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Bodily self-recognition in patients with pathological embodiment

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Abstract

The ability to discriminate between one's own and others' body parts can be lost after brain damage, as in patients who misidentify someone else's hand as their own (pathological embodiment). Surprisingly, these patients do not use visual information to discriminate between the own and the alien hand. We asked whether this impaired visual discrimination emerges only in the ecological evaluation when the pathological embodiment is triggered by the physical alien hand (the examiner's one) or whether it emerges also when hand images are displayed on a screen. Forty right brain-damaged patients, with (E+ = 20) and without (E− = 20) pathological embodiment, and 24 healthy controls underwent two tasks in which stimuli depicting self and other hands was adopted. In the Implicit task, where participants judged which of two images matched a central target, the self-advantage (better performance with Self than Other stimuli) selectively emerges in controls, but not in patients. Moreover, E+ patients show a significantly lower performance with respect to both controls and E− patients, whereas E− patients were comparable to controls. In the Explicit task, where participants judged which stimuli belonged to themselves, both E− and E+ patients performed worst when compared to controls, but only E+ patients hyper-attributed others' hand to themselves (i.e., false alarms) as observed during the ecological evaluation. The VLSM revealed that SLF damage was significantly associated with the tendency of committing false alarm errors. We demonstrate that, in E+ patients, the ability to visually recognize the own body is lost, at both implicit and explicit level.

KEYWORDS

body ownership, body part, implicit and explicit recognition, self-other

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1 | INTRODUCTION

In the last years, several studies in cognitive neuroscience have been focused on the mechanisms that contribute to properly develop a coherent sense of body ownership, that is, the feeling that different body parts belong to ourselves (for review see Blanke et al., 2015; De Vignemont, 2011; Park & Blanke, 2019). Briefly, we continuously receive from our limbs somatosensory, visual, and proprioceptive information related to the interaction of our body with the external events, but we can also perceive the internal states of our body through the interoceptive component of body-related sensory signals (Allen, 2020; Crucianelli et al., 2018; Ronchi et al., 2015). Nevertheless, how can all these signals make our body be perceived so clearly and inevitably as *my* body, is still an open question. In this respect, the boundary between our corporeal self and what we recognize as other people's body is crucial, since it allows us to reliably distinguish between what is mine and what is not.

Typically, in healthy participants the distinction between my body and other's body is automatic and immediate. However, evidence coming from experimental manipulation in healthy participants and in pathological populations indicates that our feeling of body ownership is a complex and multifaceted process with different brain mechanisms possibly serving different body representations.

In healthy participants, for example, manipulating the integration of multisensory signals may induce the illusory feeling that a fake and external body part is one's own. Growing neuroimaging and behavioral evidence on healthy participants revealed the mechanisms underlying this experience. During the rubber hand illusion (RHI; Botvinick & Cohen, 1998; Bucchioni et al., 2016; Burin et al., 2017; Della Gatta et al., 2016; Tsakiris et al., 2007; Zeller et al., 2011, 2016), the enfacement illusion (D'Angelo et al., 2020; Sforza et al., 2010; Tsakiris, 2008), and the full-body illusion (D'Angelo et al., 2017; D'Angelo et al., 2019; Ehrsson, 2007; Lenggenhager et al., 2007; Petkova & Ehrsson, 2008), participants identify themselves with another person's body part or with a virtual body. For instance, the classic RHI is elicited by simultaneously stroking the rubber hand and the participants' hand. After a short period of stimulation, participants start to experience the rubber hand as part of their own body. This experience is defined "embodiment" and is referred to a specific process in which an external body part or an object becomes part of one's own body (De Vignemont, 2011; Kilteni et al., 2015; Makin et al., 2008; Tsakiris, 2010). The rising and the strength of this feeling is associated with the activation of a large cerebral network, including premotor, insular, posterior parietal, and cerebellar cortex (Brozzoli et al., 2012; Ehrsson et al., 2004; Gentile et al., 2013; Limanowski & Blankenburg, 2015). Taken together, this evidence demonstrated how multisensory bodily signals, mainly proprioceptive, visual and tactile information, need to be integrated to perceive an external body or a body part as one's own (Grivaz et al., 2017; Seghezzi et al., 2019; Stone et al., 2018).

Critically, further interesting findings elucidating the grounds of the sense of body ownership came from neurological and neuropsychological studies. One first example is provided by studies on somatoparaphrenic patients, who, after a right unilateral brain damage, show delusional beliefs about the contralesional side of their body. Crucially, these patients attribute their paralyzed limb to another person, exhibiting a sense of disownership for the affected body parts (for a review see Garbarini et al., 2020; Romano & Maravita, 2019; Vallar & Ronchi, 2009).

Recently, Garbarini and coworkers (Errante et al., 2022; Fossataro et al., 2016, 2018, 2020; Garbarini et al., 2013, 2014, 2015; Garbarini & Pia, 2013; Pia et al., 2013, 2016, 2020; Ronga et al., 2019; Sebastiano et al., 2022) described also the opposite behavior in brain-damaged patients who erroneously identify other people's hand as their own. The term of *pathological embodiment* (PE) has been coined by the authors to refer to this clinical manifestation. Patients who are affected by PE are classified as E+ patients, while E− patients are subjects without PE. In this condition, the delusion of ownership spontaneously occurs when the examiner's hand (hereinafter alien hand) is positioned on the table internally to the patient's contralesional hand and according to the patient's egocentric coordinates. Whenever the examiner's hand is placed in this body-congruent position, E+ patients misattribute the alien hand to themselves and they treat and care for it as if it was their own hand. Interestingly, in the absence of the alien limb, E+ patients do not explicitly deny that their contralesional limb belong to themselves (as in somatoparaphrenic delusion, for a review see Gandola et al., 2012; Romano & Maravita, 2019; Vallar & Ronchi, 2009). Furthermore, PE does not occur when the alien hand is misaligned with the patient's shoulder, when it is perceived in allocentric perspective or positioned in the intact ipsilesional body side and when, instead of a human hand, a rubber hand is used (Fossataro et al., 2018; Garbarini et al., 2015; Pia et al., 2020). Going further, it has been revealed that, in E+ patients, the profound alteration of their corporeal representation affects both motor and somatosensory processing thus suggesting that this delusion is not a mere verbal confabulation, but instead, it reflects a real embodiment of the alien arm

Significance

This study is part of a neuropsychological line of research that investigates the cognitive mechanisms subserving bodily self-recognition, with especial emphasis on implicit and explicit mechanisms subserving this ability. Importantly, studying corporeal self-recognition in brain-damaged patients may disclose how a selective brain lesion affects the self-other distinction and unravel the neural basis underlying. We verified whether the impairment in self body visual recognition, previously found in patients with a right brain lesion, is modulated by the concomitant presence of a peculiar body ownership delusion, in which patients misidentify other peoples' limb as their own (the so-called pathological embodiment).

within the patient's sensorimotor system. First, the alien hand movements modulate the motor parameter of the patient's intact arm movements (Garbarini et al., 2013) and the representation of the patient's personal/peripersonal space (Fossataro et al., 2016; Garbarini et al., 2015; Ronga et al., 2019), as if the moving alien hand was the patients' real hand. Second, somatosensory stimuli delivered to the alien hand elicit a comparable phenomenological/physiological response as those delivered to the own healthy hand (Garbarini et al., 2014; Pia et al., 2013).

Together, these studies suggest that the corporeal self-representation does not inevitably match the physical body, opening up a window to the understanding of how the sense of body ownership is constructed (Brugger & Lenggenhager, 2014). For instance, during the embodiment evaluation (see details in Section 2) it is surprising how E+ patients seem to completely ignore the perceptive visual details (i.e., skin color, shape, age, or dimension) coming from the alien hand, when it is placed in the contralesional (affected) body side, next to the patients' hand. Thus, even if both hands are visible on the table, patients do not use visual information to discriminate between the one's own and the alien hand. It is important to note that E+ patients cannot rely on one of the most important information that we use to identify our own body, that is, proprioception, including both statesthesia (i.e., static position sense) and kinaesthesia (i.e., dynamic position sense). Indeed, so far, no E+ patients with spared position sense have been described (Pia et al., 2020). Importantly, in patients without pathological embodiment (E−), when the position sense is lost, the ability to visually discriminate between self and others' body is still present and they can rely on a normal elaboration of visual input to identify their own hand. On the contrary, in E+ patients, the ownership judgment seems to be based only on an abstract knowledge of body structure, so that, in the clinical evaluation, each stimulus matching the constraints of this aprioristic body spatial representation (e.g., a human hand aligned with the shoulder and perceived in egocentric perspective), regardless of its visual details, is felt as part of the own body. Capitalizing on these clinical characteristics, an opening question is whether, in E+ patients, the impaired visual discrimination between the own and the alien (embodied) hands emerges only in the context of the ecological evaluation (i.e., when the examiner's hand is present on the table, aligned with the patients' contralesional shoulder), or if it also emerges when patients have to recognize their hand displayed on a computer screen.

In the present study, two experimental protocols designed to explore the bodily self-visual recognition, by means of implicit and explicit judgments, were submitted to a group of RBD patients, divided in two subgroups (E+ and E−), whose neuropsychological assessment and lesion mapping were provided. It has been recently suggested that humans have, beyond an explicit recognition of their body, also an implicit knowledge of their own body parts. Frassinetti et al. (2008, 2009, 2011, 2012) investigated implicit/explicit hand recognition by using a visual matching-to-sample task in which stimuli depict participants' or other people's body parts. In the implicit task, participants had to judge which of two vertically aligned images (above or below) matched the central stimulus (target). The target could be the participants' or another person's hand. Note that in the implicit task the possible presence of the own hand was never mentioned. Results demonstrated that participants' judgments were more accurate with self rather than other's body parts, a facilitation defined *self-advantage effect*. Intriguingly, this effect was not found when participants were explicitly required to judge if the lower or the upper stimulus corresponded to their own body parts (Frassinetti et al., 2011). This dissociation suggests that implicit and explicit bodily self-recognition are based on different mechanisms or referred to different representations. Supporting this evidence, studies in neurological patients, reporting a lack of self-advantage effect in right but not in left brain-damaged patients (Frassinetti et al., 2008, 2009, 2010), revealed two distinct networks within the right hemisphere involved in visual processing of self-body stimuli. In particular, a greater impairment at the *implicit* task has been associated with brain lesions involving motor subcortical structures (basal ganglia and internal capsule), while a greater impairment at the *explicit* task mainly included lesions involving insular cortex and cingulate gyrus (Candini et al., 2016).

Notably, none of these studies have considered the possible presence of PE and the distinction between E+ and E− RBD patients. Thus, the aim of the current study is to verify whether the impairment found in RBD patients in implicit/explicit self body-part recognition is modulated by the presence of PE. In particular, if a specific impairment in self/other visual discrimination in E+ patients persists outside the context of the ecological evaluation, significant differences is expected between E+ and E− groups at implicit and explicit visual tasks. Alternatively, if visual body recognition is not a critical factor in PE, no differences between the two groups are expected.

2 | METHODS AND MATERIALS

2.1 | Participants and neuropsychological assessment

Twenty-four healthy participants (11 males, mean age ± SD = 66.4 ± 10.3 years; mean education ± SD = 9.4 ± 4.4 years; hereinafter *Control group*), 20 RBD patients without pathological embodiment (9 males, mean age ± SD = 65.5 ± 8.4 years; mean education ± SD = 10.3 ± 4.3 years; hereinafter *E− group*), and 20 RBD patients with pathological embodiment (11 males, mean age ± SD = 68.7 ± 9.6 years; mean education ± SD = 7.2 ± 3.1 years; hereinafter *E+ group*) participated in the study. To verify that the three groups were not significantly different for education [$F_{2,59} = 2.93$; $p = .061$; $\eta^2_p = 0.09$] and age [$F_{2,59} = 0.57$; $p = .56$; $\eta^2_p = 0.02$], two one-way ANOVAs were conducted.

All participants were right handed by their own verbal report. Patients were recruited at the ICS Maugeri (Castel Goffredo, Italy) and at the San Camillo Hospital (Torino, Italy).

To verify the presence of a general cognitive impairment the Mini-Mental State Examination (MMSE; Folstein et al., 1975) or the Montreal Cognitive Assessment (MoCA; Santangelo et al., 2015) was used. During the standard neurological evaluation, both primary motor and sensory deficits were assessed. Primary motor and sensory deficits were assessed during the standard neurological evolution whereby scores ranging from 0 (no deficit) to 3 (severe deficit) were assigned in accordance with the procedure validated in previous studies (Bisiach et al., 1986; Pia et al., 2014; Ricci et al., 2016). Proprioception, as in a previous study (Fossataro et al., 2018), was evaluated with two techniques for testing the limb localization: the Contralateral Limb Matching Task (CLMT) (Goble, 2010) and the Finger Localizing Test (FLT) (Hirayama et al., 1999). The presence/absence (+/−) of proprioceptive deficits in one of the two tests is indicated in Table 1. Based on previous studies (Fossataro et al., 2020; Pia et al., 2020), in which the presence of extra-personal neglect (N+ patients with extra-personal neglect; N- patients without extra-personal neglect) has been demonstrated to be more frequent in E+ than in E−, all patients were evaluated with the Bit Conventional scale (Halligan et al., 1991). E+ and E− patients did not differ for stroke onset ($t_{38} = 0.84$; $p = .40$). As regards the neurological/neuropsychological features, E+ and E− groups did not differ (Mann–Whitney U Tests, all $ps > .3$) in terms of general cognitive impairment (E−: 5%; E+: 10%), motor deficits (E−: 75%; E+: 75%), and personal neglect (E−: 25%; E+: 45%). Conversely, the two groups differed in terms of sensory deficit (E−: 60%; E+: 95%), proprioception (E−: 30%; E+: 100%), and extra-personal neglect (E−: 50%; E+: 90%), which were significantly (all $ps < .04$) more frequent in the E+ patients group than in the E− group. For details see Table 1.

All participants were naive to the purpose of the study and provided written informed consent before their participation. The study was approved by the local ethical committee (University of Bologna), and all procedures were in compliance with the Declaration of Helsinki (2013).

2.2 | Embodiment evaluation

At the beginning, all patients were assessed with an ad hoc protocol to evaluate the presence/absence of the pathological embodiment (Fossataro et al., 2016, 2018, 2020; Garbarini et al., 2013, 2014, 2015; Pia et al., 2013).

Patients sat on a chair with both hands lying on the table. The experimenter positioned her hand (alien hand) on the table between the patient's body and the patient's affected hand. The alien hand was in a congruent position according to the patient's trunk midline and aligned with the patient's contralesional shoulder. To cover the patient and the experimenter's arms, leaving all the hands visible on the table, a sheet of tissue was adopted. Three colored objects were positioned on the table: the blue one in front of the examiner's hand, the red one in front of the patient's affected hand, and the green one in front of the patient's intact ipsilesional hand. Patients had to (a) count how many objects and hands were on the table, (b) perform movements with their intact hand in order to reach their contralesional affected hand, and (c) identify their affected hand on the basis of the colored object in front of it. To be included in the study, a patient has to be errorless in counting three objects and three hands on the table (i.e., we did not include patients who, due to a severe ecological neglect, counted only two objects and two hands and omitted the object and the hand more on the left). To be included in the E+ group, a patient has to fail both motor and verbal tasks, (i.e., to reach the alien hand instead of his/her own hand and to name the color of the objects in front of the alien hand instead of naming the color of the cube in front of his/her own hand) (see Figure 1). Thus, to be included in the E− group, a patient has to correctly perform both the motor and verbal tasks.

2.3 | Stimuli and procedure of hand recognition task

Gray-scale pictures of the dorsal view of right and left hands were adopted as stimuli. In a session prior to the experiments, participants' hands were photographed according to the experimental procedure previously described (Frassinetti et al., 2011). Stimuli depicted the participant's own left or right hand ("self" trials) in half of the trials ($n = 32$). In the other half of the trials, stimuli depicted the right or left hand of other three individuals ($n = 32$; "other" trials). The "other" trials consisted of three stimuli selected from a database of hands' pictures as the best match with each participant's hand for size, age, skin color, and sex to make the task more difficult. Since in the clinical assessment the PE selectively occurs when the alien hand is placed in an egocentric perspective, we aimed at verifying possible differences between E+ and E− patients in bodily self-recognition driven by the visual perspective of hand. Thus, each stimulus was presented both in egocentric and allocentric perspective.

Participants sat in front of a PC screen, at a distance of about 50 cm. At the beginning of each trial, a central fixation cross lasting 1000 ms was displayed, followed by the hands' pictures on a white background. E-Prime 2.0 was adopted for stimuli presentation (Psychology Software Tools Inc.) and each trial ended as soon as the participant verbally responded. In Experiment 1 (implicit task), for each trial three stimuli were simultaneously presented, vertically aligned on the PC screen. The central stimulus (target) was presented in a black frame. Participants were instructed to judge whether the lower or the upper hand corresponded to the central target. In Experiment 2 (explicit task), each trial consisted of two hand pictures, one in the upper and the other in the lower part of the screen, while the central black frame was empty. Participants were required to explicitly judge whether one of the two displayed hands corresponded or not to their own hand (see Figure 2). Participants were asked to verbally respond as accurately as possible, and the experimenter manually recorded the participants' response by using one of the three assigned keys on the keyboard. Because of the nature of the stimuli, which depicted a participant's body part, we opted for a vocal instead of a manual response, which could have biased the results.

TABLE 1 Clinical and neuropsychological data of right brain-damaged patients according to the pathological embodiment

Patient	Onset	Sex	Age	Etiology	Cognitive impairment	HP	HA	P	BIT-C	Personal neglect
E− 1	43	F	67	I	−	3	1	−	141	−
E− 2	50	F	79	I	−	3	3	+	141	−
E− 3	34	F	55	I	−	3	1	−	144	−
E− 4	65	M	57	I	−	3	3	−	119	+
E− 5	42	M	60	H	−	3	0	+	112	+
E− 6	34	M	63	I	−	3	0	−	145	−
E− 7	40	M	66	H	−	3	3	−	141	−
E− 8	38	F	68	I	−	3	3	+	142	−
E− 9	35	F	69	I	−	1	0	−	124	+
E− 10	75	F	57	I	−	0	0	−	129	−
E− 11	65	F	61	H	−	3	0	−	142	−
E− 12	148	M	72	I	−	3	3	−	113	+
E− 13	44	F	82	H	−	0	0	−	124	−
E− 14	80	M	76	I	−	0	0	−	129	−
E− 15	59	F	63	I	−	0	1	+	88	−
E− 16	92	M	74	H	−	3	3	−	97	+
E− 17	37	M	69	I	+	0	0	−	80	−
E− 18	198	F	56	I	−	3	3	+	109	−
E− 19	54	F	51	H	−	1	1	+	120	−
E− 20	35	M	65	I	−	3	1	−	135	−
E+ 1	60	M	62	I	−	0	1	+	64	−
E+ 2	70	M	70	I	−	2	0	+	68	−
E+ 3	70	F	70	I	−	3	3	+	51	+
E+ 4	87	M	45	H	−	3	3	+	86	−
E+ 5	26	M	73	H	−	3	3	+	66	−
E+ 6	80	M	56	H	−	3	3	+	111	+
E+ 7	75	F	77	H	−	3	3	+	30	+
E+ 8	60	F	74	I	−	3	3	+	85	+
E+ 9	69	F	74	I	+	0	3	+	100	−
E+ 10	30	F	62	I	−	3	3	+	57	−
E+ 11	36	M	85	I	−	3	3	+	57	−
E+ 12	48	F	75	I	−	3	1	+	69	−
E+ 13	69	F	75	I	−	3	3	+	14	+
E+ 14	63	M	58	H	−	3	3	+	20	−
E+ 15	42	F	79	I	−	0	1	+	93	+
E+ 16	34	M	75	I	−	3	3	+	125	−
E+ 17	49	M	57	H	−	3	1	+	122	+
E+ 18	20	M	65	I	−	0	1	+	133	−
E+ 19	26	F	74	H	+	3	1	+	143	−
E+ 20	78	M	68	I	−	0	1	+	16	+

Note: E− = patients without pathological embodiment; E+ = patients with pathological embodiment; onset = days between stroke onset and assessment; sex (F = female; M = male); etiology (I = ischemic stroke; H = hemorrhagic stroke); cognitive impairment indicated as present (+) or absent (−) (scores are corrected for years of education and age according to each battery [MMSE cut off > 24; MoCA cut off > 17]); HP = motor deficit; HA = sensory deficit; P = proprioceptive deficit, indicated as present (+) or absent (−); BIT-C = score obtained at the conventional subscale (cut off > 129); personal neglect = score obtained at the fluff test (cut off omissions ≤ 2), indicated as present (+) or absent (−).

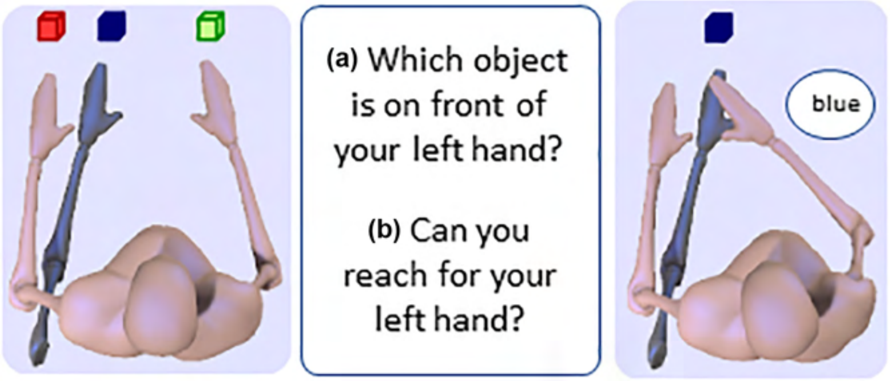

FIGURE 1 Embodiment evaluation. The patient had to identify his/her left hand by naming the colored objects in front of it and by reaching his/her left affected hand with the right intact hand. The alien hand, belonging to the confederate, was aligned with the patient's left shoulder.

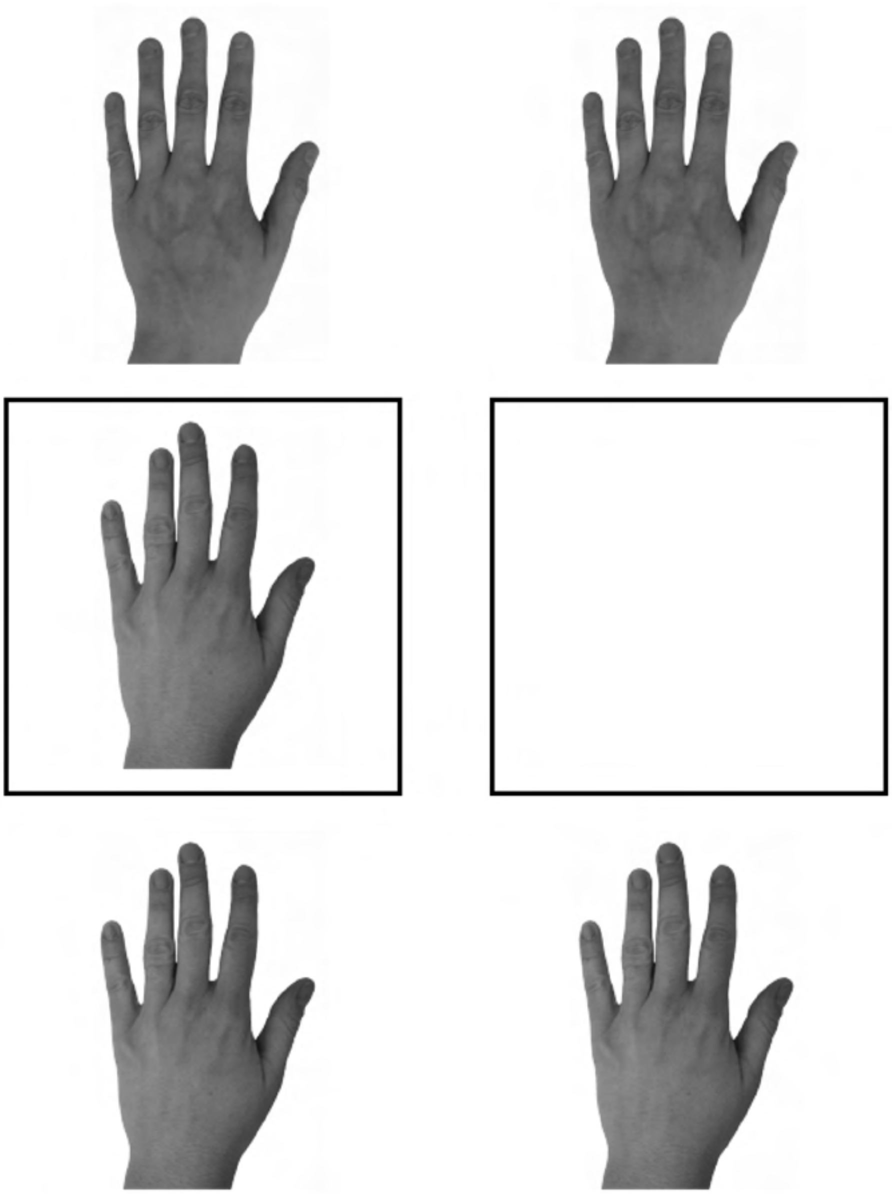

FIGURE 2 Experimental stimuli. An example of a single trial for the Implicit task (on the left) and the Explicit task (on the right).

Thus, each experiment comprised a total of 64 trials and consisted of four conditions: self-right hand, self-left hand, other-right hand, other-left hand. In each condition, 16 trials were presented: in half of the trials, stimuli were presented in egocentric perspective, whereas in the other half stimuli were presented in allocentric perspective. Since Experiment 1 investigated the implicit and Experiment 2 the explicit bodily self-recognition, Experiment 1 was always conducted before Experiment 2. Each participant performed both experiments in one single session which lasted 1 h.

2.4 | Control experiment on object visual recognition

The same procedure was adopted as in the implicit bodily self-recognition task, except that stimulus was gray-scale picture of object, instead of body part. The task consisted of a total of 32 trials in which guitar (n = 16) or scissor (n = 16) were presented in egocentric and allocentric perspective (see Figure 3). For each trial, three stimuli were simultaneously presented until the participant's response. The central stimulus (target) was presented in a black frame. Participants were required to judge whether the lower or the upper stimulus corresponded to the central one. Stimuli presentation was controlled by E-Prime 2.0 (Psychology Software Tools Inc.) and each trial was timed-out by the participant's vocal response.

2.5 | Statistical analyses

We performed a statistical power analysis to estimate the sample size based on our previous study (Candini et al., 2016). The a

FIGURE 3 Stimuli of the control experiment. An example of a single trial for the control experiment.

priori estimated sample size was $N = 60$ (20 for each group) with a power = 0.95 and an effect size $f = 0.19$ (GPower 3.1.9).

We separately analyzed data from Experiment 1 (Implicit task) and Experiment 2 (Explicit task) by using STATISTICA 10 (StatSoft Europe). According with the definition adopted in a previous study (Frassinetti et al., 2008), we compared trials in which one of the stimulus belonged to the participant (Self condition) and trials in which no pictures belonged to the participant (Other condition).

To compare healthy participants and patients' performance two ANOVAs, separately for Implicit and Explicit task, were conducted on accuracy with Group (Controls, E+ and E− patients) and Sex (Male and Female) as between-subjects factor and Owner (Self and Other), Laterality (Left and Right hand) and Perspective (Egocentric and Allocentric) as within-subject factors.

In order to look in more details at the nature of errors made by participants in the explicit recognition of self body-parts, the percentage of False Alarms (FA; erroneous recognition of self-hand calculated in Other trials), and the percentage of Misses (erroneous rejection of self-hand calculated in Self trials) were compared across the three groups. Two one-way ANOVAs were separately conducted on percentage of FA and MISS errors with Group (Controls, E− and E+ patients) as between-subjects factor.

Further analyses were conducted on neurological/neuropsychological tests in which a significant difference between E+ and E− was found (see details in Section 2.1). Two analyses of covariance (ANCOVA), separately for Implicit and Explicit task, were performed on accuracy with Group (E− and E+ patients) as between-subjects factor and scores obtained at test assessing the presence of hemianesthesia (HA) and neglect (BIT-C) scales as covariate. Since an impairment in proprioception was present in all E+ patients, a comparison between E− patients with and without proprioceptive deficit was conducted by using a *t*-test. Finally, a correlation analyses were conducted on BIT-C score and HA and the percentage of accuracy in E+ and E− patients, separately for Implicit and Explicit tasks. The Duncan test was adopted to conduct post-hoc analyses. The Partial eta square (η^2_p) express the magnitude of effect size.

2.6 | Lesion mapping and analysis

Brain lesions were identified by means of Computed Tomography and Magnetic Resonance digitalized images (CT/MRI) of 18 E+ patients and 14 E− patients (8 of 40 CT/MRI are missing). For each patient, the location and extent of brain damage was delineated and manually mapped in the MNI stereotactic space by using MRIcro software (Rorden & Brett, 2000). First, to approximate the slice plane of the patient's scan, the MNI template was rotated (pitch only). Second, brain lesions were manually drawn onto each correspondent template slice by using anatomically landmarks (MC and CF), drawn the lesion. Then, drawn lesions were inspected by two trained raters (FF and LP) and, in case of disagreement, an intersection lesion map was used. Finally, each lesions map was rotated back into the standard space applying the inverse of the transformation parameters used in the stage of adaptation to the brain scan.

The lesion overlay percentage maps for the E+ and E− patients were calculated from all lesions and superimposed on a ch2 template using MRICron. Then, we performed a subtraction analysis between E+ and E− patients' lesions, and the region more frequently damaged in E+ patients with respect to E− patients was extracted. Since MRI/CT scans of 8 of 40 patients are missing, we compared 18 E+ versus 14 E−. Note that, in this sample of 32 patients, the presence of somatosensory deficits is equally distributed between groups, while the presence of neglect is greater in E+ than in E− patients (as in the full sample). To control for this aspect, we performed an additional subtraction analysis in a subsample of 23 patients (16 N + E+ and 7 N + E−). Furthermore, to control for the lesion volume, we extracted the voxels lesioned in each patient and we entered them in an unpaired *t*-test (two-tailed).

Finally, lesion-symptom correlation employing a standard voxel-based approach based on lesion overlay (i.e., the voxel-based lesion-symptom mapping [VLSM, Rorden et al., 2007]) was computed to examine the more frequently lesions associated with PE using the embodiment assessment as predictor. VLSM was implemented using the non-parametric mapping (NPM; Rorden et al., 2007), which allows to compare the presence or absence of a lesion in a given cortical area on a voxel-by-voxel basis between the two groups by computing independent group *t*-tests (Liebermeister test). Furthermore, we also performed a second VLSM to examine the more frequently lesions associated with the tendency of hyper attributing the other hand to themselves (i.e., committing false alarm errors) by including false alarms as predictor also controlling for the lesion extension. In both analyses permutation thresholding with 1000 iterations was used to apply corrections for multiple comparisons (using family-wise error) in the whole-brain analyses. Quantitative estimates of gray and white matter regions involvement were obtained by superimposing the AAL anatomical template (Tzourio-Mazoyer et al., 2002) and the JHU-white matter template (Hua et al., 2008).

3 | RESULTS

3.1 | Experiment 1: Implicit task

A significant effect for the variable *Group* [$F_{2,58} = 17.86$; $p = .001$; $\eta^2_p = 0.38$] and its interaction *Laterality* × *Owner* × *Group* [$F_{2,58} = 5.15$, $p = .009$; $\eta^2_p = 0.15$] was found. Considering the *within-group* differences, for the right hand, a self-advantage effect emerged only in the control group (self = 93% vs. other = 87%, $p = .047$), whereas both in E− (79% vs. 78%) and E+ patients (63% vs. 68%) no significant within-group differences were observed ($p > .09$ for all comparisons). For the left hand, no significant difference between self and other's hand was found in all groups ($p > .21$ for all comparisons): Controls (90% vs. 93%), E− patients (89% vs. 87%)[1] and E+ patients (69% vs. 68%).

Interestingly, concerning the *between-groups* differences, E− patients performed selectively worse than Controls only when the stimulus depicted the right one's own hand (E− = 79% vs. C = 95%; p = .041), whereas E+ patients performed worse than Controls in all conditions (all $ps < .008$). Finally, E+ patients were overall less accurate than E− patients (all $ps < .05$), with the exception of the right other hand ($p = .176$; see Figure 4). The factor Sex was not significant [$F_{1,54} = 0.51$, $p = .48$] as well as the interaction with other factors [all $ps > .07$].

3.2 | Control experiment on object visual recognition

Previous analyses showed that E+ patients were generally impaired in all conditions considered. However, to exclude that the observed results might be ascribed to a more general impairment in matching visual stimuli, we perform a control experiment in which objects (guitars and scissors) were adopted as stimuli. If the deficit observed in E+ selectively emerged for body, we expected a worse performance when body and objects were compared. By contrast, a lack of significant difference between body and objects may suggest a general impairment in matching visual stimuli.

In this experiment, we compared the performance of each single patient of a subgroup of eight patients (four E+ and four E− patients) with a subgroup of 17 controls.

The difference in percentage of accuracy between the body visual matching recognition task and the object visual matching recognition task was tested by comparing the performance of each single case with that one of the control group. To this aim, we applied the function offered in Matlab (https://www.mathworks.com/matlabcentral/fileexchange/62968-crawford-howell-s-modified-t-test-and-revised-standardized-difference-test-rsdt) for Crawford and Garthwaite's (2007) standardized difference test. This test is specifically devised to test differential deficits in a single case on two different tasks (Crawford & Garthwaite, 2007).

Crawford tests revealed a significant difference when the performance at the two tasks in each E+ patient was compared to the control group [E+ 1: $t_{(16)} = 2.58$, $p = .02$; E+ 2: $t_{(16)} = 5.16$, $p < .001$; E+ 3: $t_{(16)} = 4.17$, $p < .001$; E+ 4: $t_{(16)} = 9.84$, $p < .001$]. Whereas, when the performance at the two tasks in each E− patient was compared to the control group, no difference emerged in three of four patients [E− 1: $t_{(16)} = 0.77$, $p = .45$; E− 2: $t_{(16)} = 1.54$, $p = .14$; E− 3: $t_{(16)} = 1.06$, $p = .31$]. The performance at the two tasks in E− 4 was instead significantly different compared to controls [E− 4: $t_{(16)} = 3.98$, $p = .001$].

Indeed, the difference between body and object stimuli was significantly bigger for E+ patients (i.e., body worse than object) compared to controls. The E− patients showed the same pattern of controls except for one patient, who showed an opposite pattern (i.e., object worse than body; see Figure 5).

3.3 | Experiment 2: Explicit task

A significant effect for the variable *Group* [$F_{2,58} = 11.47$, $p = .001$; $\eta^2_p = 0.28$] and the interaction *Owner x Group* [$F_{2,58} = 3.82$, $p = .028$; $\eta^2_p = 0.12$] was found. Notably, the significant interaction was explained by the opposite pattern observed in E+ patients versus E− patients and Controls. Indeed, considering within-group comparisons, E+ patients showed a greater accuracy for *Self* than *Other* stimuli ($p = .029$), whereas both E− patients ($p = .161$) and Controls

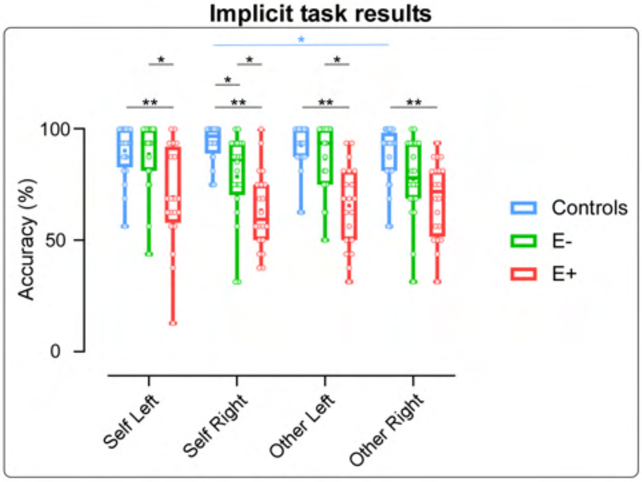

FIGURE 4 Implicit task. The Implicit task's accuracy percentages are displayed as a function of Ownership (Self, Other) and Laterality (Left, Right) respectively for Controls (in light blue), E− (in green) and E+ (in red) patients. In the boxplots, the whiskers represent the minimum and the maximum value, the limits of the box represent the first and the third quartile, the median is depicted by the line that divides the box into two parts, and the cross represents the mean. Dots represent individual values. Asterisk indicates a significant comparison (*$p < .05$; **$p < .005$; ***$p < .0005$).

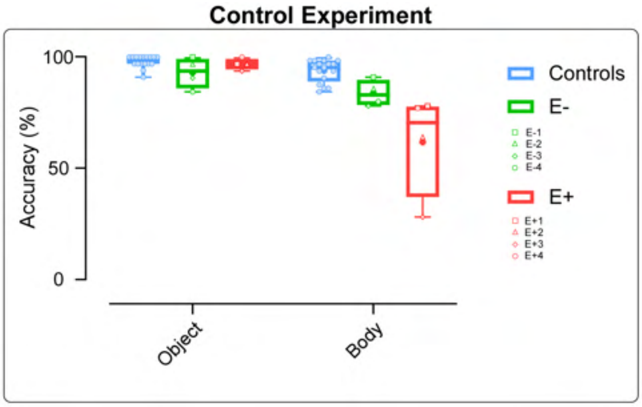

FIGURE 5 Control experiment results. The accuracy percentages in both Object and Body task are depicted for Controls (light blue), E− (green) and E+ patients (red), respectively. In the boxplots, the whiskers represent the minimum and the maximum value, the limits of the box represent the first and the third quartile, the median is depicted by the line that divides the box into two parts, and the cross represents the mean. Dots represent individual values. In E− and E+ patient groups each patient is represented with a different symbol.

performed worse with *Self* than *Other* stimuli (p = .26), even if these comparisons failed to reach the significant level. When we looked at the between-group comparisons, with *Self'* stimuli, a worse performance, compared to Controls (51%), was observed in patients which reach the significant level in E− (34%; p = .036) but not in E+ (39%, p = .13). The difference between the last two groups was not significant (p = .51). A completely different pattern of result emerged when *Other'* stimuli were considered: E+ patients (22%) performed significantly worse than Controls (60%, p = .001) and E− patients (45%; p = .003), whereas the last two groups were not significantly different (p = .073; see Figure 6). Thus, the E+ patients' performance was worse, as compared to E− patients and Controls, when they have to judge the *Other'* stimuli since they frequently attributed them to themselves. The factor Sex was not significant [$F_{1,58}$ = 1.46, p = .233] as well as the interaction with other factors [all ps > .085].

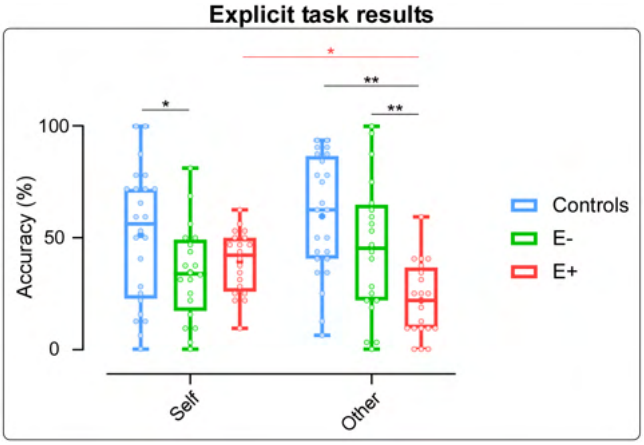

FIGURE 6 Explicit task. The Explicit task accuracy percentages are represented as a function of Ownership (Self, Other), respectively, for Controls (light blue), E− (green), and E+ patients (red). In the boxplots, the whiskers represent the minimum and the maximum value, the limits of the box represent the first and the third quartile, the median is depicted by the line that divides the box into two parts, and the cross represents the mean. Dots represent individual values. Asterisk indicates a significant comparison (*p < .05; **p < .005; ***p < .0005).

3.3.1 | Analysis on type of errors

The analysis conducted on FA errors revealed a significant main effect of *Group* [$F_{2,61}$ = 5.37, p = .007, η^2_p = 0.15]. Post-hoc comparisons revealed that E+ patients (78%) made higher False Alarms than E− patients (56%; p = .002) and Controls (64%; p = .04), whereas no differences between E− patients and Controls (p = .22).

The analysis conducted on Misses failed to reveal a main effect of Group [$F_{2,61}$ = 0.27, p = .77, η^2_p = 0.01] suggesting that the three groups equally performed (E+ patients: 61% E− patients: 64%; Controls: 60%; p > .60; Figure 7).

Finally, the sensitivity (d prime) and the type of criterion (beta) underlying patients' judgment were compared across the three groups by using two one-way ANOVAs. The analysis on sensitivity revealed a significant main effect of *Group* [$F_{2,61}$ = 5.74; p = .005, η^2_p = 0.16]: E+ patients (−1.32) were lower sensitive than E− patients (−0.74; p = .009) and Controls (−0.65; p = .004) in discriminate between the two stimuli. The analysis on the type of criterion failed to reveal a main effect of Group [$F_{2,61}$ = 3.01; p = .06, η^2_p = 0.09] suggesting that no difference emerged across the three groups for the criterion adopted in the explicit judgment (E+ patients: 4.04; E− patients: 3.14; Controls: 1.22).

3.4 | Analysis to control for neurological and neuropsychological deficits

3.4.1 | Implicit task: Experiment 1

In ANCOVA analysis, no significant effect emerged for each considered covariate variable (all ps > .38), or for its interaction with the

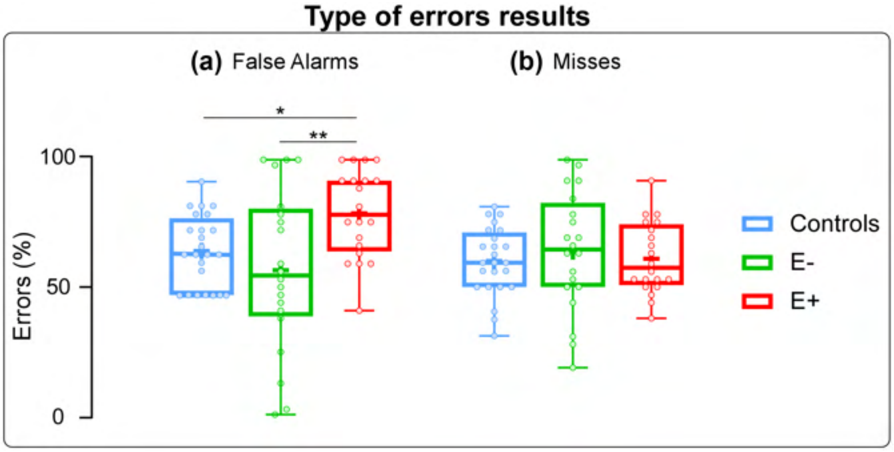

FIGURE 7 Type of errors results. Percentages of false alarms (a) and misses (b) are represented for Controls (light blue), E− (green), and E+ patients (red). In the boxplots, the whiskers represent the minimum and the maximum value, the limits of the box represent the first and the third quartile, the median is depicted by the line that divides the box into two parts, and the cross represents the mean. Dots represent individual values. Asterisk indicates a significant comparison (*p < .05; **p < .005; ***p < .0005).

variable Group. The variable Group was always still significant (all $ps < .05$): E+ (67%) performed worse compared to E− patients (83%). T-test was not significant [$t_{18} = 0.27$, $p = .79$], excluding that proprioceptive deficit may influence the performance in implicit bodily self-recognition.

The Pearson's correlation on BIT-C score and percentage of accuracy was not significant either in E+ patients ($r = -.24$, $p = .31$) or in E− patients ($r = .26$, $p = .27$). Similarly, the Pearson's correlation on hemianesthesia score and percentage of accuracy was not significant either in E+ patients ($r = -.28$, $p = .24$) or in E− patients ($r = .24$, $p = .32$).

3.4.2 | Explicit task: Experiment 2

In ANCOVA no significant effect emerged for each considered covariate variable (all $ps > .23$), or for its interaction with the variable Group. The variable Group was always still significant (all $ps < .05$): E+ (31%) performed worse compared to E− patients (41%). Moreover, *t*-test was not significant [$t_{18} = 0.47$, $p = .54$], excluding that proprioceptive deficit may influence the performance in explicit bodily self-recognition.

The Pearson's correlation on BIT-C score and percentage of accuracy was not significant either in E+ patients ($r = -.06$, $p = .81$) or in E− patients ($r = .33$, $p = .15$). The Pearson's correlation on hemianesthesia score and percentage of accuracy was not significant level either in E+ patients ($r = -.09$, $p = .72$) or in E− patients ($r = .24$, $p = .32$).

3.5 | Lesion mapping results

The area of maximal overlay across E+ patients is centered around the insula, external capsule, superior corona radiata, middle and superior temporal gyrus, rolandic operculum, and the superior longitudinal fasciculus (SLF) (Figure 8a). Whereas in E− patients the area of maximal overlap is centered around the insula, external capsule, superior corona radiata, putamen, and rolandic operculum (Figure 8b). The subtraction analysis shows that SLF and middle temporal gyrus were more frequently damaged in E+ patients as compared to E− patients group (Figure 8c). The additional subtraction analysis in the subsample of 23 patients confirms the greater involvement of SLF and middle temporal gyrus that were more frequently damaged in E+ patients as compared to E− patients group.

The *t*-test performed over the lesion volume showed that the two groups did not differ in terms of lesion volume ($t_{30} = -1.09$; $p = .28$), thus ruling out that any difference in the lesional pattern between group was due to differences in the lesion volume.

VLSM performed on the PE assessment showed that lesions involving voxels within middle temporal gyrus and SLF were significantly associated with the presence of PE (Figure 8d). The threshold for statistical significance was $z = 3.74030$ (corrected, $p < .05$) and the maximum voxels values were around the middle temporal gyrus ($z = 3.74033$, $p < .05$) and SLF ($z = 3.74030$, $p < .05$) that partially corresponds to the area of maximal overlay indicated on the percentage lesion overlay maps.

VLSM performed on the false alarm errors confirmed the obtained results, showing that lesions involving voxels within SLF were significantly associated with the tendency of committing false alarm errors (Figure 8e). The threshold for statistical significance was $z = -3.622$ (corrected, $p < .05$) and the maximum voxel values were within SLF ($z = -3.935$, $p < .02$). The association of SLF to the tendency of hyper attributing the other hand to themselves was confirmed also controlling for the lesion extension.

4 | DISCUSSION

We commonly take for granted that *"our body may be the object that we know the best,"* as Fréderique de Vignemont said (De Vignemont, 2018, p. 5). However, following a brain damage, the ability to correctly recognize our body may be impaired, as suggested by several neuropsychological evidence (Moro et al., 2016; Candini et al., 2016; Frassinetti et al., 2008; for a review see, Garbarini et al., 2020; Romano & Maravita, 2019; Vallar & Ronchi, 2009).

The present study focused on the relationship between the sense of body ownership, selectively damaged in neuropsychological patients affected by pathological embodiment, and the implicit and explicit bodily self-recognition processing. Thus, two groups of RBD patients, with (E+) and without (E−) pathological embodiment, were compared to a group of neurologically healthy participants adopting two experimental tasks developed for exploring implicit (Experiment 1) and explicit bodily self-recognition (Experiment 2), respectively.

In the ***Implicit Task***, when a matching to sample task was required without an explicit recognition of one's own hand, we observe differences both *within* and *across* the three groups. Regarding the differences *within* groups, in healthy participants a self-advantage (i.e., a more accurate performance for *Self* than *Other* stimuli) emerged when right hands were displayed. We acknowledge that in a previous study on bodily self-recognition in which the same paradigm was adopted, no difference for stimuli depicting left and right hand was found (Frassinetti et al., 2008), however, the occurrence of such a facilitation when judging one's own right compared to others' hands is in accord with recent findings in young right-handed healthy participants (Conson et al., 2010, 2017; Ferri et al., 2011; Frassinetti et al., 2011; Galigani et al., 2021). In right-handed participants, the neural efficiency of the sensorimotor network contralateral to the dominant (right) hand can be enhanced, thus explaining the observed facilitation for the right *Self* hand, at least in our sample. Indeed, it was demonstrated (Ferri et al., 2012; Frassinetti et al., 2011) that the implicit visual recognition of one's own hand activates a sensorimotor experience-based representation of the hand. Importantly, this advantage in implicit self-body recognition was not present in both E− and E+ patients. The lack of this facilitation suggests that, following a right brain damage, the ability to implicitly recognize one's own

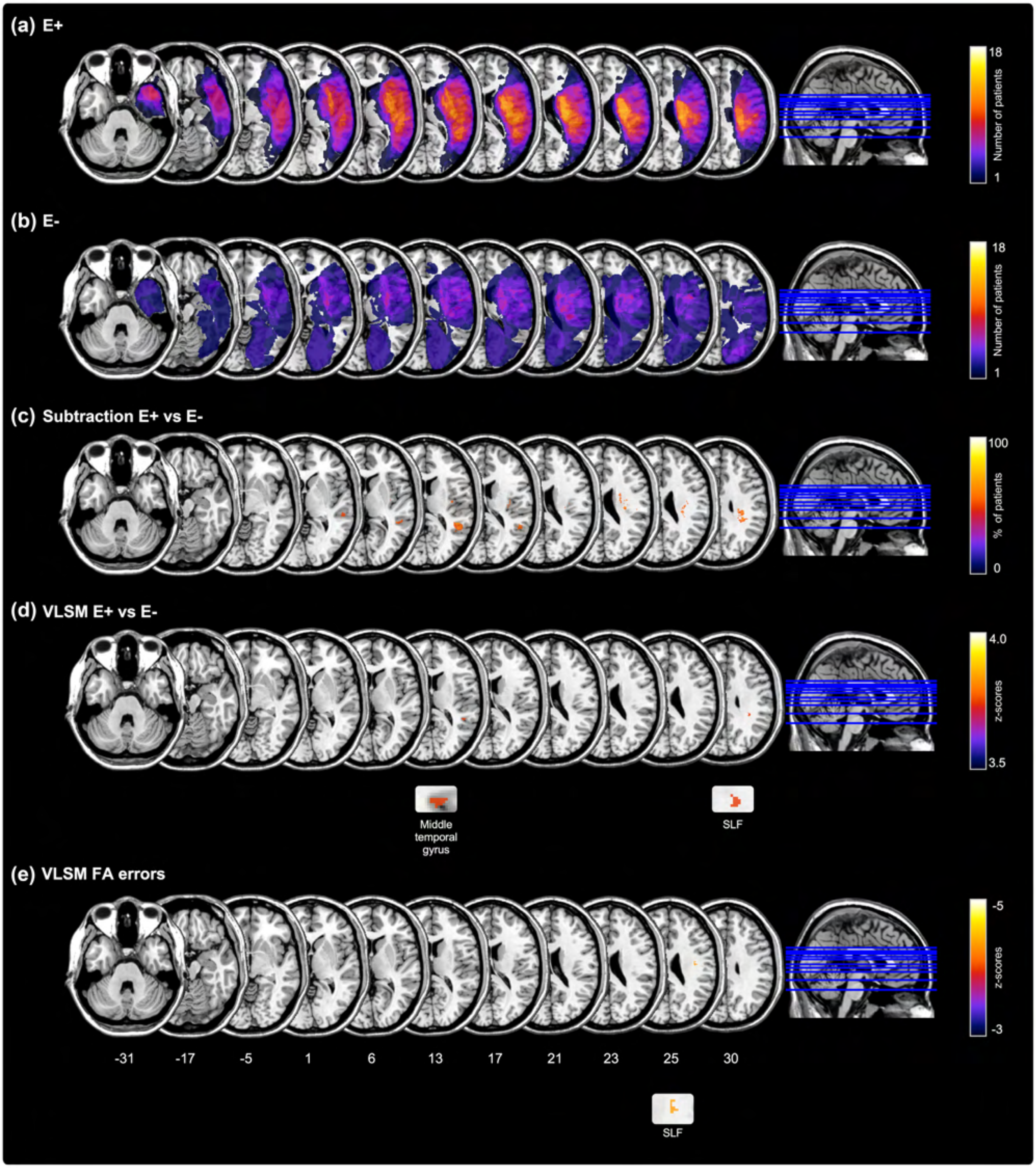

FIGURE 8 Overlay lesion plots. (a) 18 E+ patients and (b) 14 E− patients. The regional frequency of brain lesions in each area is expressed according to the color scale ranging from dark purple to light yellow. (c) Subtraction lesion plot. The plot represents the region more frequently damaged in E+ group illustrated by different colors, from dark purple to light yellow. Only brain regions that were at least 50% or more frequently damaged in E+ with respect to E− patients are shown. (d) VLSM E+ versus E− results. High *z*-scores (light yellow) indicate that lesions to these voxels have a highly significant association with PE. (e) VLSM FA errors results. High *z*-scores (light yellow) indicate that lesions to these voxels have a highly significant association with the tendency of committing false alarm errors. Only voxels that were significant at $p = .05$ (corrected with 1000 permutations) are shown. Axial slices are numbered according to MNI *z* coordinate.

body parts is severely impaired. Present data confirm and extend previous neuropsychological findings (Frassinetti et al., 2008, 2009, 2010; but see also Candini et al., 2014, 2018 on self-voice recognition). First, in E− patients the self-advantage is lost (i.e., for the right hand, no difference between Self and Other stimuli was found), but their overall performance was comparable to that shown by healthy controls. Going further, E+ patients not only did not exhibit the self-advantage, but they also showed a lower overall performance with respect to both healthy controls and E− patients. Thus, at the Implicit task, the difference between E+ and E− patients is not specific for the Self stimuli, but it emerges in all experimental conditions. To exclude that the worst performance observed in E+ patients during the Implicit task was simply due to a general impairment when performing a visual discrimination task, we conducted a control experiment in which objects, instead of hands, were presented. We found that E+ patients (but not E− patients) performed worse with hands as compared to objects, suggesting that their impairment is specific for visual processing of body parts, at least when they include human hand images.

In the ***Explicit Task***, when bodily self-recognition was explicitly required, differences were found *across* the three groups: both E+ and E− showed an overall worse performance than Controls, confirming that a right brain lesion impairs the ability to explicitly discriminate between self and other's body (Candini et al., 2016, 2018). When we look at the *within* group comparisons no differences between Self and Other stimuli emerged, even if we observed a worse performance with Self than Other stimuli in both Controls and E− patients. This lack of significance can be explained by a difference in term of age (Frassinetti et al., 2011) and of experimental paradigm (Candini et al., 2018) with previous studies in which a "self-disadvantage effect" emerged (i.e., a worse performance with self than other stimuli).

More critical for the present study, while in E− patients, with intact body ownership, the same pattern shown by healthy controls was present, E+ patients performed worse with *Other* compared to *Self* stimuli. In this respect, it is worth to note that a bad performance with *Other* stimuli means the tendency to hyper attribute others' hand to themselves (i.e., higher false alarm rates when compared to E− patients; see Analysis of type of errors). This means that, at the explicit level, the same type of errors observed during the ecological evaluation, when PE is induced by the physical presence of the alien hand, emerges also when patients have to recognize hand images displayed on a computer screen, thus suggesting that explicit visual body recognition is a critical factor in PE. However, when hand pictures were displayed on a screen (as in the Explicit Task), instead of real hands positioned either on the right or on the left patients' body side (as during the clinical evaluation), some important differences emerged. In particular, we know from the literature that, when the alien limb was in the intact (right) body side or when it was in allocentric perspective, E+ patients correctly recognized it as belonging to another person (Garbarini et al., 2013, 2014, 2015; Pia et al., 2013, 2020). On the contrary, in the Explicit Task, neither hand laterality nor perspective effects were found. This means that, in E+ patients, the explicit self-other body discrimination is damaged irrespective of the ecological constraints of the pathological embodiment that seems to be not relevant when stimuli are pictures displayed on a screen.

Importantly, even if tactile deficit and extra-personal neglect are more common in E+ patients, additional ANCOVAs further confirm that the worse performance of E+ patients, both in Implicit and Explicit tasks, cannot be ascribed to the greater frequency and severity of neurological and cognitive deficits. Indeed, when scores obtained at the tactile evaluation, as well as at the BIT-C battery, were considered as covariate variables, the difference between the two patients' groups was still present, excluding that the observed difference, both at implicit and explicit levels, were simply due to greater somatosensory or attentional and visuospatial impairments. These negative results were also confirmed by additional correlation analyses, showing no significant effects when scores at the tactile evaluation and at the BIT-C battery were used to predict the patients' performance at implicit and explicit tasks. In a similar vein, even if proprioceptive deficits are always associated with the pathological embodiment in our sample, their presence also in E− patients proves that the position sense loss is necessary but not sufficient for the pathological embodiment to occur (see Fossataro et al., 2020; Pia et al., 2020). This is also confirmed by ad hoc analyses showing no significant differences between E− patients with and without proprioceptive deficit. Thus, the phenomenon of pathological embodiment may be due to the co-occurrence of a proprioceptive deficit and an impaired recognition of the visual characteristics of the hand.

From an anatomical point of view, the present data (see Figure 8d) support the view of PE as a disconnection deficit with the superior longitudinal fasciculus (SLF) as the mainly involved fiber tract (for an extension discussion of similar results in different samples see also Fossataro et al., 2018; Pia et al., 2020). In particular, it was found that the lesion disrupts the more ventral component of this fasciculus (i.e., SLF III) connecting temporal areas, including the extrastriate body area (EBA) involved in the visual recognition of the body, and frontal areas, involved in the sensorimotor representation of the body (i.e., the ventral premotor cortex, vPMC) (Errante et al., 2022). We may hypothesize that this fiber tract lesion, together with the selective damage at the middle temporal gyrus (see Figure 8d), interrupts the flow of information to and from EBA that are critical for body parts visual processing (Cazzato et al., 2014; Downing & Peelen, 2016; Myers & Sowden, 2008; Urgesi et al., 2004), thus potentially explaining the overall worst performance of E+ patients at the implicit task, as compared to E− patients and Controls. Furthermore, according to different lines of research, employing the RHI in healthy subjects, the normal functioning of a visual-sensorimotor network, mainly involving EBA and vPMC and their functional connectivity, is critical to construct a coherent representation of the bodily self (Gentile et al., 2013; Guterstam et al., 2013; Limanowski & Blankenburg, 2015). Indeed, while we usually distinguish other people's body only by vision, for self-body recognition we might rely on the integration between visual and sensorimotor representations. Coherently, when the connectivity between regions storing visual and sensorimotor representations of the body is disrupted due to a brain damage, as in E+ patients, the ability to visually discriminate between self and others' body parts is lost, as shown by the hyper-attribution effect described in the PE ecological evaluation and mirrored by the present results at the explicit task. Importantly, VLSM performed on the false alarm errors supports this interpretation, showing that lesions involving voxels within SLF are significantly associated with the tendency of committing false alarm errors (Figure 8e).

4.1 | Limitations of the study

We acknowledge that our study presents limitations which should be investigate in more detail in the future. For instance, here to ruled out that the deficit observed in E+ patients in the Implicit task was due to a visual impairment in matching stimuli, we introduced a control experiment in which objects were presented as stimuli. In the control experiment we recruited only a subgroup of patients (E+ patients = 4; E− patients = 4) and controls (n = 17). We acknowledge that a larger sample size also for the control experiment should be preferred, however, this represented a first step to exclude a more general deficit in visual processing in E+ patient group.

5 | CONCLUSION

Taken together, the present findings revealed that E+ patients showed a pathological performance with respect to both healthy participants and E−, in Implicit as well as in Explicit tasks. For the implicit bodily recognition, while a self-advantage emerges in normal circumstances, both E+ and E− patients lost this facilitation, but only E+ patients exhibited a selective impairment in body parts processing. For the explicit bodily recognition, E+ patients showed a worse performance (i.e., greater false alarms) with *Other* compared to *Self* stimuli, confirming their tendency to hyper attribute others' hand to themselves as observed during the ecological evaluation. In conclusion, the present findings demonstrate that when the sense of body ownership is altered after brain damage, as in E+ patients, we lost the ability to implicitly and explicitly recognize *"our own body as the object that we know the best"* (De Vignemont, 2011).

AUTHOR CONTRIBUTIONS

All the authors take responsibility for the integrity of the data and the accuracy of the data analysis. *Conceptualization*, A.B., C.F., F.F., F.G., L.P., and M.C.; *Investigation*, C.F., M.C., and M.G.; *Formal Analysis*, C.F. and M.C.; *Resources*, P.G. and G.V.; *Writing – Original Draft*, M.C.; *Writing – Review and Editing*, A.B., C.F., F.F., F.G., L.P., and M.C.; *Visualization*, CF.

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CONFLICT OF INTEREST

None declared.

DECLARATION OF TRANSPARENCY

The authors, reviewers and editors affirm that in accordance to the policies set by the *Journal of Neuroscience Research*, this manuscript presents an accurate and transparent account of the study being reported and that all critical details describing the methods and results are present.

PEER REVIEW

The peer review history for this article is available at https://publons.com/publon/10.1002/jnr.25109.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

ENDNOTE

[1] E− patients were less accurate with right than left hands (all $ps < .002$), regardless of the ownership of the stimuli.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

Appendix S1 Transparent Science Questionnaire for Authors

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