Selective impairment of self body-parts processing in right brain-damaged patients

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Abstract
To investigate whether the processing of the visual appearance of one’s own body, that is the corporeal self is a unified or modular function we submitted eight right brain-damaged (RBD) patients and a group of fourteen age-matched neurologically healthy subjects, to a visual matching-to-sample task testing for corporeal self processing. If corporeal self processing is a unique function (i.e., body- and face-parts are processed by the same network), patients impaired in self body-parts (i.e., showing no self-advantage) should be impaired also in self face-parts; alternatively, if corporeal self processing is a modular function (i.e., body- and face-parts are processed by different networks), patients impaired in self body-parts should be unimpaired in self face-parts, unless the face-module is also damaged by the lesion. Results showed that healthy participants were more accurate in processing pictures representing their own as compared to other people’s body- and face-parts, showing the so-called self-advantage. The patients’ findings revealed a simple dissociation, in that patients who were impaired in the processing of self-related body-parts showed a preserved self-advantage when processing self-related face-parts, thus providing initial evidence of a modular representation of the corporeal self.

Keywords:
Corporal self
Body
Face
Self-other
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1. Introduction
Right hemisphere lesion may cause unawareness for contralesional body (personal neglect) and motor deficits (anosognosia) more frequently than left hemisphere lesion (Bisiach et al., 1986; Guariglia and Antonucci, 1992; Berti et al., 2005). Right brain damage (RBD) can also bring to mirror-sign, a condition in which patients misidentify their own face while retaining the ability to identifying other people’s faces (Breen et al., 2001). Functional neuroimaging studies suggested that a right fronto-parietal network may be crucially involved in different aspects of self processing (Decety and Sommerville, 2003; Decety and Chaminade, 2003; Platek et al., 2004), such as own-body perception (Blanke et al., 2002, 2005), self awareness (Stuss, 1991; Andelman et al., 2004; Barnacz et al., 2004), and autobiographical memory (Fink et al., 1996; Levine et al., 1998;
2. Methods

2.1. Subjects and neuropsychological screening

Fourteen participants, with no history of previous neurological or psychiatric disease (mean age 61 years; range 43–70) and eight patients with right brain lesion (mean age 61 years; range 48–68), without general cognitive impairment (score over 24 at the Mini-Mental State Examination; Folstein et al., 1975) were recruited from a consecutive series of inpatients in two hospitals. Patients did not show any sign of personal (Zoccolotti and colleagues’ test, Zoccolotti et al., 1992; Fluff test, Cocchini et al., 2001) or extrapersonal neglect (behavioural inattention test (BIT) battery, Wilson et al., 1987) and anosognosia (Berti et al., 1996). All participants gave their informed consent to participate to the study that was approved by the local ethics committee and all procedures were in agreement with the 1975 Helsinki Declaration.

2.2. Stimuli and procedure

Stimuli were grey-scale pictures of participants’ face-parts and body-parts (see below). Flash photographs were taken with a digital camera, perpendicular to each part of the body. Subjects’ pictures were taken in an indirectly illuminated environment while standing against a uniform white background. 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 relevant portion of the body-part and centering it on a uniform white background. In Experiment 1, stimuli represented body-parts: other people’s body-parts or the subject’s own body-parts (hands, limbs, legs, feet). In Experiment 2, stimuli represented other people’s or the subject’s own face-parts (eyes, noses, mouths, ears). Pictures were counterbalanced for gender (male/female) and side of the body (left/right). Each picture could be presented as target sample (or alternative) with respect to the subject who performed the task. In each trial three stimuli of the same category were simultaneously presented, vertically aligned along the vertical meridian of the computer screen, until the subject’s response was obtained. The central stimulus was presented up-right, in a black frame, and corresponded to the target stimulus. Subjects sat in front of the PC screen, at a distance of about 30 cm, and were required to decide which of the two images (the upper or the lower one) matched the central target stimulus (un-speeded forced-choice paradigm). Verbal responses were recorded. To minimize an automatic match between stimuli, the upper and the lower stimuli were tilted (30° for body parts; 20° for face-parts) to the left or to the right with respect to the central template (see Fig. 1).

Stimulus presentation and randomization in a block were controlled using E-prime V1.1 software (Psychology Software Tools, Pittsburgh, PA) running on a PC. Experiment 1 consisted of 96 trials: 48 trials contained the subject’s own body parts and 48 trials contained other people’s body-parts (hands, limbs, legs, feet). Experiment 2 consisted of 96 trials: 48 trials contained the subject’s own face-parts and 48 trials contained other people’s face-parts (eyes, noses, mouths, ears).

3. Results

3.1. Controls

To first characterize normal subjects’ performance, an analysis of variance (ANOVA) was conducted on their percentage of errors, with Type of stimulus (parts of body/parts of face) and Owner (other people’s parts and one’s own parts) as within-subject variables. The Newman–Keuls test was used for all post-hoc comparisons. Taking into account the sample size and the standard deviation of the measures, the power was 80% or higher for all the tested effects in this as well as in the following analysis.

The variable Type of stimulus was significant \[F(1,13) = 7.5, p < .05\], since subjects tended to perform better with face than with body stimuli (4% vs 8%). The variable Owner was also significant \[F(1,13) = 19.49, p < .001\], since subjects performed better with their own than with other people’s stimuli (5% vs 7%), showing the so-called ‘self-advantage’. This self-advantage was present both with body (t-test \(p < .01\)) and with face stimuli (t-test \(p < .04\), as indicated by the lack of a significant interaction between Type of stimulus and Owner (\(p = .51\)) (see Fig. 2a).

3.2. RBD patients

Since the deficit in body-parts self processing in RBD patients is not an all or none phenomenon and maybe linked to the
lesion site (Frassinetti et al., 2008), RBD patients were divided into two Groups on the basis of the absence (G1: self body ≥ other body errors) or presence (G2) of self-advantage in body-parts processing. The rationale being that if corporeal self processing is an unique function (i.e., body- and face-parts are processed by the same network), patients impaired in self body-parts (i.e., showing no self-advantage) should be impaired also in self face-parts; alternatively, if corporeal self processing is a modular function (i.e., body- and face-parts are processed by different networks), patients impaired in self body-parts should be unimpaired in self face-parts, unless the face-module is also damaged by the lesion. First, the patients’ performance was characterized by submitting the mean percentage of error to an ANOVA with Group (G1 and G2) as between-subject variable and Type of stimulus and Owner as within-subject variables. The performance of both patients groups was also compared with the performance of the control Group (G3) with a similar ANOVA. The Tukey’s ‘Honest Significant Difference’ (HSD) test for unequal N was used for all post-hoc comparisons in this analysis.

In the first analysis, the variable Group was not significant \( (p = .67) \), as the two groups of patients were equally impaired in performing the task (G1 = 24%, G2 = 21% of error). The variables Type of stimulus \( [F(1,6) = 5.9, p < .05] \) and Owner \( [F(1,6) = 30.9, p < .001] \) were significant, subjects’ performance

Fig. 1 – An example of stimuli representing face-parts (a) and body-parts (b). Participants were required to decide which of the two images (the upper or the lower one) matched the central target stimulus, presented within a black frame (redrawn from Frassinetti et al., 2008).
being better with face- than body-parts (18% vs 27%) and with self than others’ stimuli (17% vs 28%). Crucially, the three-way interaction between Group, Type of stimulus and Owner was significant [F(1,6) = 14.5, p < .01]: as expected, G1 patients did not show any self-advantage with stimuli depicting body-parts (33% vs 28%, p = .43); in contrast, they showed a significant self-advantage with stimuli depicting face-parts (8% vs 25%, p < .01). The performance of G2 patients revealed the presence of self-advantage with both body-parts (12% vs 33%, p < .01) and face-parts stimuli (12% vs 27%, p < .02) (see Fig. 2b).

The analysis comparing patients’ (G1 and G2) and controls’ (G3) performance showed a significant effect of the variable Group [F(2,19) = 26.02, p < .0001], as patients’ performance (G1 = 24%; G2 = 21%) was overall worse than controls’ performance (G3 = 6%, p < .002 for both comparisons). In addition, G1’s performance was worse than controls in self body-parts (p < .0001), but not in self face-parts processing (p = .64), whereas G2’s performance was worse than controls in self face-parts (p < .03), but not in self body-parts processing (p = .59). Both patients’ groups were worse than controls when comparing their performance concerning other’s body- and face-parts processing (p < .0001).

3.3. Anatomical correlates of self body-parts processing

To identify the key regions within the right hemisphere responsible of self body-parts processing the lesion of five out of eight patients recruited for the study (scan of three patients was not available) was plotted against a digitized brain template from the Damasio and Damasio’s (1989) atlas. For patients of both Groups (G1 scan N = 2; G2 scan N = 3), lesions were transcribed onto the appropriate template (Fig. 3a and b). Fig. 3c illustrates patients’ lesions overlap on the same template, and shows that areas involved by G1 patients’ lesions were more anterior and ventral compared to those involved by G2 patients’ lesions. Moreover, the self-related areas, as previously identified by a subtraction method on a larger sample of patients (see Frassinetti et al., 2008), were plotted against the same template (see Fig. 3c) showing substantial sparing of these areas in G2, and a partial overlap with G1 patients’ lesion.

4. Discussion

The main aim of this study was to investigate whether the cognitive functions of the right hemisphere allowing for the processing of “self body-parts” are independent from those possibly involved in the processing of “self face-parts”. To this aim, eight RBD patients and fourteen age-matched neurologically healthy subjects were submitted to a matching-to-sample task designed for testing self body-parts and self face-parts processing in the visual modality.

First, healthy subjects showed an advantage in processing their own as compared to somebody else’s body- and face-parts. These results confirm previous findings (Frassinetti et al., 2008) showing that normal subjects are more accurate in processing pictures representing their own compared to other people’s body-parts, and extend the results to face-parts processing (see also Knoblich and Prinz, 2001). Since the advantage is manifest in a task in which explicit recognition of the corporeal self is not necessary, this phenomenon appears to depend upon an early, possibly automatic activation of corporeal self-recognition processes that, once activated, may facilitate the perceptual judgments that are based on the visual appearance of the body and its parts. The mechanism upon which such functional processes are based might be particularly useful when the most important sources of one’s identity (e.g., the face) is not available and corporeal processing can only be based on partial information from body-parts (Knoblich and Flach, 2001).

Second, and in striking contrast, four out of eight RBD patients (G1) did not take any advantage when processing self versus others’ body-parts, whereas they took this advantage in self face-parts processing, suggesting that the part of the mechanism responsible for early processing of corporeal self is dysfunctional in these patients. Although based on a simple dissociation, the finding that in the same patients the processing of self body-parts is impaired, whereas the processing of self face-parts is spared, strongly supports the hypothesis that the “corporeal-self” processing is a modular function. In addition, when the performance of each RBD group of patients was compared to that of controls,
Fig. 3 – The figure illustrates lesion plots of single patients of the two groups separately, G1 (a) (red) and G2 (b) (grey), as well as jointly on the same template (c), as reconstructed following the Damasio and Damasio’s (1989) method. Panel c also reports the crucial areas for self body-parts processing (black empty areas, redrawn from Frassinetti et al., 2008). Subcortical structures (thalamus and basal ganglia) are also reported in the template (orange).
it emerged that self face-parts processing was spared in the first group of patients (G1). The latter finding indicated that this group’s deficit in ‘self body-parts’ processing cannot be ascribed to any unspecific impairment in visual processing of corporeal stimuli. Moreover, the deficit of the second group of patients (G2) in self face-parts processing, as compared with controls, rules out the possibility that the self body-parts processing is more difficult than self face-parts processing.

The idea that the visual representation of the corporeal self is based on a modular functional organization is in accordance with both neuropsychological studies in RBD patients with anosognosia and neuroimaging findings in neurologically unimpaired subjects. Indeed, patients with anosognosia can be unaware of their motor deficit at the contralesional lower limb, but not at the contralesional upper limb (Von Hagen and Ives, 1937; Berti et al., 1996; see, for review, Valla and Ronchi, 2006). Moreover, unawareness of RBD patients’ motor deficit can be dissociated from patients’ visual field deficits such as hemianopia, or visual spatial deficits such as personal and extrapersonal neglect (Bisiach et al., 1986). Similarly, multiple circuits, involving right posterior and frontal regions, play different roles in the visual recognition of one’s own body (Sugiuira et al., 2006). This is also in accordance with the modularity of other human brain systems and functions. For example, it is well known that different cortical areas sub-serve object-related (lateral occipital cortex – LOC), face-related (fusiform face area – FFA) and body-related (extras-areas serve object-related (lateral occipital cortex – LOC), and functions. For example, it is well known that different cortical of patients (Sugiura et al., 2006). This is also in processing is more difficult than self face-parts processing.


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