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ORIGINAL ARTICLE

Impaired processing of self-face recognition in anorexia nervosa

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Abstract Body image disturbances and massive weight loss are major clinical symptoms of anorexia nervosa (AN). The aim of the present study was to examine the influence of body changes and eating attitudes on self-face recognition ability in AN. Twenty-seven subjects suffering from AN and 27 control participants performed a self-face recognition task (SFRT). During the task, digital morphs between their own face and a gender-matched unfamiliar face were presented in a random sequence. Participants' self-face recognition failures, cognitive flexibility, body concern and eating habits were assessed with the Self-Face Recognition Questionnaire (SFRQ), Trail Making Test (TMT), Body Shape Questionnaire (BSQ) and Eating Disorder Inventory-2 (EDI-2), respectively. Subjects suffering from AN exhibited significantly greater difficulties than control participants in identifying their own face ($p = 0.028$). No significant difference was observed between the two groups for TMT (all $p > 0.1$, non-significant). Regarding predictors of self-face recognition skills, there was a negative correlation between SFRT and body mass index ($p = 0.01$) and a positive correlation between SFRQ and EDI-2 ($p < 0.001$) or BSQ ($p < 0.001$). Among factors involved, nutritional status and intensity of eating disorders could play a part in impaired self-face recognition.

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Introduction

When watching oneself on photograph, it is commonplace to experience a feeling of strangeness about one's face and body. As noted by Freud [1], "there are cases in which parts of a person's own body, even portions of his mental life, his perceptions, thoughts and feelings, appear alien to him and as not belonging to his ego (…). Thus even the feeling of our own ego is subject to disturbances and the boundaries of the ego are not constant". In some extreme cases, the distortion of this representation is so strong that it becomes pathological, such as in neuropathologies of the self [2] where visual self-recognition is disrupted. This phenomenon is observed in prosopagnosia where patients do not recognize their own face [3], Capgras delusion where patients regard themselves as impostor [4], asomatognosia characterized as loss of recognition or awareness of part of the body [5], or in severe Alzheimer's dementia with the so-called mirrored self-misidentification, in which patients fail to recognize their own reflection in the mirror [6]. Mismatches between reality and expectations of own appearances have been observed in mental disorders such as body dysmorphic disorder defined as an obsessive preoccupation with a perceived defect in one's own appearance, and anorexia nervosa (AN). Indeed self-representation disturbances are common in anorexia nervosa (AN). Patients usually report feeling fatter and larger than they really are [7–9]. This alteration in body representation is a major clinical symptom of AN [10] and a major prognostic factor by increasing the patient's body dissatisfaction and their obsessive will to lose weight, thus maintaining restrictive eating behaviors [11–13]. Despite the crucial importance of this bias, little is known about its exact nature and consequences.

Recently, some authors have suggested that these body distortions may be related to an hemispheric asymmetry and dysfunction of the right parietal cortex (PC) [14–16], since the latter structure was found to be crucial for establishing a coherent body schema [17]. The development of this coherent representation of the body requires prior integration and synthesis of many different sources of sensory information (e.g. visual and proprioceptive information) in PC. However, several studies have recently evidenced disturbances of multisensory integration in AN [18, 19]. This dysfunction might be more extensive and involve the frontoparietal network. In an fMRI study, Sachdev, Mondraty, Wen and Gulliford [20] explored the neural basis of one's own body recognition in patients with AN. The sample consisted of 10 patients with AN and 10 healthy control women. In a controlled epoch design, images of the self and non-self were presented to the subjects. The processing of non-self-images by control participants and patients activated the same patterns: the frontal and parietal lobes, the cerebellum and the thalamus. However, when the two groups were contrasted for differential activation with self vs. non-self-images, patients with AN had no significant region of activation with self-images compared to baseline. According to the authors, patients with AN processed non-self images similarly to control participants, but their processing of self-images was quite discrepant [20]. Vocks et al. [21] exposed 13 patients suffering from AN and 27 control subjects to photographs of their own body and the body of unknown woman. In the AN group, viewing their own body was associated with a significant decrease in the activation of a complex network involving the bilateral frontal, parietal, occipital and hippocampal areas. For Vocks et al. [21], these results might reflect body-related avoidance behavior. These stimuli would be interpreted as a threat and the allocated attention would be insufficient to activate the amygdala. Another indication of avoidance behavior was related to the reduced activity in parietal network [21], which is involved in visuospatial information and attentional processes [22]. However, an alternative hypothesis could be proposed, i.e. a disturbance in self-recognition processing. Indeed, it has been shown that this neural network was also involved in visual self-recognition [23].

The ability to recognize one's own visual image is a key component of the concept of self. For Gallup [24], the ability to identify oneself would be a prerequisite for introspection and also representation of other people's states of mind. Empirically, self-processing has been studied most extensively using face stimuli [25]. The search for the neural signature of visual self-recognition has attracted significant interest in recent years. However, the specific pattern of areas activated is not consistent across imaging studies [26], which may be due to the diversity of experimental paradigms employed. Studies vary in the target stimuli (e.g. face, full body, morphs) and the task to be conducted (e.g. identification of self, judgment of familiarity). However, the face remains the most distinctive physical marker of self [27], and the ability to recognize one's own face in a mirror [28] or photographs [29] has been regarded as a reliable marker of self-awareness. The results from behavioral and neuroimaging studies point out a predominant implication of the prefrontal and temporo-parietal cortices during self-recognition [26, 30]. The role of the hemispheres remains controversial [26, 31, 32]. However, recent data suggest a right hemisphere advantage for self-related cognitive processes, including self-related cognition [28], self-awareness [27] and recognition of one's own face [26, 28, 30]. Some studies revealed dysfunctions of right frontoparietal cortex in AN when patients address haptic perception or spatial processing tasks [15, 33]. In addition, compared to healthy subjects abnormal patterns of activation have been documented in the frontoparietal regions of patients' brains when observing a digitally distorted image of their own body [34] but also during self-other identification tasks [20, 21]. This frontoparietal dysfunction might contribute to disturb self-face recognition and self-awareness [19, 35].

Nutritional states, body size and weight changes in AN constitute potential sources of bias because malnutrition could lead to the impairment of sensory integration and/or changes in body size [36, 37]. The knowledge gained by studying neurological phenomena such as phantom limbs might shed light on this topic. In fact, many amputees continue to feel the presence of a phantom limb after amputation [38]. Many explanatory models of phantom limb syndrome have emerged in recent years. One of these postulates a degree of mismatch between the sensory feedback from the phantom and the cortical regions representing the limb [39]. In patients with AN, there could be a conflict between the previous body representation (i.e. before the weight change) and the current sensorimotor feedback. Some other neuropsychological deficits could maintain their misperception such as a decrease of set-shifting abilities or a weak central coherence [40, 41]. Indeed, the impairment of set-shifting abilities leads to rigidity, expressed by inflexibility and perseveration, both in reasoning and behavior. The weakness in central coherence causes an excessive attention to details and a decrease in global integration. This cognitive profile could induce a significant change blindness. Thus, patients would find themselves locked into a larger body [42]. Therefore, the hypothesis of a cognitive bias, related to a rapid and massive weight loss and a failure of the CNS to update the body representation, and a greater difficulty in self-recognition does not seem unreasonable [16, 18]. Thus, patients could recognize themselves not only as they are but as they imagine being.

For the first time, we examined self-face recognition ability in AN using a self vs. unfamiliar face identification task. We adapted the experimental paradigm used by Uddin, Kaplan, Molnar-Szakacs, Zaidel and Iacoboni [30]. In this study, stimuli were individually tailored to each subject, and consisted of static images constructed from pictures of the subjects' own face and a gender-matched familiar face. A software was used to create digital morphs between the subjects' and the familiar faces, resulting in different faces, each morphed to a varying extent. After each stimulus presentation, subjects were asked to identify if the face was familiar or not [30]. Regarding our experimental paradigm, stimuli were constructed from pictures of the subjects' own face and a gender- and age-matched unfamiliar face to avoid confusion between self-identification and familiarity. Participants were instructed to view static morphed images of themselves and an unfamiliar subject and to indicate by a button press whether they saw a "self" or "other." If the processing of self-face recognition is impaired in AN, we would expect to see an increase in the self-identification threshold, i.e. the images presented would need to contain more of the participant's own face to be recognized. We also evaluated the influence of several factors such as cognitive style, body concerns and weight changes in the processing of self-face recognition. The set-shifting abilities were controlled using Trail Making Test (TMT), a robust indicator of executive control abilities [40]. Spearman correlations were calculated between the self-face recognition skills and clinical variables, such as body mass index (BMI), eating attitudes and body concerns. Finally, a linear regression analysis was used to explore the respective influence of eating attitudes and BMI on the self-face recognition skills.

Methods

Ethics statement

This study was approved by an independent ethics committee (Comité de Protection des Personnes Nord Ouest IV; study number: 2011-A01240-41). The study adhered to the tenets of the Declaration of Helsinki. Each participant received a study information sheet and provided her written, informed consent to participation. Parental consent was additionally required for participants under the age of 18.

Participants

The study included 54 female volunteers (27 patients with AN and 27 healthy controls). The two groups were matched for age and educational level. All patients suffered from eating disorders for at least 1 year and were recruited from an eating disorder clinic. The clinical evaluation of the participants by the psychiatrist did not reveal any perceptual, attentional or intellectual impairment. Administration of the Mini-International Neuropsychiatric Interview by a psychiatrist confirmed the diagnosis of AN, according to the DSM IV criteria [10, 43]. All patients with AN belonged to the restrictive subtype of AN. Healthy controls were recruited from a college and university population. The Mini-International Neuropsychiatric Interview confirmed the diagnosis in the AN group and the absence of comorbidity in both groups, according to the DSM IV criteria [43]. Participants' age and BMI are reported in Table 1. People with psychiatric, neurological or ophthalmic comorbidities were excluded, and those receiving psychotropic treatment. Each participant signed an informed consent form. Parental consent was required for minors (1 AN and 1 control).

Materials and procedures

Clinical assessment

The experimenter's measurements of height and body weight were standardized. Body dissatisfaction and concerns about weight and shape were assessed in control and AN groups by administering the Body Shape Questionnaire (BSQ) and the Eating Disorder Inventory-2 (EDI-2). The BSQ is a one-dimensional, 34-item self-questionnaire that assesses concerns regarding body shape for the most recent 4 weeks [44]. Answers are given according to a 6-point Likert scale (i.e. a score of 0 means that the concern is not present and 5 means that it is always present). The EDI-2 consists of 11 scores measuring psychological features commonly associated with eating disorders [45]. The score reflects the intensity of eating disorders. Ninety-one items are rated on Likert scales from 1 (never) to 6 (always). The EDI-2 total score was used in the present study.

The Trail Making Test (TMT) was used to assess executive function by the measurement of set-shifting ability [46]. The TMT requires participants to connect an alphabetical sequence on a page in a 'dot-to-dot' fashion (trail A) before alternatively linking numbers and letters in order [that is, 1-A-2-B-3-C (trail B)]. A paper–pencil version of the TMT was employed here [46]. The construct validity of the TMT has been confirmed in several studies. For Sánchez-Cubillo et al. [47], trail A would require

Table 1 Demographical data for the anorexia nervosa and control groups

	AN group $n = 27$				Control group $n = 27$				p
	Mean	SD	Median	Min; max	Mean	SD	Median	Min; max	
Age (years)	24.11	6.57	24	14; 48	24.26	5.81	23	16; 48	0.944
Educational level	5.74	2.47	5	2; 10	6.63	2.31	7	3; 12	0.252
BMI (kg/cm^2)	15.54	1.34	15.23	14; 17.99	20.7	1.94	20.38	18.5; 24.91	<0.001

Educational level: number of years in full-time education after secondary school

BMI body mass index

mainly visuo-perceptual abilities and trail B primarily reflected working memory and secondarily switching ability, while B–A difference score would minimize visuo-perceptual and working memory demands, providing a relatively pure indicator of executive control abilities. Therefore, we used the A–B difference scores (time and errors) to assess the cognitive flexibility in this study.

To examine self-face recognition failures, participants completed the Self-Face Recognition Questionnaire (SFRQ) [48]. The SFRQ consists of six items: three of which concern self-face recognition difficulties (for example, “when looking at myself in a mirror, a window, a video, or on a photo, I have sometimes mistaken my face for someone else’s face”) and three of which concern recognition failures of others (for example, “I have sometimes mistaken the face of someone I know with someone else’s face”). For each item, participants must determine whether they have already experienced this type of recognition failure. When they answer affirmatively to an item, they are required to answer on a 4-point scale three additional questions concerning the frequency, the degree of stress and the degree of tiredness. We used the three following scores: the total score; the self-face subscale, which measures the self-face recognition difficulties; and the other-face subscale, which evaluates the difficulties in recognizing other faces.

Self-face recognition task (SFRT)

To examine self-face recognition failures in AN, we adapted the experimental paradigm used by Uddin, Kaplan, Molnar-Szakacs, Zaidel and Iacoboni [30]. Stimuli were individually tailored to each participant and consisted of a series of static black-and-white images constructed from pictures of the subjects’ own face and the face of a gender- and age-matched stranger. The BMI of the models were normal (i.e. range: 18–25 kg/m^2). Photographs of each participant were taken using a digital camera. Participants were asked to maintain neutral facial expression while their pictures were being taken. The faces of several researchers were used for the unfamiliar and age-matched condition. They were unknown to all participants. Thus, the experimental conditions were similar to each participant. To prevent changes in eye or skin color, we used black-and-white pictures and luminance was adjusted. FantaMorphEditor 5.0 (Abrasoft Corporation, Portland, USA) was used to create digital morphs between the unknown and the participants’ face, resulting in 10 unique faces, each morphed to a varying extent (5, 15, 25, 35, 45, 55, 65, 75, 85, and 95 %). Thus, for each participant, the image of an unknown was digitally morphed into an image of the participant in 10 % increments. Images were edited using Adobe Photoshop 7.0 to remove external features (hair and ears) and to create a uniform gray background (see Fig. 1).

The participant was instructed to identify whether the image presented corresponded to their own face. Each stimulus was presented three times for 300 ms each during three random sequences. According to the Edinburgh test, participants pressed a button with their dominant index finger if the image presented looked like “self” and button with their dominant middle finger if it looked like an “other”. The response time was unlimited. Once the answer was given, the next stimulus was presented. To detect the perceptual threshold, we applied the method of constant stimuli. We determined the perceptual threshold corresponding to the perceived critical self-other morph, that is, the morph for which we obtained a 50 % positive response rate (“Yes, I recognize myself”, according to a Yes/No paradigm). The perceived critical self-other morph was calculated as follows [16]: answer $= 1/[1 + \exp^{(-k(c - \text{stimuli}))}]$, where c is the perceived critical self-other morph with a 50 % “yes” response rate and k is the slope of the curve around the point c. The slope of the psychometric curve provided information on the discriminability of the performance: a steep slope corresponds to good discrimination and a shallow slope corresponds to poor discrimination.

Statistical analysis

All analyses were performed with Statistica 7.1 software (Statsoft Inc., Tulsa, OK, 2007). The validity of each test’s conditions of application was always determined beforehand. Non-parametric Mann–Whitney *U* and Spearman’s

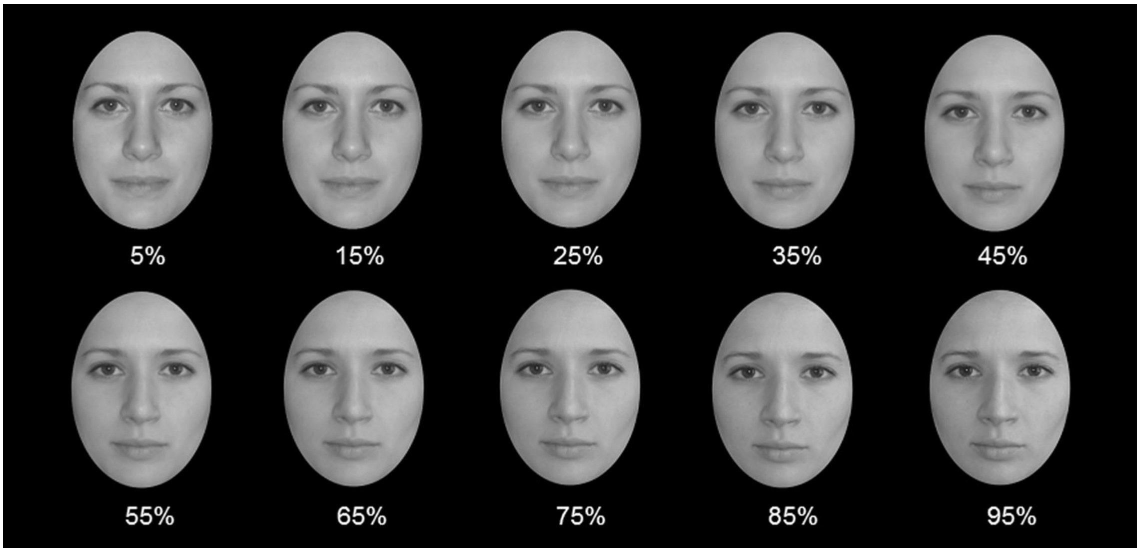

Fig. 1 Examples of stimuli. For each individual subject, an image of an unfamiliar face was digitally morphed into an image of the subject's face in 10 % increments (from 5 to 95 % of the participant's own face)

tests were used when non-normal distributions ($p < 0.1$, Levene's test) and non-homogenous inter-group variances ($p < 0.1$, Shapiro–Wilk test) were observed. Spearman's correlations were calculated between the self-face recognition skills (SFRT and SFRQ) and clinical variables (BMI, EDI-2, BSQ score, TMT). According to Bonferroni adjustment, the level of significance for any one correlation would be: 0.05/5 = 0.01. To explore the respective influence of eating disorders and nutritional states, a linear regression analysis was conducted between the perceptual threshold as the criterion variable and the following predictor variables: BMI and EDI-2 total score.

Results

Clinical parameters

The participants' characteristics are reported in Table 1. As expected, there was no significant difference between the AN and control groups for age ($U = 416$, $Z = 0.07$, $p = 0.944$) and educational level ($U = 347.5$, $Z = -1.135$, $p = 0.252$). The BMI was significantly lower in the AN group ($U < 0.001$, $Z = -6.306$, $p < 0.001$). Clinical data are reported in Table 2. The EDI-2 total score was significantly higher in the patient group ($mean_{AN} = 88.07 \pm 43.45$ vs. $mean_C = 22.3 \pm 20.06$; $U = 52.5$, $Z = 5.397$, $p < 0.001$). The scores were also significantly higher in the patient group for the BSQ ($mean_{AN} = 128.74 \pm 38.17$ vs. $mean_C = 65.04 \pm 22.31$; $U = 35.5$, $Z = 4.938$, $p < 0.001$). The TMT analysis revealed no significant difference between the AN and control groups for shifting errors (B–A difference score: $mean_{AN} = 0.13 \pm 0.74$ vs. $mean_C = 0.27 \pm 0.88$; $U = 100.5$, $Z = -0.498$, $p = 0.619$). However, the shifting time was significantly lower in the patient group (B–A difference score: $mean_{AN} = 10.47 \pm 8.36$ vs. $mean_C = 18.73 \pm 12.98$; $U = 64$, $Z = -2.012$, $p = 0.044$). Finally, the SFRQ total score was significantly higher in the AN group ($mean_{AN} = 17.78 \pm 12.95$ vs. $mean_C = 8.56 \pm 7.1$; $U = 202$, $Z = 2.811$, $p = 0.005$). The subscore analysis revealed that the other-face recognition difficulties were similar in both groups ($mean_{AN} = 8.26 \pm 9.8$ vs. $mean_C = 5.04 \pm 6.24$; $U = 213$, $Z = 0.908$, $p = 0.337$). However, the self-face recognition difficulties were significantly higher in the AN group ($mean_{AN} = 9.04 \pm 7.88$ vs. $mean_C = 1.86 \pm 4.74$; $U = 105$, $Z = 3.36$, $p < 0.001$).

Self-face recognition task

The participants were able to perform the required task (see Fig. 2). As expected, 100 % of the participants correctly identified 5 % morphed images as "other," and the number of "self" responses increased with increased morphing. Thus, 96.3 % of the participants (26 AN and 26 control) identified 95 % morphed images as "self". The analysis revealed a significant difference between the two groups for the perceptual threshold. Patients with AN exhibited a significantly higher mean threshold than control participants: $mean_{AN} = 52.48 \pm 13.86$ vs. $mean_C = 44.57 \pm 11.26$; $U = 218$, $Z = 2.196$, $p = 0.028$ (see Table 2). To verify that the inter-group difference was not due to a difference in perceptual discrimination, we analyzed the

Table 2 Clinical parameters for the anorexia nervosa and control group

	AN group $n = 27$				Control group $n = 27$				p
	Mean	SD	Median	Min; max	Mean	SD	Median	Min; max	
SFRT									
Threshold	52.48	13.86	42.92	35.55; 95	44.57	11.26	44.54	25.09; 70	0.028
Slope	−1.42	1.94	−0.83	−6; −0.02	−1.77	2.02	−0.85	−6; 0.83	0.203
TMT B-A									
Errors	0.13	0.74	0	−1; 2	0.27	0.88	0	−1; 2	0.619
Time (sec)	10.47	8.36	10	2; 36	18.73	12.98	16	3; 48	0.044
SFRQ									
Total score	17.78	12.95	16	0; 58	8.56	7.1	8	0; 20	0.005
Self-face	9.04	7.88	7	0; 26	1.86	4.74	0	0; 20	<0.001
Other-face	8.26	9.8	7	0; 29	5.04	6.24	3	0; 20	0.337
BSQ score	128.74	38.17	128	63; 188	65.04	22.31	59.5	37; 132	<0.001
EDI-2 score	88.07	43.45	85	21; 195	22.3	20.06	16	3; 86	<0.001

SFRT self-face recognition task, *TMT* trail making test *B–A* difference score, *SFRQ* Self-Face Recognition Questionnaire, *BSQ* Body Shape Questionnaire, *EDI-2* eating disorder inventory, second version

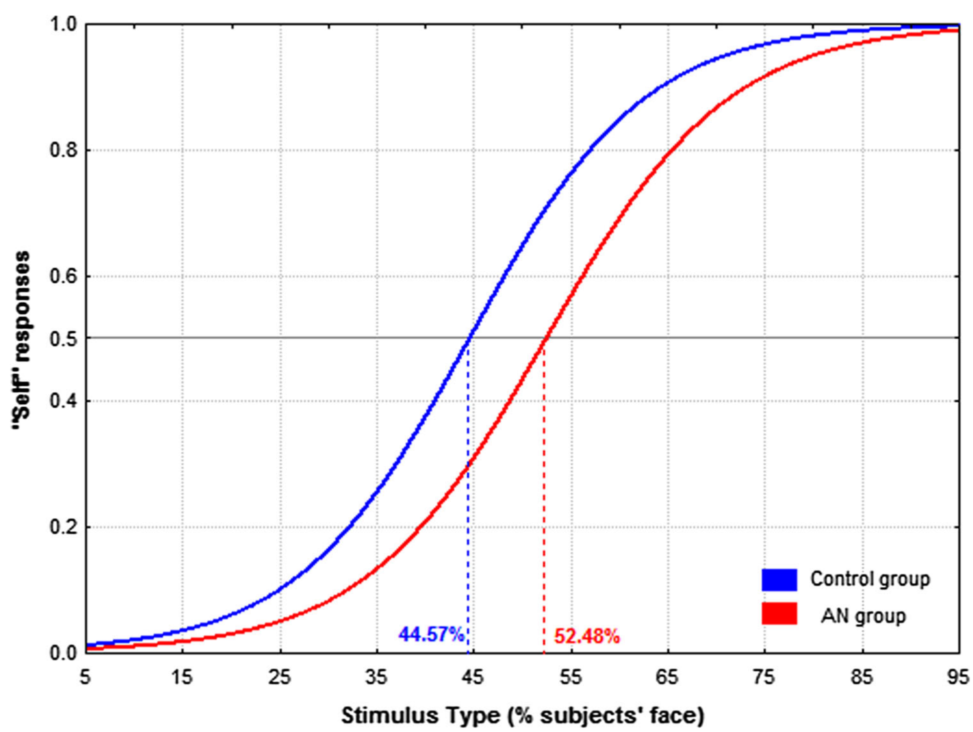

Fig. 2 Self-response rates per stimulus ranked in ascending order of familiarity (other to self) in the two groups (mean critical threshold are indicated on threshold curve for each group)

slopes of the psychometric curves. There was no significant inter-group difference in discriminability: $\text{mean}_{AN} =$ -1.52 ± 1.94 vs. $\text{mean}_{C} = -1.77 \pm 2.02$; $U = 257.5$, $Z = 1.272$, $p = 0.203$. Finally, there was no significant difference between the AN and control groups for mean response times ($\text{mean}_{AN} = 1.54$ s ± 6.01 vs. $\text{mean}_{C} =$ 1.6 s ± 7.57; $t_{(50)} = -1.906$, $p = 0.073$).

To evaluate the effect of nutritional status and eating disorders (EDI-2 and BSQ) on self-face recognition (SFRT and SFRQ scores), correlation analyses of the study population were performed using Spearman's coefficient according to Bonferroni adjustment. In the whole group, a significant negative correlation between the SFRT perceptual threshold and the BMI ($r = -0.356$, $p = 0.01$), and significant positive correlations between the SFRQ total score and EDI-2 total score ($r = 0.516$, $p < 0.001$) and BSQ total score ($r = 0.585$, $p < 0.001$) were found. There was no significant correlation between SFRT perceptual threshold and EDI-2 (total score: $r = 0.109$, $p = 0.439$; perfectionism subscale: $r = -0{,}07$, $p = 0.644$), BSQ ($r = 0.053$, $p = 0.734$) and TMT B-A (errors: $r = -0.186$, p = 0.343; time: $r = -0.098$, $p = 0.618$), or between SFRQ total score and BMI ($r = -0.219$, $p = 0.111$). No significant correlation was found between SFRT perceptual threshold and SFRQ (total score:$r = -0.032$, $p = 0.821$; self-face: $r = -0.042$, $p = 0.788$; other-face: $r = -0.1$, $p = 0.52$). The correlation analysis of the control subgroup revealed no significant correlation between SFRT perceptual threshold and EDI-2 (total score: $r = -0.437$, $p = 0.025$; perfectionism subscale: $r = -0.325$, $p = 0.13$), BMI ($r = -0.214$, $p = 0.293$), BSQ ($r = -0.39$, $p = 0.081$), TMT B-A (errors: $r = -0.349$, $p = 0.222$; time: $r = -0.01$, $p = 0.734$), or SFRQ (total score: $r = -0.108$, $p = 0.599$; self-face: $r = 0.051$, $p = 0.825$; other-face: $r = -0.154$, $p = 0.505$), and no significant correlation between SFRQ total score and EDI-2 ($r = 0.156$, $p = 0.437$), BMI ($r = 0.236$, $p = 0.236$), or BSQ ($r = 0.215$, $p = 0.336$). The analysis of the AN subgroup revealed a significant positive correlation between the SFRQ total score and EDI-2 total score ($r = 0.568$, $p = 0.002$) and BSQ ($r = 0.677$, $p < 0.001$). Analysis did not reveal a significant correlation between SFRT perceptual threshold and EDI-2 (total score: $r = -0.152$, $p = 0.458$; perfectionism subscale: $r = -0.02$, $p = 0.928$), BMI ($r = -0.172$, $p = 0.401$), BSQ ($r = -0.125$, $p = 0.58$), TMT B-A (errors: $r = 0.07$, $p = 0.81$; time: $r = -0.197$, $p = 0.5$), or between SFRT perceptual threshold and SFRQ (total score: $r = -0.239$, $p = 0.239$; self-face: $r = -0.459$, $p = 0.214$; other-face: $r = 0.396$, $p = 0.291$).

A multiple regression was used, according to the general linear models procedure, to identify the individual variables (BMI and eating disorders) that played a dominant role in self-face recognition. The multiple R (0.41) was significant: $F_{2,50} = 4.824$, $p = 0.012$. The variables explained 16.5 % of the variance ($R^2 = 0.165$). In the whole sample, the main determinant for the perceptual threshold was the BMI ($B = -1.922 \pm 0.64$; $\beta = -0.453 \pm 0.151$; $p = 0.004$). However, we did not observe an effect of EDI-2 total score ($B = -0.037 \pm 0.045$; $\beta = -0.124 \pm 0.151$; $p = 0.416$). The self-face recognition skills are negatively associated with the nutritional state.

Discussion

Our results provide evidence of the impaired processing of self-face recognition in AN. As expected, patients and healthy participants exhibited no difficulty in correctly identifying 95 % morphed images as "self," and the number of "self" responses diminished as the images morphed increasingly into "other." The perceptual threshold corresponding to a 50 % positive response rate ("Yes, it's me") was 44.57 % morphed in the control group vs. 52.48 % in the AN group. In other words, patients with AN had more difficulties to detect facial changes and required images that contained more "self" to recognize themselves. These results are consistent with past research, indicating that the self-recognition skills could be disrupted in AN [20, 49] and induced by a disturbance of self-consciousness [19, 35]. This difference cannot be readily explained by poorer discrimination of visual stimuli by the patients, nor by a decrease in set-shifting ability. This impairment in the self-face recognition task is consistent with the increased SFRQ total score in AN group. Patients with AN seemed to exhibit greater difficulties in recognizing faces, especially their own face. However, the other-face recognition skills seemed to be preserved. These results are consistent with previous research, showing that the disturbances in body representation observed in AN were solely related to the patient's own body [33]. Our correlation analysis confirmed the relationship between the self-face recognition skills and the severity of eating disorders by revealing a significant, positive correlation between the patient's SFRQ scores on one hand and body concern and eating attitudes on the other. This disruption could cause restrictive eating behaviors to persist by increasing self dissatisfaction.

Patients with AN were more intolerant of uncertainty and experienced it as stressful [50]. Uncertain situations led participants to feel anxious, resulting in a strong desire for control which manifested in extreme organizing and planning [50]. Thus, our results could simply reflect patients' perfectionism and fear of making mistakes that makes them want to be more certain and have greater levels of evidence before responding. To control this bias (perfectionism and intolerance of uncertainty), we performed additional statistical analyses. We analyzed mean response times in each group. We hypothesized that greater the fear of making mistake was, longer would be the time taken to respond. Results failed to reveal a significant inter-group difference. We studied also the correlation between the perceptual threshold and the EDI-2 subscale "perfectionism". No significant correlation has been found ($p = 0.412$). However, these analyses do not allow us to conclude with precision. Thereafter, it would be interesting to assess the cognitive, emotional and behavioral aspects of intolerance of uncertainty, using for example the Intolerance of Uncertainty Scale [51].

The last key finding of the present study was the negative correlation between the results obtained in the self-face recognition task and BMI, suggesting the mixed influence of eating disorders and nutritional state. The results of the multiple regression analysis reinforce this hypothesis. Indeed, the main determinant for the perceptual threshold was the BMI. Major and rapid weight loss in AN constitutes a potential source of bias because malnutrition could lead to changes in body size and facial aspects. The body schema modified by malnutrition may not be updated by the central nervous system [16, 18]. There could be a conflict between the previous representation (i.e. before the weight change) and the current sensorimotor feedback. Furthermore, some other neuropsychological deficits could maintain their misperception. Patients with AN show impaired set-shifting (i.e. rigid response to changing rules and elevated perseverative responses) [40]. However, our results cannot be explained by a lack of cognitive flexibility. Indeed, performances appear similar or even higher in the AN group than in the control group and the correlation analysis revealed no significant correlation between the self-face recognition test and the TMT scores (all $p > 0.01$). Another issue of recent interest in the field of ED is weak central coherence that refers a bias towards local processing at the expense of global meaning. It fits with findings from neurocognitive literature that describe a preoccupation with detail and a narrow style of information processing. For Lopez, Tchanturia, Stahl and Treasure [41], weak coherence may trigger core behavioral and cognitive traits of ED such as perfectionism, fear of mistakes, and change. Thus, patients would find themselves locked into an obsolete representation of themselves [16, 42].

Nevertheless, our study had a number of limitations. No correlation was found between the self-face recognition threshold and the SFRQ scores in the whole sample. Several factors could contribute to this result. Recent studies report disconnections between self-report and behavioral measures of executive function [52, 53] and emotional reactions [21, 54, 55]. A similar dissociation between subjective perceptions and objective abilities could explain such results. Finally, the lack of significance could also result from a low sample size relative to the effect size of the potential link between the SFRQ scores and the self-face recognition threshold. It is the same for the lack of correlation between SFRT and BSQ or EDI-2 scores. Future studies should employ larger cohorts. Moreover, it would be interesting to include a clinical control group with body image disturbances but no underweight, such as body dysmorphic disorders, to control the influence of BMI. Also a second stimuli set with body parts to control whether self-recognition deficits are specific to facial information or body parts may be interesting. Finally, the influence of nutritional and psychopathological states on self-face recognition task remains unclear. Within the control group, there were no significant correlations between SFRQ scores and EDI-2 total scores (all $p > 0.1$, n.s.). Moreover, the variables used for the linear regression analysis (BMI and EDI-2 total score) explained only 16.5 % of the variance. Finally, results could be explained by the difference between the participants' BMI and the BMI of the model. To test this hypothesis, a similar study should be conducted with photographs of their own face morphed into thinner and larger sizes. Improvements sof the self-face identification with a bigger face strengthen the hypothesis of a failure to update self-representation. Among future research directions, it would be interesting to include a clinical control group who have lost weight recently, such as dieters, to control the effect of group.

In conclusion, neuropsychological investigations and neuroimaging studies are promising approaches to study the various aspects of self-cognition in AN. New therapeutic perspectives such as cognitive training should be introduced to counter body distortions in AN and to facilitate embodiment. By consciously confronting the patients with who they think they are and who they actually are, we could improve their self-representation. By directly influencing tactile and visual body image in a training programme, proprioceptive integration therapy might be a valuable adjunct treatment for accelerating the updating of new body dimensions and correcting self-misperception.

Compliance with ethical standards

Conflict of interest The authors have no competing interests to declare. We thank the study subjects for their participation.

Ethical approval All procedures performed in this study were in accordance with the ethical standards of the institutional and national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent Informed consent was obtained from all individual participants included in the study.

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