Psychiatry Research 230 (2015) 181–188

Contents lists available at ScienceDirect

Psychiatry Research

journal homepage: www.elsevier.com/locate/psychres

The two dimensions of the body representation in women suffering from Anorexia Nervosa

Grazia Fernanda Spitoni [a,b,*], Andrea Serino [c], Armando Cotugno [d], Francesco Mancini [e], Gabriella Antonucci [a,b], Luigi Pizzamiglio [a,b]

[a] Department of Psychology, University of Rome "La Sapienza", Rome, Italy
[b] Santa Lucia Foundation IRCCS, Rome, Italy
[c] Center for Neuroprosthetics, School of Life Sciences, Ecole Polytechnique Fédérale de Lausanne, Lausanne, Switzerland
[d] U.O.S.D. Disturbi del Comportamento Alimentare-Azienda Sanitaria Locale Roma E, Rome, Italy
[e] Scuola di Psicoterapia Cognitiva S.r.l., Viale Castro Pretorio 116, 00185 Roma, Italy

ARTICLE INFO

Article history:
Received 1 April 2015
Received in revised form
10 August 2015
Accepted 28 August 2015
Available online 29 August 2015

Keywords:
Affective touch
Anorexia Nervosa
Body representation
Body discontent
Tactile discrimination
Somatoperception

ABSTRACT

A core symptom of Anorexia Nervosa (AN) is a severe alteration of body representations. Evidence from somatoperception studies point to a generic disturbances of somatosensory components of body representations. Here we have investigated whether AN patients ($N=18$) and controls differed in the perception of tactile stimuli differently oriented along the body axes. We tested the hypothesis that patients perceive and represent their body selectively larger in only one dimension. To this aim we used elementary tactile measures for tactile acuity (Von Frey's test and two-point discrimination thresholds – 2 PD) and tactile discrimination measures. The rationale is based on the assumption that AN patients have a wider body representation, and that tactile body representation tasks (Tactile Distance task) oriented across the bodies (horizontally) are influenced by distorted body representations compared with tactile stimuli oriented along the bodies (vertically) which should not be influenced by body representations. Results showed that patients judged horizontal tactile stimuli significantly wider than the same stimuli oriented vertically.These results suggest that human brain perceives things differently based on body representations and that the beliefs concerning body size influence the specific somatosensory process of tactile experience.

1. Introduction

Anorexia Nervosa (AN) is an eating disorder characterized by intense concerns over body weight, body image, and dieting. The restriction of food can be also associated with binge eating and purging episodes causing severe and persistent physical and psychological consequences (DSM-IV-American Psychiatric Association.). While the etiology of AN is still unclear, there is a consensus that its origins are multifactorial and that neurobiological and cognitive factors contribute to the onset and maintenance of the disorder (Connan et al., 2003; Via et al., 2014).

Importantly, a core symptom of AN is a severe alteration of body representation (Cash and Deagle, 1997; Fairburn and Harrison, 2003; Garner et al., 2006; Sala et al., 2012; Castellini et al., 2013).

The term body representations refers to abstract perceptual representations of the body's features, such as shape, body-part size, body-part position in space, and the integration of parts into an organized whole (see Taylor-Clarke et al. (2004), Longo et al. (2010), Serino and Haggard (2010) and de Vignemont (2010)).

Studies of healthy subjects have demonstrated that cortical body representations are not fixed entities but are continuously modified by experience. Most of these studies used tactile stimulation to measure body representations, and multisensory stimulation or motor activity to illusorily manipulate them. For example, (Taylor-Clarke et al., 2004) found that the visual experience of one's own arm alters the perception of tactile distances on the arm. Using a tool to extend the arm action space analogously affects tactile distance perception on the upper limb, as well as the perceived size and shape of the limb (Canzoneri et al., 2013; Miller et al., 2014).

Serino and Haggard (2010) proposed that body representations are constructed from and reciprocally influenced by touch stimulations, so that the structure of the physical body organizes tactile sensations contributing to form body representations, which, in

* Correspondence to: Grazia Fernanda Spitoni, Departmente of Psychology, Sapienza University of Rome, Via dei Marsi, 78, 00182 Rome, Italy.
E-mail address: grazia.spitoni@uniroma1.it (G.F. Spitoni).

http://dx.doi.org/10.1016/j.psychres.2015.08.036
0165-1781/

turn influence primary tactile processing and mediate the formation of object representation from primary tactile sensations. In line with this view, we and other authors have suggested that primary tactile processing responsible for detecting an object in contact with the skin, can be anatomically and functionally dissociated from a secondary higher-order tactile processing, such as the discrimination of the sizes of objects touching different body parts (Serino et al., 2008; Gallace and Spence, 2009; Spitoni et al., 2010, 2013) We have proposed that, in order to extract metric information from the skin surface, the brain has to link information related to the single locations on the skin where touch is applied with a representation of the stimulated body part, and therefore, a "tactile size estimation task" can be used as an implicit proxy of the body representations.

(Keizer et al., 2011, 2012) used a tactile size estimation task to study tactile performance in patients suffering from AN and they found that relative to controls, AN patients overestimated the distance between two tactile stimuli for the stimulated body parts. According to the authors, this evidence result from top-down influences of body dissatisfaction on the body representations. Such body dissatisfaction bias in AN patients influences mental body representations, which distort tactile size estimates related to their body.

The tactile distance estimation task is a powerful tool to measure body representations in ED patients. In the present study we applied this approach to a group of female anorexic patients. Differently from Keizer et al. (2011, 2012) however, we believe that in order to measure the perceived size of a body part, tactile stimuli need to be presented as oriented at least along the two main proximo-distal and medio-laterally axes, so to provide a measure of 2D perception of specific body parts. In particular, we hypothesize that AN patients represent their bodies wider and fatter that they really are, so we expected that tactile perception of the stimuli oriented across their bodies (mediolaterally/horizontal) should be profoundly disturbed by representational distortions. Conversely we expect that tactile discriminations with stimuli oriented along the bodies (proximodistally/vertical) should not be affected by alterations of body representation. In addition, beside the tactile size estimation task, we also introduced two control tasks, assessing tactile acuity and the duration of tactile stimulation. We expect that in those tasks, not requiring processing of tactile inputs as references to body representations, AN patients would perform not differently than controls.

2. Method

2.1. Participants

Eighteen AN patients were recruited from an eating disorder department of the Italian National Health Service for outpatient population (UOSD Disturbi del Comportamento Alimentare-ASL Roma-E). Patients were enrolled over a 36-months time on the basis of a sequential recruitment procedure. They were all female and the weight ranged between 39 and 53 kg. Patients were all restricted type. Diagnosis of AN was defined by a psychiatric interview and in accordance to Diagnostic and Statistical Manual of Mental Disorders–Fourth Edition, Text Revision (DSM – IV–TR) criteria (American Psychiatric Association, 1994) a Body Mass Index (BMI) below 18.5 and by the Eating Disorder Inventory 2 (EDI-2, Garner et al., 1983).

The EDI-2 consists of 91 items and eleven subscales measuring (1) drive for thinness, (2) bulimia, (3) body dissatisfaction, (4) ineffectiveness, (5) perfectionism, (6) interpersonal distrust, (7) interoceptive awareness, and (8) maturity fears, (9) asceticism, (10) impulse regulation, and (11) social insecurity. Patients also received a full diagnostic test battery which includes the Body Shape Questionnaire (BSQ, Cooper et al.,1987), the Body Uneasiness Test (BUT, Cuzzolaro et al., 2006).

Mean disease duration was on average of 46.69 (±18.12; range: 13–72) months.

Exclusion criteria were: any personality or psychotic disorder; diagnosis of mental retardation; general medical pathology not correlated with the eating disorder; significant general medical instability, presence of neurological illness and any substance or alcohol abuse or dependence during the foregoing year. The mean duration of AN disease was 46.69 (±18.12) months.

Matched control participants ($N=32$ females) had no history of neurological or psychiatric diseases, were in good health, and were not on medication. Exclusion criteria for controls included the presence of any type of ED, a BMI below 19, and any dependence during the last 24 months.

Written informed consent was obtained from each subject in a manner approved by the local ethics committee of the "Fondazione Santa Lucia". The study conforms with The Code of Ethics of the World Medical Association (Declaration of Helsinki) as printed in the British Medical Journal (18 July, 1964).

The demographics and clinical data of the patients and controls are shown in Table 1.

2.2. Materials, instruments, and procedures

All participants were evaluated in two separate sessions with an interval of three days.

In the first session subjects received the questionnaires and the Body Image Test (Daurat-Hmeljiak et al., 1978). During the second sessions, participants were first evaluated with elementary tactile measures and then they performed the two tactile tasks, namely the tactile Distance task (Dt) and the tactile Time Duration task (TDt).

2.2.1. Elementary tactile measures-tactile acuity: Von Frey's test and Two-point discrimination thresholds

Tactile acuity was measured using Von Frey's test and the two point discrimination task (2 PD). Von Frey's test is a classic measure of sensitivity to tactile pressure used for diagnosis or research (North Coast Medical, Inc., Morgan Hill, CA, USA). In this test, the tip of a fiber of a given weight (from 0.008 to 300 g) is pressed against the skin at right angles. The force of application increases as long as the researcher continues to advance the probe, until the fibre bends. In this study, the procedure was repeated using different weight fibers in both an ascending and a descending staircase. At each level of the staircase, 10 actual stimulation and 5 catch trials (a total of 15 stimulation) were presented. In each trial, the experimenter asked the participants whether they felt the stimulus, and they had to respond verbally. The threshold was established at the staircase level when the subjects reported 6 out of 10 stimuli correctly.

Two-point discrimination thresholds were estimated by using an adjustable aesthesiometer (Med Core, St. Louis, MO, USA) with two spatially separated tips. Stimuli were manually delivered to the

Table 1
Demographic and clinical information of AN patients and control and results of their comparison with independent-sample *t* test.

	AN patients (18) Mean (SD)	Healthy controls (32) Mean (SD)	*P*-value
Age	24.8 (3.71)	23.9 (4.24)	0.951
Education (years)	14.6 (2.6)	15.4 (3.2)	0.974
BMI	16 (1.3)	22.1 (2.4)	$t=5.9$, $p<0.001$
Duration of illness (months)	46.69 (±18.12)	–	
EDI-2 (total score)	97.54 (26.03)	30.9 (12.8)	$t=6.24$, $p<0.001$

Notes: BMI=Body Mass Index; EDI-2=Eating Disorder Inventory-2. Data were compared by means of independent sample *t*-test (two-tailed).

sternum, to the abdomen and to the right thigh. For each subject we determined the horizontal and the vertical threshold. Participants were blindfolded and were requested to discriminate between single and double taps and to respond verbally. In this procedure, double or single taps were given randomly. Only double taps were used to calculate the threshold. The separation between the two starting points were 1 and 5 cm in the ascending and descending mode, respectively. The separation was then reduced progressively by 1 cm after each correct response. When an error was made, the separation was subsequently increased by 1 cm. The participants' threshold was derived from the minimum distance perceived between the two points five times consecutively.

Body Image test-Daurat-Hmeljak

The body schema test, the Daurat-Hmeljiak Test (Daurat-Hmeljiak et al., 1978) provides information about the spatial organization of the body and it allows us to quantitatively study the body image without explicitly asking about body size and shape (Fuentes et al., 2013; Cimmino et al., 2013; Palermo et al., 2014; Di Vita et al., 2014). We asked to the participants to put one tile depicting a body part in the appropriate position on an empty board, where the contour of the model's face was drawn, in order to ideally reconstruct the model's entire body. As the tiles were all rectangular, there was nothing to suggest their correct location. After each trial, the previously placed tile was removed and the board returned to be completely empty. Thus, to perform the task the participants had to refer to an internal representation of a human body image that depend on the representation of their own physical body (Di Russo et al., 2006). There are a total of 9 tiles (right arm, left arm, right leg, left leg, right hand, left hand, right trunk, left trunk, neck).

Participants performed the task seated at a desk in front of the examiner and no time limit was given.

Performance was recorded by a fixed photo camera positioned perpendicular to the test tablet. The camera was controlled by custom made software that captured the images and saved them in a JPEG format (600×800 pixel) for further offline coding. The *x–y* pixel coordinates of different critical landmarks (center of gravity for right arm, left arm, right leg, left leg, right hand, left hand, right trunk, left trunk, neck), which corresponded to the judged locations, were computed using Microsoft Paint 5.1. This method has been developed by our group and it has been previously utilized in other studies (i.e. Cimmino et al., 2013).

The *XY* coordinates of each tile were entered in a mixed factorial Anova, with diagnosis as between subjects factors (patients-controls) and coordinates (x and y axes), laterality (right and left) and body parts (arm, leg, hand, trunk) as within subjects factors.

2.2.2. Experimental stimuli and tasks

Two different experimental conditions with identical tactile stimuli were alternated in a block-design paradigm: the distance task (DT) and the time duration task (TDt). The tactile stimuli consisted of pairs of wooden sticks (3 mm diameter) of equal length (11 cm) separated by a variable distance. The two sticks were pressed on the body surface producing a tap (Fig. 1).

The taps were given on the abdomen, on the thigh and on the sternum. The latter was selected as a "neutral" part of the body and was used as a reference body part, whereas abdomen and thighs were considered the emotional biased body parts, and were used as target body parts. Thus, in one condition participants received a pairs of taps administered to the sternum and a pair to abdomen, and in another a pair of taps was given to the sternum and a pair to the thigh.

The stimuli sizes varied from 4 to 10 cm and in each trial a reference stimulus of fixed distance (7 cm) stimulated the sternum, the thigh or the abdomen in a random order. So the fixed stimulus could be administered to the sternum to the thigh or to the abdomen and it could be given as a first or second stimulation

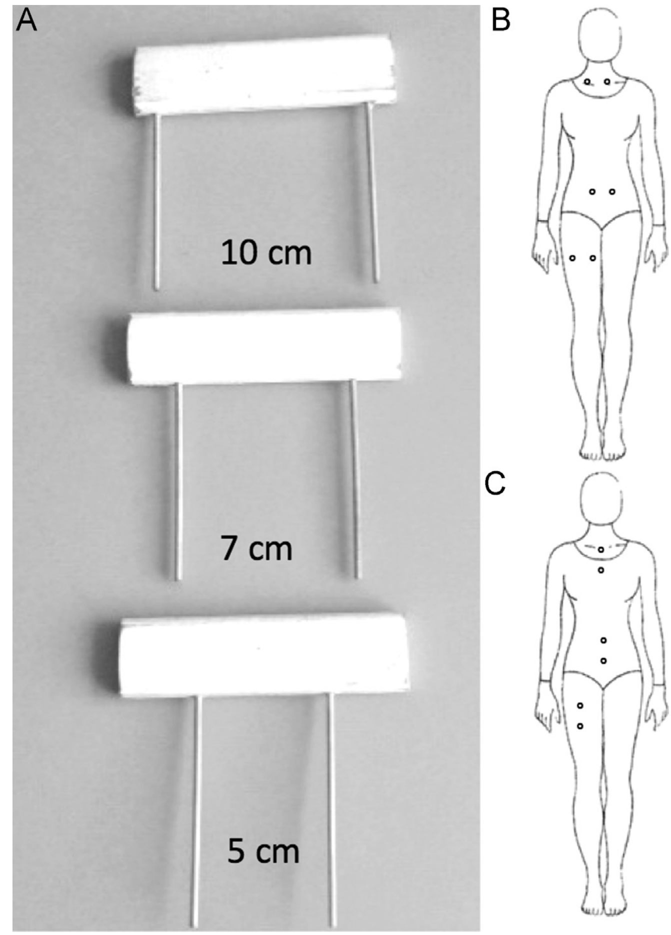

Fig. 1. Panel (a) examples of experimental stimuli of different distances. Panel (b) horizontal stimulation displacement. Panel (c) vertical stimulation displacement.

randomly. Also, the order of stimulation was balanced across participants so that each subject could receive the first stimulation either on the sternum or on the target body parts.

For both conditions, stimulations were delivered vertically and horizontally. In DT, we asked participants to judge in which stimulation the two taps were more distant (which is larger?) whereas in the TDt we invited the subjects to evaluate which one among the two stimulations, lasted more in terms of time (which lasted more?). TDt has been selected as a control task because in order to make a comparison between two time durations, the subject does not need to relay to the size of the touched body parts. Subjects were instructed to respond vocally as fast and as accurately as possible. The answer could have been: sternum, thigh or abdomen. As in previous studies (Hagen and Pardo, 2002; Serino et al., 2008), stimuli were manually delivered.

(More experimental design details in Table 1 in Supplementary section)

2.2.3. Relationship between tactile perception, body dissatisfaction, and interoceptive awareness

Two separate linear regression models were created with performance measures from Dt and TDt (percentage of corrected responses) as dependent variables and clinical scores at the eleven scales of EDI-2, BMI, duration of illness (in months), and age as independent variables. A forward stepwise method was chosen to identify a subset of significant and independent predictors in performing DT and TDt.

3. Results

Elementary tactile measures: tactile acuity

Table 2 shows the partecipants' means thresholds on the Von Frey's and on the two Points Discrimination test (2 PD) both in the vertical and horizontal dimensions (axes).

3.1. Von Frey

A mixed repeated measures ANOVA showed no main effect for group, ($F(1,64)=0.37$, $p=0.127$), for body part, ($F(1,64)=0.26$, $p=0.111=$ns) nor an interaction between body part and group, ($F(1,64)=0.49$, $p=0.235$). These data indicate that elementary tactile detection was not altered in anorexic patients.

3.2. Two Points discrimination

A mixed repeated ANOVA revealed an interaction between body part and group with anorexic patients showing a wider 2 PD threshold ($F_{(2,44)}=13.26$, $p<0.01$; partial eta squared$=0.37$; observed power$=0.99$). Post hoc Bonferroni-corrected independent sample t-tests showed that patients and controls had significantly different 2 PD thresholds for the abdomen ($t=31.8$, $p<0.01$) and thigh ($t=12.7$, $p<0.05$) but not for the sternum. In addition, we found the patients were different than controls for 2 PD administered both in the vertical and horizontal dimensions (three ways interaction: $F=11{,}49_{\ (2,47)}$, $p<0.001$; partial eta squared$=0.32$; observed power$=0.99$) see also Table 3 in Supplementary section) These results suggest that patients require wider distances between stimuli to perceive separate points on abdomen and on thigh.

3.3. Body image test-Daurat-Hmeljak

As shows in Fig. 2, the shape of the reconstructed mannequin reproduced by the patient appeared wider and more spatially confused than that reproduced by healthy controls, suggesting that AN patients have a distorted representation of their body.

A significant effect of group by XY coordinates (axes) emerged [$F=12.26_{(1,46)}$; $p<0.001$; partial eta squared$=0.25$; observed power$=0.97$], with AN patients performed differently from controls in the displacement of the tiles in the X axis. Interestingly a significant group by XY coordinates, by laterality by body parts effect also emerged [$F=25.51_{(3,44)}$; $p<0.0001$; partial eta squared$=0.65$; observed power$=1$] with patients and controls performed differently in the positioning of the trunk tiles along the two axes (see also Fig. 1 in supplementary section). Table 3., shows the participants performance in the displacement of each tiles for X and Y axes.

As can be seen in Fig. 2B, patients represent their thorax as wider (cm$=7.8$) compared to controls (cm$=5.2$). The horizontal perspective of the thorax includes also the abdomen of the mannequin, so this measure can be considered as the representation of the abdomen itself. On the contrary, no difference in the perceived height was found between the two groups (patients$=18.7$ cm; controls$=20.1$ cm).

3.4. Distance task (DT) and time duration task (TDt)

Since performance on the thigh and abdomen were not significantly different, the data were collapsed. Accuracy in both tasks is shown in Fig. 3.

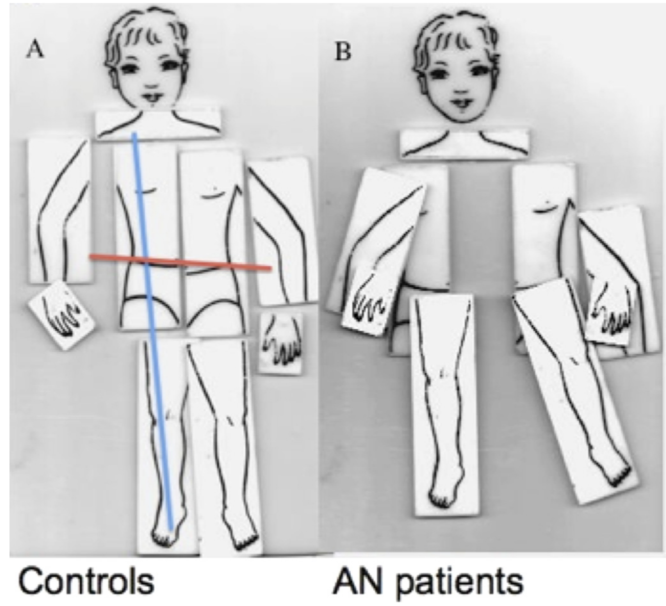

Fig. 2. Groups performance at DH. The red and blue lines superimposed to panel A show the controls performance with red line indicating the patients' representation of the abdomen (thorax) and blue line indicating the patients' representation of height. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

Table 3
Groups performance in the displacement of the tiles of the Daurat-Hmeljiak test in the X and Y coordinates.

	Body parts	Controls Mean (SD)	AN patients Mean (SD)	F	p
X AXIS	Right arm	4.997 (0.6438)	6.282 (2.6723)	44.49	0.000
	Right hand	5.606 (0.7291)	5.847 (0.7508)	1.23	0.273
	Right thorax	9.575 (0.9133)	7.088 (1.7213)	118.43	0.000
	Right leg	9.425 (0.4157)	9.394 (2.7596)	0.21	0.88
	Left arm	16.491 (0.423)	16.2 (3.6795)	0.19	0.65
	Left hand	16.584 (0.7527)	18.347 (5.7437)	63.71	0.000
	Left thorax	13.397 (3.566)	15.329 (1.0179)	74.97	0.000
	Left leg	14.491 (2.8271)	15.953 (0.626)	42.42	0.000
Y AXIS	Right arm	14.309 (2.5777)	13.741 (4.5446)	11.6	0.001
	Right hand	15.544 (0.6237)	15.311 (1.5301)	1.7	0.18
	Right thorax	14.428 (0.6371)	14.711 (4.6067)	2.3	0.13
	Right leg	22.969 (5.7545)	22.494 (6.9643)	3.7	0.06
	Left arm	14.734 (1.1261)	16.028 (5.8936)	17.4	0.000
	Left hand	18.209 (3.9355)	17.817 (2.0695)	1.8	0.18
	Left thorax	15.644 (1.1927)	15.789 (1.1386)	0.17	0.67
	Left leg	23.037 (3.4432)	21.022 (2.3718)	4.84	0.03

Table 2
Mean (SD) thresholds on the Von Frey's and on the 2PD in patients and controls.

	Von Frey Control (gr)	AN patients (gr)	2 PD vertical Controls (cm)	AN patients (cm)	2 PD horizontal Controls (cm)	AN patients (cm)
Sternum	3.22 (1.1)	3.22 (0.9)	6.6 (1.61)	8.06 (1.16)	7.5 (1.46)	6.88 (1.27)
Thigh	4.08 (1.2)	3.84 (0.6)	5.85 (1.86)	7.02 (1.57)	6.37 (2.01)	9.3 (0.77)
Abdomen	3.84 (1)	3.61 (1.1)	4.84 (2.24)	6.3 (1.95)	6.3 (1.26)	8.67 (1.27)

Two 2 × 2 Anovas, were conducted separately for the Distance Task and Time duration Tasks

In the case of the Distance Task, a 2 × 2 mixed repeated measures Anova was run with group (AN patients and Controls) as the between-subject factor and *XY* axes (horizontal; vertical) as the within-subjects factors. The results (post-hoc with Bonferroni correction) showed no main effect for Group ($F_{(1,48)}=0.4$, $p=0.54$), however we have found a significant effect of axes with subject generally more accurate in vertical trials ($F_{(1,48)}=15$, $p<0.001$). Also, we have found a significant interaction "group by *XY* axes" ($F_{(1,48)}=6.35$, $p<0.01$) with patients performing significantly worse then controls in the horizontal trials only.

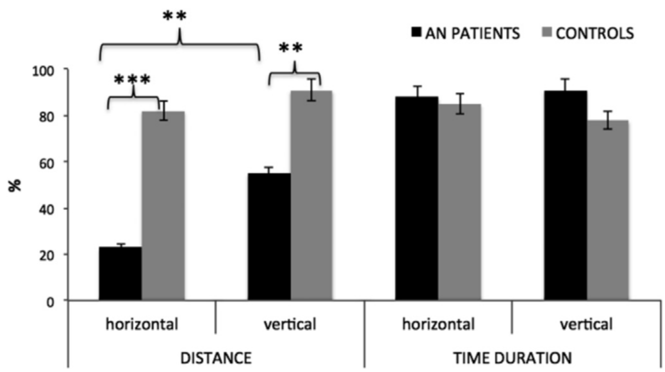

Fig. 3. Performance of patients and controls in distance discrimination and in Time duration tests.

As for the Distance Task, a second 2 × 2 mixed repeated measures Anova was run for the Time duration Tasks. Results showed no main effects for group and *XY* axes $F_{(1,48)}=0.21$, $p=0.91$); $F_{(1,48)}=0.27$, $p=0.86$ respectively) nor a significant interaction "group by *XY* axes" ($F_{(1,48)}=0.35$, $p=0.55$).

To investigate a possible response bias in participants' performance, data were analysed using point of subjective equality (PSE) and just noticeable difference (JND) for both tasks. PSE refers to any point along a stimulus dimension at which no relevant differences between responses to a variable stimulus and a standard stimulus can be detected in the human behavior. JND indicates the smallest detectable difference between a starting and secondary level of a particular sensory stimulus. Psychophysical estimates were obtained by submitting the proportions of bigger/longer responses (for each stimulus distance/duration) to a probit model of maximum likelihood estimation, an iterative procedure of weighted linear regression which adapts a cumulative normal curve to a set of forced-choice psychometric data (McKee et al., 1985). The best estimates of the function parameters (intercept and slope) were used to derive the point of subjective equality (PSE), corresponding to the difference in sternum and thigh/abdomen stimulus distance or stimuli duration which the stimuli feel identical, and the proportion of larger/longer responses is therefore 50%. We also computed for each task and subject individual values for d' and beta, which represent measures of discriminability and response bias, respectively, according to the signal detection theory (Swets, 1964).

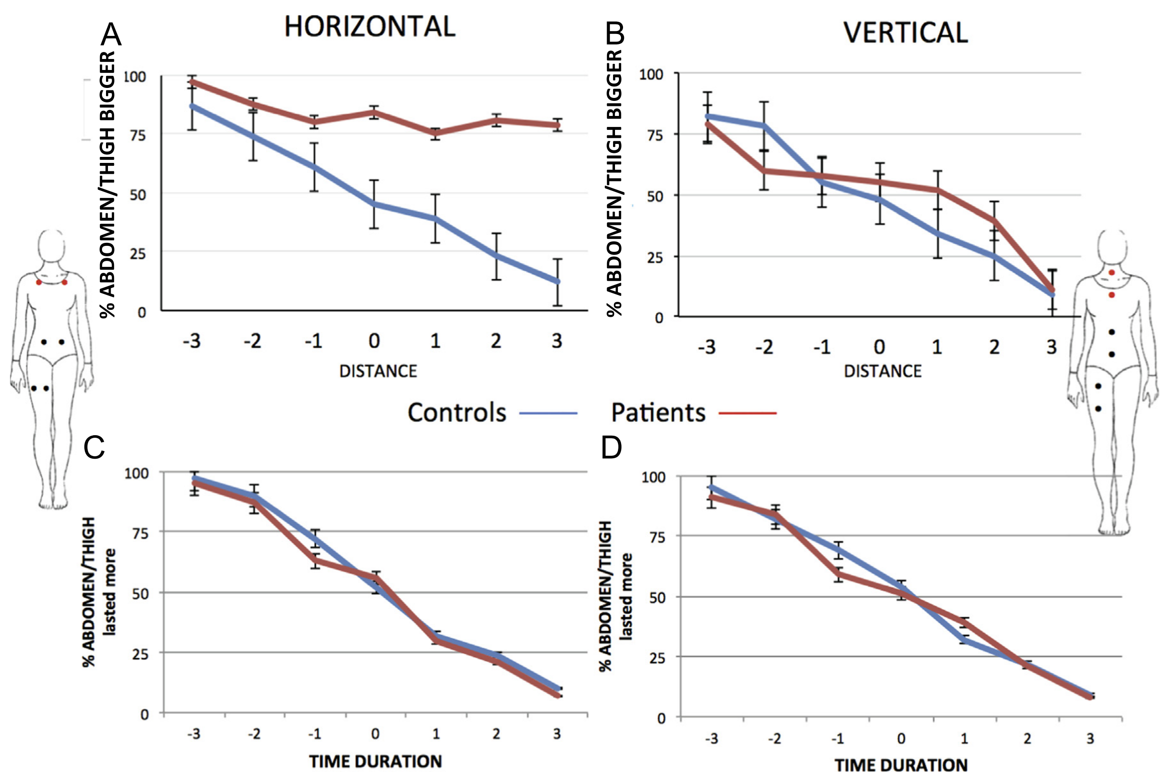

Fig. 4. ABCD Experimental results of Dt and TdT. A–B Psychophysical relationship between physical distance and perceived stimulus distance in AN patients (*red curve*) and Controls (*blue curve*). Panel A refers to horizontal trials. Panel B refers to vertical trials In each trial, either the abdomen/thigh or the sternum stimulus was of fixed dimensions (distance = 7 cm) and the other randomly changed (distance = 4–10 cm). *Y* axis shows the percentage of trials (group average) in which subjects judged the changing stimulus as bigger than the fixed stimulus, as a function of its distance. *X* axis shows the difference in the distances perceived in each comparison (±3 easy comparisons; ±1 difficult comparisons). C–D Psychophysical relationship between actual duration of stimulus and perceived stimulus duration in AN patients (*red curve*) and Controls (*blue curve*). Panel C refers to horizontal trials. Panel D refers to vertical trials In each duration trial, either the abdomen/thigh or the sternum stimulus lasted the same time (time 5 s) and the other randomly changed (distance = 2–7 s). *Y* axis shows the percentage of trials (group average) in which subjects judged the changing stimulus as lasted more than the fixed stimulus, as a function of its duration. *X* axis shows the difference in time perceived in each comparison (±3 easy comparisons; ±1 difficult comparisons). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

Distance Task

In order to analyse the response biases in the distance task, we have run separate 2 × 2 mixed factorial Anovas (group X axes) for PSE and JND.

For the JND we have found a significant interaction Group-XAxes ($F_{(1,48)}=2.4$; $p<0.04$; Partial eta squared=0.46; Observed power=0.33), with patients performing differently from controls in the horizontal axis ($t=2,08$; $p<.04$) but not in the vertical ($t=0.45$; $p=0.13$).

For the PSE we have found a similar pattern of results with a significant interaction GroupXAxes (PSE: $F_{(1,48)}=65.98$; $p<0.001$; Partial eta squared=0.58; Observed power=1), with patients performing differently from controls in the X axis ($t=9.86$; $p<0.001$but not in the Y axis ($t=0.45$; $p=0.11$) (see also Table 4 in the Supplementary section).

These results (Fig. 4A–B) indicate that AN patients perceived distances on the abdomen and thigh to be significantly wider then controls when the stimulation was given in the horizontal orientation whereas stimuli delivered vertically were perceived with no bias.

Time duration Task (TDt)

No significant differences were found in the TDt, for either the horizontal (PSE [$t=1.39$, $p=0.37$.] JND [$t=1.5$, $p=0.42$]) or vertical trails (pSE [$t=2.06$, $p=0.57$.] JND [$t=1.9$, $p=0.48$]). These data indicate that anorexic patients perform normally when asked to compare stimuli that are unrelated to body size or perception of size (Fig. 4C–D).

3.5. Relationship between tactile perception, body dissatisfaction and interoceptive awareness in AN patients

The first linear regression analysis using DT accuracy (% of correct responses) as a dependent variable and EDI-2 (11 subscales), BMI, age, and duration of illness (in months) as independent variables, showed that one was identified variable is a predictor of the performance on DT (corrected $R^2=0.567$; $F=19.6$; $p<0.001$). More specifically, results indicated that a body dissatisfaction high score predicts a low DT accuracy (Beta=0.0753.; $t=-3.5$; $p<0.001$).

The second linear regression analysis used the same independent variables and TDt as the dependent variable. In the analysis, we found that a perfectionism high score predicts high TDt performance (corrected $R^2=0.323$; $F=8,61$; $p<0.01$-beta=0.604; $t=6.32$, $p<0.001$). This indicates that the ability to perform a temporal discrimination task on the body is not linked to the patients' BR.

4. Discussion

In the present study, we systematically assessed the perceived size of the abdomen and the thigh in AN patients by applying an implicit measure based on tactile distance estimation. Our results show that patients suffering from AN perceive and represent their body selectively wider, but not generally bigger.

Such conclusion is based on the finding that AN participants, differently from healthy controls, systematically judged tactile stimuli delivered medio-laterally across the body axis (horizontally) on their thight and the abdomen significantly wider than the same stimuli presented on the sternum. Importantly, such a bias was not found when the same stimuli were applied proximo-distally along the body axis over the same body parts.

There are some precedents for predicting that, as we found in our work, the human brain might represents tactile stimulations differently from the actual occurrence. (Blankenburg et al., 2006) used magnetic resonance imaging (fMRI) to study neural correlates of a strong somatosensory illusion able to dissociate tactile perception from the actual physical stimulation. In this illusion, named the "rabbit illusion", repetitive speedy stimulation at the wrist, then near the elbow, generate the illusion of touches at intervening positions along the arm, as if "… a rabbit hopped along it… (Blankenburg et al., 2006)". Authors found that the illusory sequences activated the contralateral primary somatosensory cortex, at a somatotopic location corresponding to the filled-in illusory perception on the forearm, providing a clear evidence that tactile illusory somatosensory percepts can affect primary somatosensory cortex in a manner that corresponds to the illusory percept.

Following the model proposed by Serino and Haggard (2010) in which body representations are constructed from and reciprocally influenced by touch stimulations, we have studied the performance on a tactile distance discrimination task (Dt) in the emotional biased body parts (namely abdomen and thighs). Data showed that the perceived bodies' dimensions affects the perception of the size of the tactile stimuli oriented in the altered body representation fashion. In other words, we found that AN participants overestimated the size of the objects on the thigh and on the abdomen as an implicit results of the overestimation of size of their thigh and abdomen. Indeed, this selective evidence was also supported by the AN performance on the Body Image test.

Previous studies have analysed the effect of anorexia nervosa on a distance discrimination tactile task. Keizer et al. (2012) found that AN patients overestimated distances between tactile stimuli on both the arm and abdomen suggesting a generalized trend of AN patients to perceive the whole body as bigger. Our study refines this conclusion, since we show that AN patients overestimate only the stimuli oriented along the altered dimension of the body which support the hypothesis of a selective abnormal body representation only in the horizontal direction. Such a bias is compatible with a distortion of the patients' body image, which concern the dimension of width rather than the whole body generically. In other words, AN's brain seems to be biased only when the touches are delivered along the dimorphic body dimensions. Moreover, the very same stimuli oriented in the unbiased dimension (namely vertical), are perceive more accurately.

Importantly, the distortion in tactile processing found in AN patients is specific for spatial tactile perception and does not concern other dimensions of touch. Indeed, patients were accurate and not different from control in a classic measure of tactile detection, i.e. the Von Frey filaments test, even when stimuli were applied to the abdomen and to the thigh. In addition, patients were fully comparable to healthy participants in a control task requiring a temporal comparisons between the duration of pairs of tactile stimuli administered on the sternum and the thigh / abdomen. We note that this task involved the same body parts and the same stimuli as the tactile distance task, but did not require referencing to a spatial mental representation of the body.

Our results on pure tactile detection are not fully in line with those by Keizer et al. (2011), who described unusual somatosensory performance in eating disorders participants. The authors found that as compared to controls, AN patients need a lower pressure to detect a simple stimulus on the abdomen, whereas they have a worse discrimination threshold when asked to discriminate between one or two touches on the abdomen or on the arm. In our study, we found no significant differences between AN and controls in elementary tactile acuity suggesting that the basic somatosensory mechanisms of AN are not impaired. On the contrary and in agreement with Keizer et al. (2011) we found that patients required higher discrimination thresholds to perform the Two Points discrimination task

These findings are very important not only per se, but even more for interpreting the results at the tactile distance task and for our proposal of a deficit in body representations in AN. Indeed, a spatial analysis of tactile stimuli is required for the tactile distance task, thus, in principle, an elementary deficit in tactile spatial acuity could explain also patients' deficit in tactile distance perception, without implying a deficit in body representation. We can however discharge this confound for two main reasons. First, the deficit in 2 PD is present for both dimensions, whereas the bias in tactile distance, the patients' bias is specific for the horizontal dimension. Second, accordingly to the Weber effect, the deficits at the 2 PD should induce an effect in the opposite direction at the tactile distance task, because higher tactile acuity is associated with wider perceived distances (see Weber (1978) and Taylor-Clarke et al. (2004)). Thus, our results actually point for two possibly related, but independent deficits, one at level of tactile sensation (spatial acuity) and the other related to the spatial computation of tactile distance on the body, which is more related to a distortion of body perception than to reduced somatosensory sensitivity (see Serino and Haggard (2010) and Longo et al. (2010)).

Taken together these findings support the view of a selective impairment of AN on tasks tapping on a spatial representation of the body, and for a specific spatial dimension. In particular, our data support the option of a selective impairment of AN patients in tasks that require to rescale tactile distance in respect to the body representations.

Dissociations among the different components of body representations have been previously described and schematized (Longo et al., 2010). In the attempt to hierarchized the functional and neuroanatomical bases of the various components of body representations, the authors referred to primary somatosensory processing of somatic stimuli as “somatosensation” whereas they used the term “somatoperception” to denote the processing of the metric properties of tactile stimuli: they linked somatoperception to parietal cortices and somatosensation to primary somatosensory areas. In previous experiments (Spitoni et al., 2010, 2013) we have pointed out that the neural circuits underlying a tactile discrimination tasks involved a right fronto-pariatal network and that a distance tactile discrimination test selectively activate the right angular gyrus. If we consider the performance of AN patients in the Two Points and in the Distance tactile discrimination tasks, we can speculate that the right parietal areas involved in these tasks appeared to be functionally altered in AN participants. This evidence support the challenging issue of a link between body distortions and right parietal lobe dysfunction (Nico et al., 2010; Gaudio et al., 2011; Gaudio and Quattrocchi 2012).

Body image disturbances were also assessed in both groups. As expected, AN performed differently from controls, showing an impaired ability to position the tiles depicted body parts in an empty board. Interestingly the shape of the mannequin made by AN was wider but not highest than that of controls. This evidence is in line with the general hypothesis of our study that assumes that AN patients represent their body wider but not wholly bigger. The Daurat-Hmeljak body image test has been previously used to test the modifications of the body representations in studies on the cortical plasticity following limbs elongation (Cimmino et al., 2013). Results of both the studies showed the validity of the test to measure the changes in the representations of the elongated limbs. Also, Fuentes et al. (2013) recently proposed a computerized version of the Daurat-Hmeljak confirming the efficacy of the the Daurat-Hmeljak in the assessment of the body representation.

Finally, we also investigated the possible relationship between tactile perception, body dissatisfaction and interoceptive awereness. Even if correlational, our results pointed to a significant relationship between body dissatisfaction and tactile perception; a high level of body discontent predicts a low performance in tactile distance discrimination. No relation was found between displeasure about the body and the ability to make the tactile time duration task. Again, these correlational evidence seem to reinforce the hypotheses of a link between an irregular BR and the body dissatisfaction. It should be noted that our analyses failed to find a relation between tactile abilities and interoceptive awereness. This lack of a significant result can be partially due to the operationalization of the interoceptive awerness that in the EDI-2 questionnaire relied more to psychological dimension then to interoceptive physiological parameters such as heart rate. We believe that a specific study aimed to investigate the relation between the physiological interoception and body representation could bring to more reliable results.

If we attempt to combine the evidence here reported, we can propose that women suffer from anorexia nervosa perceive their body wider than it actual is but not broadly bigger. Even thought previous studies have already documented the abnormal body size perception of AN patients, according to our knowledge this is the first investigation that showed converging evidence on the specific dimensions of the body miss-perception in relation with body dissatisfaction. The dissociation between performance on horizontal and vertical tactile tasks, allow us to state that the believes and feeling of AN regarding body size involved selectivity the perception of width, rather than the dimensions of the entire body. This result can be explained if we take into account the Mental Body Representations (MBRs) model proposed by Serino and Haggard (2010). As previously reported, the model proposes that the physical body organizes tactile sensations, which contribute to form a MBRs. The MBRs reciprocally influence primary tactile processing and it mediates the formation of the representation from primary tactile sensations. We believe that in AN patients, the skin surface organizes the horizontal tactile distances which provides the formation of the horizontal BR; this latter affects primary tactile processing mediating the perception of tactile stimuli, that in this case, are perceived wider but not bigger. Thus, we can legitimately suppose that the abnormal beliefs of AN regarding body dimensions, disturbs the somatosensory processing responsible for the formation of width but not the for the formation of the size of the whole body.

One limitation of our study is the absence of a comparison between the sternum and another non emotional body part. Unfortunately, the selection of an additional body part was limited by technical constraints related to tactile acuity, lateralization and visual exposure. In fact tactile acuity of the sternum is quite similar to that of the abdomen and thighs. Also the sternum is not lateralized and it is not affected by any hemisphere dominance. Finally, as for the abdomen and the thighs, the sternum is equally exposes to visual sense. The only part of the body that could have been of interest was the forehead, but preliminary data of a pilot study showed that the tactile acuity of the forehead in 8 healthy females was significantly smaller than in the other body parts. Also the forehead was to small to allow the extreme vertical stimulations. We believe that a new study on the direct comparison between two non emotional body parts, could add interesting evidence to the topic.

Another limitation of our study is the lack of a deeper investigation of the somesthetic sense. We know from previous studies that there are several variables that could interfere with somatosensation. For example Stevens (1982) found that the temperature of the stimuli influences tactile discrimination; also Lautenbacher et al. (1991) found that AN patients exhibit a reduced pain sensitivity and that this effect is not a mere consequence of fasting, but a true pathological feature. Following this line of reasoning we believe that a novel study on the somesthetic sense in Eating Disorders patients including tactile acuity, vibroaction, texture perception, perception of location and movement and thermoreception would be of great help in the interpretation of our results.

A last limit of the study concerns the size of the clinical sample.

It is worth nothing that although in line with previous studies on body representation in eating disorders (Nico et al. 2010; Keizer et al. 2011, 2012), the sample size of the present study is relatively low due to practical difficulties in recruiting well-diagnosed cases of AN and involving patients is such kind of tasks. Future investigations will hopefully confirm the present findings.

Current literature on AN is lacking of evidence-based findings providing support to effective treatments (Abbate-Daga et al., 2013); the majority of patients do not respond to the available treatments and develop an enduring and disabling illness. Recently (Morgan et al., 2014) have demonstrated that in a group of 55 AN patients, a body image therapy based on mirror exposure and mental reflection on distorted size beliefs (BAT-10), significantly improved crucial anorexic beliefs regarding the shape and the weight and it significantly reduced the avoidance behaviors and eating and body image anxiety. These evidence support the fundamental role of the implicit body representations in the maintenance or remission of a distorted body image in AN. From this perspective, we believe that our results can bring a supportive therapeutic tools if used to reflect on the selective horizontal tactile performance during the mirror exposure. Also, the implicit and non-invasive nature of he Distance Tactile Task can be suggested as a longitudinal parameter to monitor the evolution of patients' recovery from Anorexia Nervosa.

Conflicts of interest

None.

Acknowledgments

The study was supported by a Grant of the Italian Ministry of Health (RF-2009-1547884)

Appendix A. Supplementary material

Supplementary data associated with this article can be found in the online version at http://dx.doi.org/10.1016/j.psychres.2015.08.036.

References

Abbate-Daga, G., Amianto, F., Delsedime, N., De-Bacco, C., Fassino, S., 2013. Resistance to treatment and change in anorexia nervosa: a clinical overview. BMC Psychiatry 7, 13–294.
American Psychiatric Association, 1994. Diagnostic and Statistical Manual of Mental Disorders, 4th ed.
Blankenburg, F., Ruff, C.C., Deichmann, R., Rees, G., Driver, J., 2006. The cutaneous rabbit illusion affects human primary sensory cortex somatotopically. PLoS Biol. 4, e69.
Canzoneri, E., Ubaldi, S., Rastelli, V., Finisguerra, A., Bassolino, M., Serino, A., 2013. Tool-use reshapes the boundaries of body and peripersonal space representations. Exp. Brain Res. 228, 25–42.
Cash, T.F., Deagle, E.A., 1997. The nature and extent of body-image disturbances in anorexia nervosa and bulimia nervosa: a meta- analysis. Int. J. Eat. Disord. 22, 107–125.
Castellini, G., Polito, C., Bolognesi, E., D'Argenio, A., Ginestroni, A., Mascalchi, M., Pellicanò, G., Mazzoni, L.N., Rotella, F., Faravelli, C., Pupi, A., Ricca, V., 2013. Looking at my body. Similarities and differences between anorexia nervosa patients and controls in body image visual processing. Eur. Psychiatry 28, 427–435.
Cimmino, R.L., Spitoni, G., Serino, A., Antonucci, G., Catagni, M., Camagni, M., Haggard, P., Pizzamiglio, L., 2013. Plasticity of body representations after surgical arm elongation in an achondroplasic patient. Restor. Neurol. Neurosci. 31, 287–298.
Connan, F., Campbell, I.C., Katzman, M., Lightman, S.L., Treasure, J., 2003. A neurodevelopmental model for anorexia nervosa. Physiol. Behav. 79, 13–24.
Cooper, P.J., Taylor, M.J., Cooper, Z., Fairbum, C.G., 1987. The development and validation of the Body Shape Questionnaire. Int. J. Eat. Disord. 6, 485–494.
Cuzzolaro, M., Vetrone, G., Marano, G., Garfinkel, P.E., 2006. The Body Uneasiness Test (BUT): development and validation of a new body image assessment scale. Eat Weight Disord. 11, 1–13.
Daurat-Hmeljiak, C., Stambak, M., Berges, J., 1978. Il test dello schema corporeo. Una prova di conoscenza e costruzione dell'immagine del corpo. Organizzazioni Speciali, Firenze, Hove.
Di Russo, F., Committeri, G., Pitzalis, S., Spitoni, G., Piccardi, L., Galati, G., Catagni, M., Nico, D., Guariglia, C., Pizzamiglio, L., 2006. Cortical plasticity following surgical extension of lower limbs. Neuroimage.Neuroimage 30 (1), 172–183.
Di Vita, Palermo, L., Piccardi, L., Guariglia, C., 2014. Peculiar body representation alterations in hemineglect: a case report. Neurocase 31, 1–10.
Hagen, M.C., Pardo, J.V., 2002. PET studies of somatosensory processing of light touch. Behav. Brain Res. 135, 133–140.
de Vignemont, F., 2010. Body schema and body image–pros and cons. Neuropsychologia 48, 669–680.
Fairburn, C.G., Harrison, P.J., 2003. Eating disorders. Body dissatisfaction is improved but the ideal silhouette is unchanged during weight recovery in anorexia nervosa female inpatients. Lancet 36, 407–416.
Fuentes, C.T., Longo, M.R., Haggard, P., 2013. Body image distortions in healthy adults. Acta Psychol. (Amst.) 144 (2), 344–351.
Gallace, A., Spence, C., 2009. The cognitive and neural correlates of tactile memory. Psychol. Bull. 135, 380–406.
Garner, D.M., Olmstead, M., Polivy, J., 2006. Development and validation of a multidimensional eating disorder inventory for anorexia nervosa and bulimia. Int. J. Eat. Disord. 2, 15–34.
Gaudio, S., Nocchi, F., Franchin, T., Genovese, E., Cannatà, V., Longo, D., Fariello, G., 2011. Gray matter decrease distribution in the early stages of Anorexia Nervosa restrictive type in adolescents. Psychiatry Res. 191, 24–30.
Gaudio, S., Quattrocchi, C.C., 2012. Neural basis of a multidimensional model of body image distortion in anorexia nervosa. Neurosci. Biobehav. Rev. 36, 1839–1847.
Keizer, A., Smeets, M.A., Dijkerman, H.C., van Elburg, A., Postma, A., 2012. Aberrant somatosensory perception in Anorexia Nervosa. Psychiatry Res. 200, 530–537.
Keizer, A., Smeets, M.A., Dijkerman, H.C., van den Hout, M., Klugkist, I., van Elburg, A., Postma, A., 2011. Tactile body image disturbance in anorexia nervosa. Psychiatry Res. 190, 115–120.
Lautenbacher, S.1, Barth, K., Friess, E., Strian, F., Pirke, K.M., Krieg, J.C., 1991. Dieting and pain sensitivity: a validation of clinical findings. Physiol. Behav. 50 (3), 629–631.
Longo, M.R., Azañón, E., Haggard, P., 2010. More than skin deep: body representation beyond primary somatosensory cortex. Neuropsychologia 48, 655–668.
McKee, S.P., Klein, S.A., Teller, D.Y., 1985. Statistical properties of forced-choice psychometric functions: implications of probit analysis. Percept. Psychophys. 37, 286–298.
Miller, L.E., Longo, M.R., Saygin, A.P., 2014. Tool Morphology Constrains the Effects of Tool Use on Body Representations. J. Exp. Psychol.: Human Percep. Perform. 40, 2143–2153.
Morgan, J.F., Lazarova, S., Schelhase, M., Saeidi, S., 2014. Ten session body image therapy: efficacy of a manualised body image therapy. Eur. Eat. Disord. Rev. 22, 66–71.
Nico, D., Daprati, E., Nighoghossian, N., Carrier, E., Duhamel, J.R., Sirigu, A., 2010. The role of the right parietal lobe in anorexia nervosa. Psychol. Med. 40, 1531–1539.
Palermo, L., Di Vita, A., Piccardi, L., Traballesi, M., Guariglia, C., 2014. Bottom-up and top-down processes in body representation: a study of brain-damaged and amputee patients. Neuropsychology 28 (5), 772–781.
Sala, L., Mirabel-Sarron, C., Pham-Scottez, A., Blanchet, A., Rouillon, F., Gorwood, P., 2012. Body dissatisfaction is improved but the ideal silhouette is unchanged during weight recovery in anorexia nervosa female inpatients. Eat. Weight Disord. 17, 109–115.
Serino, A., Haggard, P., 2010. Touch and the body. Neurosci. Biobehav. Rev. 34, 224–236.
Serino, A., Giovagnoli, G., de Vignemont, F., Haggard, P., 2008. Spatial organisation in passive tactile perception: is there a tactile field? Acta Psychol. 128, 355–360.
Spitoni, G.F., Galati, G., Antonucci, G., Haggard, P., Pizzamiglio, L., 2010. Two forms of touch perception in the human brain. Exp. Brain Res. 207, 185–195.
Spitoni, G.F., Pireddu, G., Cimmino, R.L., Galati, G., Priori, A., Lavidor, M., Jacobson, L., Pizzamiglio, L., 2013. Right but not left angular gyrus modulates the metric component of the mental body representation: a tDCS study. Exp. Brain Res. 228, 63–72.
Stevens, J.C., 1982. Temperature can sharpen tactile acuity. Percept. Psychophys. 31, 577–580.
Swets, J.A., 1964. Signal Detection and Recognition by Human Observers. Wiley, New York.
Taylor-Clarke, M., Jacobsen, P., Haggard, P., 2004. Keeping the world a constant size: object constancy in human touch. Nature Neurosci. 7, 219–220.
Via, E., Zalesky, A., Sánchez, I., Forcano, L., Harrison, B.J., Pujol, J., Fernández-Aranda, F., Menchón, J.M., Soriano-Mas, C., Cardoner, N., Fornito, A., 2014. Disruption of brain white matter microstructure in women with anorexia nervosa. J. Psychiatry Neurosci. 39, 367–375.
Weber, E.H., 1978. The Sense of Touch. Academic Press, London, UK.