance in this second task would strictly depend on the amount of available visual information.

However, an alternative hypothesis on the nature of the implicit body self-advantage is that it is due to a mere visual perceptual facilitation mechanism. If this is true, the same results should be found regardless of whether the self (body)-recognition is either implicitly or explicitly required. Specifically, with the same stimuli, the self-advantage should be evident also when one has to explicitly compare the image of the observed body-part with the corresponding "internal" image of one's own body-part.

To disentangle these two hypotheses, healthy participants were required to implicitly or explicitly recognize their own body-effectors (hand and foot). Moreover, to verify the selectivity of the self-advantage for body-effectors, we contrasted the observation of self and others' body-effectors with that of self and others' inanimate-objects (mobile phone and shoes). Both body-effectors and inanimate-objects were presented in egocentric and allocentric perspectives.

## Methods

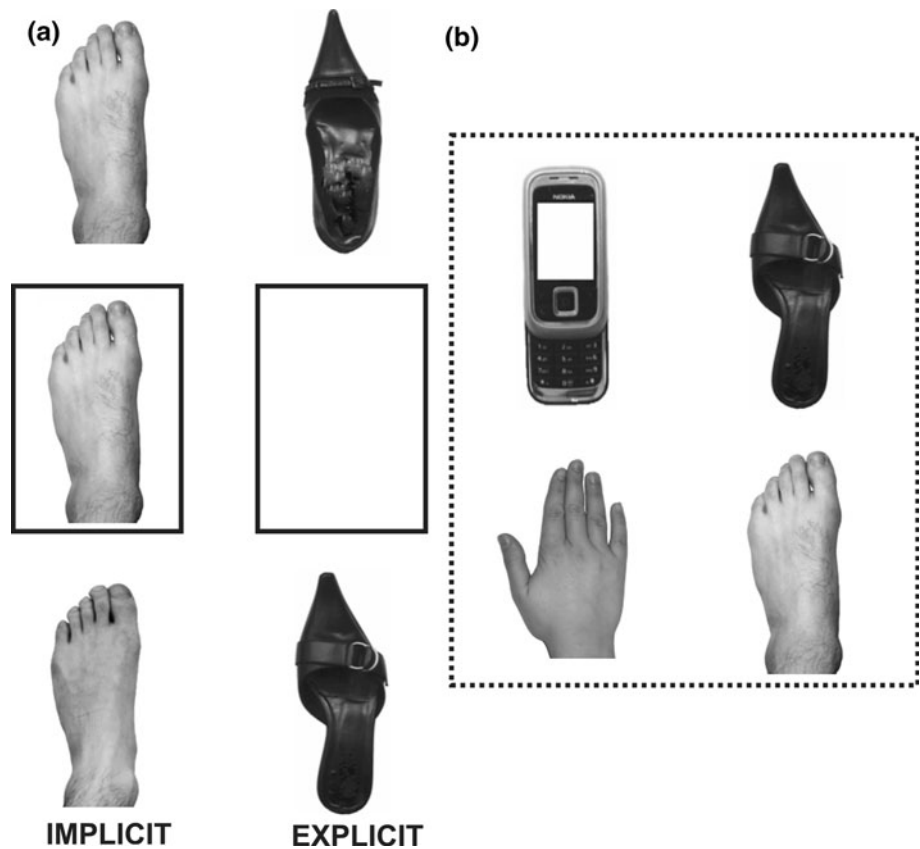
### Participants

Thirty-five right-handed healthy participants (16 men; age range: 21–55, mean 29.8 years), naive to the purpose of the study, with no history of neurological diseases, participated in the experimental investigation. All participants gave their informed consent for participation in the study, approved by the local ethics committee.

### Stimuli and procedure

Stimuli were gray-scale pictures of participants' body-effectors and objects. Flash photographs were taken with a digital camera, perpendicular to effectors or objects, 1 week before carrying out the experiments. This session took place in a controlled environment with constant artificial light and a fixed distance between the camera lens and the body-effectors (40 cm), which were always photographed in the same position. The pictures were equalized for visual properties, such as brightness and contrast, and digitally edited (Adobe Photoshop) for extracting the background, equalizing the size across participants, isolating the body-effectors, and centering them on a uniform white background. Stimuli represented body-effectors (hands and feet), matched according to participants' gender (male/female) and counterbalanced for laterality (left, right), and objects (mobile phones and shoes) (Fig. 1b). All stimuli were presented in egocentric and allocentric perspectives.

**Fig. 1 a** An example of a single trial. In Experiment 1 (implicit task), participants were required to decide which of the two images (the *upper* or the *lower* one) matched the central stimulus target. In Experiment 2 (explicit task), participants were required to judge whether and which image, between the *upper* or *lower*, corresponded to their own body-effectors or objects. **b** Examples of the experimental stimuli. For each category (body-effectors and inanimate-objects), two stimuli (hand/foot and mobile phone/shoes) were presented, in both egocentric or allocentric perspective (in the figure, egocentric)



In Experiment 1, three stimuli depicting the same body-effector, or the same type of inanimate-object, were simultaneously presented in each trial, aligned along the vertical meridian of the computer screen, until the participant responded. The central stimulus was presented upright, in a black frame, and corresponded to the target stimulus. Stimuli presented in each trial were matched for visual similarity. Participants sat in front of the PC screen, at a distance of about 30 cm, and were required to press, with their right index finger, an upper or a lower vertically aligned and previously assigned response key, as soon as they decided whether the upper or the lower stimulus matched the central target stimulus. Key-press RTs and response accuracy were recorded (see Fig. 1a-implicit task).

In Experiment 2, two stimuli depicting the same body-effectors or the same type of inanimate-object, matched for visual similarity, were simultaneously presented in each trial, in the same position in which the upper and the lower stimuli were located in Experiment 1. A white frame replaced the central target stimulus used in Experiment 1. Participants were requested to press an upper or a lower, vertically aligned and previously assigned, response key, to indicate whether the upper or the lower image corresponded to their own body-effector or object, and to press a central response key, when neither image corresponded to their own stimuli (see Fig. 1a-explicit task). The two “self”

buttons (upper and lower) were each correct 25% of the time, whereas the central “other” button was correct 50% of the time.

In both experiments, half of the trials contained at least one stimulus representing the participant’s own body-effectors or inanimate-objects (“self” trials), whereas the other half contained stimuli representing body-effectors or inanimate-objects from three other people (“other” trials).

Stimulus presentation and randomization in a block were controlled using E-prime V1.1 software (Psychology Software Tools, Pittsburgh, PA) running on a PC. Each experiment consisted of 64 trials divided into two blocks, one containing body-effectors (32 trials) and the other containing inanimate-objects (32 trials). For each block, stimuli presented in half of the trials depicted participant’s body-parts or inanimate-objects (8 in egocentric perspective and 8 in allocentric perspective), whereas stimuli presented in the other half depicted others’ body-parts or inanimate-objects (8 in egocentric perspective and 8 in allocentric perspective). All participants carried out both Experiments in one single session, with 12 practice trials before each block. Since Experiment 1 investigated the implicit and Experiment 2 the explicit self-body recognition, Experiment 1 was always conducted before Experiment 2. The order of the blocks within each Experiment was randomized across participants.

## Results

To verify the presence of the self-advantage for body-effectors and its selectivity compared with objects belonging to the self, a MANOVA for repeated measures was conducted on the arc sine square root transformation of the percentage of correct responses, with type of stimulus (body-effectors and inanimate-objects), owner (others' stimuli and self stimuli), and perspective (egocentric and allocentric) as within-subject variables.

To investigate whether participants' performance was influenced by a specific *body-effector* or *inanimate-object* for either Experiment, a MANOVA was conducted for body-effectors and objects, with Stimulus (hand and foot, for body-effectors; mobile phone and shoe, for objects), owner (others' stimuli and self stimuli) and perspective (egocentric or allocentric) as within-subject variables. Similar MANOVAs were run on mean response times. The Newman-Keuls test was used for all post hoc comparisons.

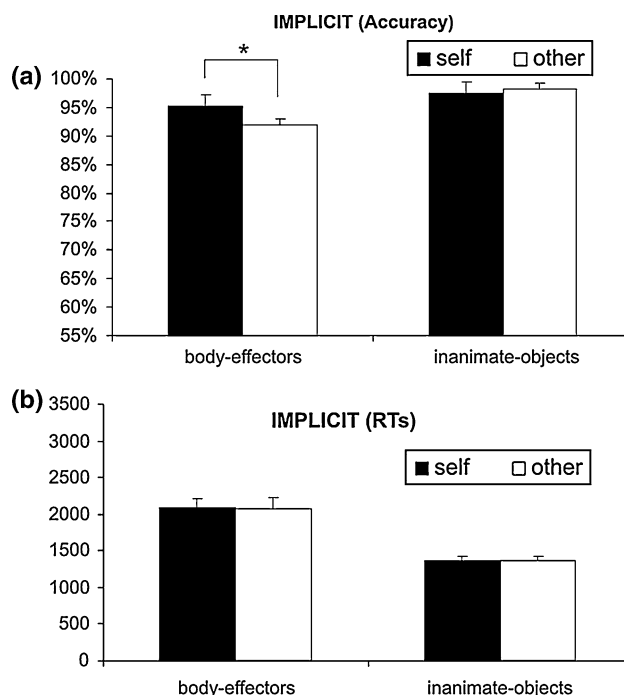
### Response accuracy

#### Experiment 1

The variable type of stimulus was significant  $F(1,34) = 11.03$ ;  $P < .001$ , since participants performed better with objects than with body stimuli (98% vs. 94%). Also the interaction type of stimulus X owner was significant  $F(1,34) = 4.43$ ;  $P < .04$ , since participants performed better with their own rather than with other people's body-effectors (95% vs. 92%,  $P < .02$ ), showing the so-called self-advantage. This self-advantage was not present with objects (accuracy 98% for self and others' objects,  $P = .58$ ) (Fig. 2a).

The variable perspective showed no main effect, and its interactions with the other variables were not significant.

The separate analysis on *body-effectors* showed that the self-advantage found in the previous analysis was present for both hands and feet. Indeed, the owner variable was significant ( $F(1,34) = 4.2$ ;  $P < .05$ ), whereas the variable stimuli and its interaction with owner were not significant. Also the interaction owner X perspective was almost significant ( $F(1,34) = 3.8$ ;  $P < .05$ ), participants being more accurate with self than with others' body-effectors (96% vs. 90%,  $P < .01$ ), only when presented with body stimuli in egocentric perspective. No difference was found between self and others' body-effectors (93% for both stimuli,  $P = .61$ ) for stimuli presented in allocentric perspective. When a similar analysis was conducted on *object stimuli*, the variables owner, stimuli, perspective and their interactions were not significant.



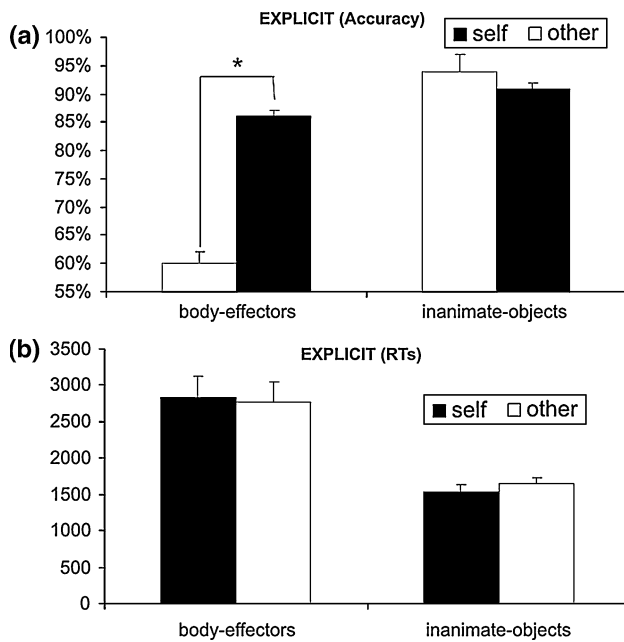
**Fig. 2** Mean percentages of correct responses (accuracy) (a) and mean reaction times (RTs) (ms) (b) for self and others' body-effectors and inanimate-objects in the implicit task. Error bars depict the standard error of the mean

#### Experiment 2

The variables type of stimulus ( $F(1,34) = 49$ ;  $P < .0001$ ) and owner ( $F(1,34) = 15.4$ ;  $P < .0004$ ) and their interaction ( $F(1,34) = 21$ ;  $P < .0001$ ) were significant. Participants performed substantially worse with their own than with others' body-effectors (60% vs. 86%,  $P < .0001$ ), showing a kind of "self-disadvantage." This effect was not present with objects (self 94% vs. other 91%). The variable perspective and its interactions with the other variables were not significant.

The different pattern of results for body-effectors and objects rules out the possibility that the body "self-disadvantage" in the explicit task was influenced by response frequency. If participants were strategic, such an arrangement could produce a cueing effect such that they would be less accurate to respond with the less frequent keys (self-condition) both with body-effectors and with objects. However, this possibility can be excluded, because no "self-disadvantage" was found with objects (Fig. 3a).

It could be argued that in the self-other dichotomy, the erroneous rejection of one's own body-part necessarily entails a false positive judgment that this image belongs to the "other," and vice versa, the erroneous judgment that someone else's body-part belongs to oneself leads to false



**Fig. 3** Mean percentages of correct responses (accuracy) (a) and mean reaction times (RTs) (ms) (b) for self and others' body-effectors and inanimate-objects in the explicit task. Error bars depict the standard error of the mean

self-attribution (false positive) of this body-part. Thus, the final accuracy value should take into account the false positives in each category, since those categories are no longer independent from each other. To tackle this criticism, responses were classified as: self-correct response (when it was correctly recognized that a self-stimulus was present), other-correct response (when it was correctly recognized that a self-stimulus was *not* present), self-false positive (when an other's stimulus was erroneously recognized as a self-stimulus), and other-false positive (when a self-stimulus was erroneously recognized as an other's stimulus).

The same MANOVA conducted on the arc sine square root transformation of the percentage of correct responses (calculated as explained previously) confirmed the results of the previous analysis. Indeed, the variables type of stimulus ( $F(1,34) = 41.78$ ;  $P < .0001$ ), owner ( $F(1,34) = 17.8$ ;  $P < .0002$ ), and their interaction ( $F(1,34) = 26.8$ ;  $P < .0001$ ) were significant. Post hoc analysis revealed that participants performed substantially worse with their own than with others' body-effectors (29% vs. 44%,  $P < .0001$ ), whereas no difference was found between self and others' inanimate-objects (47% vs. 46%,  $P = .51$ ).

As in the previous Experiment, to verify the contribution of each single stimulus in determining the results, two separate MANOVAs were conducted for body and objects, with stimuli, owner, and perspective as within group variables. The analysis on *body-effectors* showed that the "self-disadvantage" found in the previous analysis was present for both stimuli representing hand and foot. Indeed, the owner

variable was significant ( $F(1,34) = 25.4$ ;  $P < .00001$ ), whereas the variable stimuli (hand 68% vs. foot 78%), perspective and their interactions with owner were not. When similar analysis was conducted on *object stimuli*, the variable stimuli (mobile 92% and shoe 94%), owner, perspective and their interactions were not significant.

In conclusion, a body self-advantage was found in the implicit, but not in the explicit task. These differing results may be, at least partially, related to differences in the experimental procedures. Indeed, in order to give a response, in Experiment 2, participants had to choose between three keys, instead of two, as was the case for Experiment 1. This would have made the explicit task more difficult than the implicit one, as suggested by the comparison between RTs. A second possible reason explaining the dramatic (and quite surprising) lack of body self-advantage in the second experiment may be that in the first experiment the upper and the lower stimuli were compared with the central (self or others') one, and this allowed the response accuracy to be calculated separately for the two categories (self vs. others'). The same did not hold for the second experiment, where participants were requested to judge whether the images they saw belonged to them or not. Thus, all images needed to be compared with the same point of reference. To face these criticisms, a third experiment was run with body stimuli, in which (1) two response keys were used, in order to make the explicit task easier; (2) two different explicit judgments were required, in order to allow the response accuracy to be calculated separately for the two stimulus categories (self vs. others').

### Experiment 3

A subgroup of 18 participants took part in a modified version of the explicit task with body stimuli. As in Experiment 2, two stimuli of the same body-effectors were simultaneously presented in each trial, in egocentric, or in allocentric perspective. However, two *Types of judgment* were required: in the "self-judgment" condition, participants were asked whether *one of the two stimuli belonged to them*; whereas in the "other-judgement" condition, participants were asked whether *one of the two stimuli belonged to another person*. Each judgement was made in a separate block (32 trials). In each block, half of the trials contained both stimuli belonging to the *same owner* (other/other in the "self-judgement" block or self/self in the "other-judgement" block), whereas the other half contained stimuli belonging to *different owner* (self/other). Thus, each participant was presented with the same number of self and others' stimuli. Participants responded "yes" or "no" by pressing the upper or the lower key. The position of self and other stimuli was counterbalanced within a block. The assignment of the keys to "yes" or "no" responses and the

order of the blocks were counterbalanced across participants.

A MANOVA was conducted on the arc sine square root transformation of the percentage of correct responses with type of judgement (self vs. other) and owner of the stimuli (same owner vs. different owner). The variable type of judgement was not significant (self = 79%, other = 79%,  $P = .75$ ). The variable owner of the stimuli was significant ( $F(1,17) = 7.2$ ;  $P < .02$ ), accuracy being higher for different—than for same—owner stimuli (83% vs. 75%). However, the interaction between the two variables was not significant ( $P = .47$ ). Indeed, direct comparisons (two-tailed  $t$  test) showed that when the two stimuli belonged to different owners (self/other), the “self-judgment” was not different from the “other-judgment” ( $P = .50$ ). Similarly, when the two stimuli belonged to the same owner (self/self; other/other), no difference was found between “self-” and “other-judgment” ( $P = .42$ ). In conclusion, when the response accuracy for the explicit recognition of body-effectors is calculated separately for the two categories (self vs. others’), no significant effect of the point of reference (self body-parts vs. others’ body-parts), related to the type of judgment, was found. Thus, a lack of self-advantage, rather than a kind of “self-disadvantage”, as in experiment 2, emerged in this variant of the explicit body-parts recognition task.

## Response times

### Experiment 1

The ANOVA conducted on the RTs with type of stimulus, owner, and perspective as within-subject variables, showed a significant main effect of type of stimulus ( $F(1,34) = 64.6$ ;  $P < .0001$ ). Participants were slower with body-effectors than with inanimate-objects (2084 ms vs. 1368 ms). The interaction type of stimulus X owner was not significant (see Fig. 2b). The variables owner and perspective and their interactions were not significant.

### Experiment 2

The ANOVA conducted on the RTs of 27 participants (8 participants gave no correct responses in at least one condition in the self-body condition) showed a significant effect of type of stimulus ( $F(1,26) = 26.6$ ;  $P < .0001$ ), perspective ( $F(1,26) = 9.68$ ;  $P < .004$ ), and their interaction ( $F(1,26) = 10.7$ ;  $P < .003$ ). Participants were faster with body-effectors in egocentric than in allocentric perspective (2583 ms vs. 3014 ms,  $P < .003$ ). This effect was not found with objects (egocentric 1603, allocentric 1589,  $P = .88$ ).

What is important to note here is that the interaction type of stimulus X owner was not significant ( $P = .41$ ). Participants, if anything, tended to be *slower* with self than with others’ body-effectors (2827 ms vs. 2771 ms) and to be *faster* with self than with others’ objects (1539 ms vs. 1653 ms), thus excluding a speed accuracy trade-off (Fig. 3b).

### Experiment 3

When RTs were analyzed, the variables type of judgment (self = 2039 ms vs. other = 1964 ms), owner of the stimuli (same owner = 1990 ms vs. different owner = 2013 ms), and their interaction were not significant.

## Discussion

The main result of the present study is that the self-advantage for body-effectors emerged only when an explicit recognition of them was *not* required. Indeed, while the implicit self-advantage (Frassinetti 2008, 2009, 2010) was confirmed in Experiment 1, a better performance for self body-parts, in comparison with others’, was not observed whenever participants were asked to explicitly recognize their own body-effectors, in Experiment 2 and Experiment 3.

Even if the implicit and the explicit tasks cannot be directly compared, the presence of the self-advantage in the implicit, but not in any explicit task, rules out the possibility that the self-advantage is due to a mere visual perceptual facilitation process. In this case, a better performance for self rather than for others’ stimuli should have been observed in all tasks.

We started from the hypothesis that the implicit body self-advantage relies upon the integration of visual body-part information with other modalities, with the sensorimotor representation of body-effectors having a crucial role. This hypothesis rested on various empirical evidence. For instance, previous findings have shown that the self-advantage emerging in an implicit task is stronger for dynamic than for static stimuli (Frassinetti et al. 2009). Indeed, participants performed better with dynamic than with static images depicting self body-parts, even if the dynamic condition was more difficult than the static one. Other evidence supports the notion that movements can help the self/other distinction of body-parts. For instance, spatial and temporal contingencies of seen and executed movements prove salient cues for self/other action attribution (Jeannerod 2003, 2004; Ruby and Decety 2001). Similarly, people can successfully distinguish one’s own action from somebody else’s actions, even when the body-parts’ movement is only implicit in still images (Beardsworth and Buckner 1981;

Johansson 1973; Knoblich and Flach 2003; Knoblich and Prinz 2001).

Coming back to the present study, we found that participants were more accurate with self than with others' body-effectors, only when the stimuli were in egocentric perspective. This result is consistent with the facilitation of self-body processing in egocentric perspective reported by van den Bos and Jeannerod (2002). The selectivity of the self-advantage for body stimuli in egocentric perspective supports the idea that the implicit representation of self body-effectors relies also upon their sensorimotor representation, being the sensorimotor experience of our body based on an egocentric perspective. According to this evidence, it can be speculated that the body is primarily given to us as the variety of motor potentialities defining the horizon of our interactions with the world (Gallese and Sinigaglia 2010). In other words, our experience of surrounding things cannot but be accompanied by the experience of ourselves as a bodily "power" or "source" for action, that is, as the variety of possibilities for action that belong to our own motor repertoire (Gallese and Sinigaglia 2010). Thus, the body self-advantage may be the expression of an implicit body knowledge related to the potentiality for action of body-effectors.

Regarding the explicit recognition of body-effectors, Urgesi et al. (2007) showed that, when participants are *explicitly* required to discriminate between static images depicting different body-part postures, reversible deactivation of the ventral premotor cortex impairs discrimination between them. In contrast, reversible deactivation of EBA selectively impairs the recognition of *the identity* of similar body-parts (Urgesi et al. 2007). This suggests that the explicit recognition of body identity (as in the case of our Experiments 2 and 3) crucially depends on the functional integrity of a visual perceptual area, like EBA.

The image of our own body-parts, which we likely activate when being explicitly asked to match it to another body image, appears to be more vulnerable to errors than the motor knowledge we implicitly hold about the same body parts. This might account for the lack of self-advantage found in the explicit tasks. Indeed, the explicit self-recognition probably requires attention and memory abilities not required in the implicit task. Furthermore, the type of images employed in the present study (gray-scale rather than color pictures, as in Frassinetti et al. 2008, 2009, 2010) likely made it difficult for participants to recognize their own body-effectors when explicitly, despite not when implicitly, required.

The second result of the present study is that neither the self-advantage for body-effectors in the implicit task nor the lack of this effect in the explicit ones extended to objects belonging to self, even if mobile phones and shoes are objects habitually kept in close contact with or manipulated

by the same body-effectors we used as body stimuli. In our opinion, the different pattern of results for body-effectors and objects suggests that the implicit body self-advantage is unlikely to be due to a visual familiarity facilitation. Indeed, if visual familiarity was the explanation for the results of Experiment 1, a self-advantage should have been found also for self-belonging objects. It may be argued that this inference is drawn from results that cannot be directly compared. Indeed, in both the implicit and explicit tasks, the object discrimination is much easier than the body-part discrimination, as indicated by the reaction times. Even if we matched objects carefully, considering all the different characteristics of both mobile phones (number and position of keys, size and position of the display...) and shoes (style, shape...), it may be that the larger number of details still made objects easier to distinguish than body-parts, whose configuration is more repetitive and difficult to discriminate. However, the lack of self-facilitation for objects would further corroborate the notion that our body is a very particular type of "object," whose perception obeys different rules pertaining to different mechanisms with respect to inanimate objects (Downing et al. 2001; Moro et al. 2008; Peelen and Downing 2007).

In conclusion, our results show that the representation of our body-effectors is not only different from the way we represent inanimate objects, but—more importantly—contributes differently to our sense of self as bodily self when implicitly or explicitly accessed. This is suggested by the different accuracy and speed of self-recognition displayed by participants in these two different access conditions. Our results are in line with much evidence in the neuropsychological domain showing that the same information may be accessed by two ways: one way leading to an implicit, but not to an explicit knowledge, and the other way leading to explicit knowledge. An example of this dissociation is the blindsight phenomenon, where patients are unable to consciously perceive visually presented objects, but still able to point toward them (Tamietto et al. 2010). Another example comes from neglect syndrome. Neglect patients fail to explicitly detect stimuli presented in the contralesional affected field. However, they can implicitly process the same stimuli up to the semantic level (Berti and Rizzolatti 1992; Berti et al. 1994). Brain imaging experiments are being carried out to assess which brain circuits underpin the implicit and explicit access routes for body knowledge.

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**Conflicts of interests** The authors declare no conflicts of interests that could influence the results or their interpretation.

## References

- Aspell JE, Lenggenhager B, Blanke O (2009) Keeping in touch with one's self: multisensory mechanisms of self-consciousness. *PLoS One* 4(8):e6488
- Beardsworth T, Buckner T (1981) The ability to recognize oneself from a video recording of one's movements without seeing one's body. *Bull Psychon Soc* 18:19–22
- Berti A, Rizzolatti G (1992) Visual processing without awareness: evidence from unilateral neglect. *J Cogn Neurosci* 4:345–351
- Berti A, Umiltà C, Frassinetti F (1994) Nonconscious reading? Evidence from neglect dyslexia. *Cortex* 30:181–197
- Downing PE, Jiang Y, Shuman M, Kanwisher N (2001) A cortical area selective for visual processing of the human body. *Science* 293:2470–2473
- Ehrsson HH, Holmes NP, Passingham RE (2005) Touching a rubber hand: feeling of body ownership is associated with activity in multisensory brain areas. *J Neurosci* 25(45):10564–10573
- Frassinetti F, Maini M, Romualdi S, Galante E, Avanzi S (2008) Is it mine? Hemispheric asymmetries in corporeal self-recognition. *J Cogn Neurosci* 20:1507–1516
- Frassinetti F, Pavani F, Zamagni E, Fusaroli G, Vescovi M, Benassi M, Avanzi S, Farnè A (2009) Visual processing of moving and static self body-parts. *Neuropsychologia* 47:1988–1993
- Frassinetti F, Maini M, Benassi M, Avanzi S, Cantagallo A, Farnè A (2010) Selective impairment of self body-parts processing in right brain-damaged patients. *Cortex* 46:322–328
- Gallese V, Sinigaglia C (2010) The bodily self as power for action. *Neuropsychologia* 48:746–755
- Hodzic A, Muckli L, Singer W, Stirn A (2009) Cortical responses to self and others. *Hum Brain Mapp* 30:951–962
- Jeannerod M (2003) The mechanism of self-recognition in humans. *Behav Brain Res* 142:1–15
- Jeannerod M (2004) Visual and action cues contribute to the self-other distinction. *Nat Neurosci* 7:422–423
- Johansson G (1973) Visual perception of biological motion and a model for its analysis. *Percept Psychophys* 14:201–211
- Knoblich G, Flach R (2003) Action identity: evidence from self-recognition, prediction, and coordination. *Conscious Cogn* 12:620–632
- Knoblich G, Prinz W (2001) Recognition of self-generated actions from kinematic displays of drawing. *J Exp Psychol Hum Percept Perform* 27:456–465
- Makin TR, Holmes NP, Ehrsson HH (2008) On the other hand: dummy hands and peripersonal space. *Behav Brain Res* 191(1):1–10
- Moro V, Urgesi C, Pernigo S, Lanteri P, Pazzaglia M et al (2008) The neural basis of body form and body action agnosia. *Neuron* 60:235–246
- Myers A, Sowden PT (2008) Your hand or mine? The extrastriate body area. *NeuroImage* 42:1669–1677
- Peelen MV, Downing PE (2007) The neural basis of visual body perception. *Nat Rev Neurosci* 8:636–648
- Ruby P, Decety J (2001) Effect of subjective perspective taking during simulation of action: a PET investigation of agency. *Nat Neurosci* 4(5):546–550
- Slater M, Perez-Marcos D, Ehrsson HH, Sanchez-Vives MV (2009) Inducing illusory ownership of a virtual body. *Front Neurosci* 3(2):214–220
- Sugiura M, Sassa Y, Jeong H, Miura N, Akitsuki Y, Horie K et al (2006) Multiple brain networks for visual self-recognition with different sensitivity for motion and body part. *Neuroimage* 32:1905–1917
- Tamietto M, Cauda F, Corazzini LL, Savazzi S, Marzi CA, Goebel R, Weiskrantz L, de Galder B (2010) Collicular vision guides non-conscious behavior. *J Cogn Neurosci* 22(5):888–902
- Tsakiris M, Fotopoulou A (2008) Is my body the sum of online and offline body-representations? *Conscious Cogn* 17(4):1317–1320
- Urgesi C, Candidi M, Ionta S, Aglioti SM (2007) Representation of body identity and body actions in extrastriate body area and ventral premotor cortex. *Nat Neurosci* 10(1):30–31
- Vallar G, Ronchi R (2009) Somatoparaphrenia: a body delusion. A review of the neuropsychological literature. *Exp Brain Res* 192(3):533–551
- van den Bos E, Jeannerod M (2002) Sense of body and sense of action both contribute to self recognition. *Cognition* 85(2):177–187